European Urology

European Urology 48 (2005) 584–592

Renal Cancer

Minimally Invasive Treatment of Renal Cell Carcinoma: Comparison of 4 Different Monopolar Radiofrequency Devices

Axel Häcker[a,*], Stefan Vallo[a], Christel Weiss[b], Rainer Grobholz[c], Peter Alken[a], Thomas Knoll[a], Maurice Stephan Michel[a]

[a]Department of Urology, University Hospital Mannheim, Faculty of Clinical Medicine Mannheim, Ruprecht-Karls University of Heidelberg, Germany
[b]Department of Biomathematics, University Hospital Mannheim, Faculty of Clinical Medicine Mannheim, Ruprecht-Karls University of Heidelberg, Germany
[c]Institute of Pathology, University Hospital Mannheim, Faculty of Clinical Medicine Mannheim, Ruprecht-Karls University of Heidelberg, Germany

Accepted 14 June 2005

Available online 1 July 2005

Abstract

Objectives: Radiofrequency Ablation is an investigational treatment option for RCC. The aim of our study was to test the ablation algorithms of four different RF systems in a standardized ex vivo perfused porcine kidney model.
Materials and methods: A multitine monopolar dry electrode (impedance-based system), a multitine monopolar dry electrode (temperature-based system), a single monopolar wet electrode (impedance-based system) and a single monopolar dry, internally-cooled electrode (impedance-based system) were selected. RF energy was applied at different treatment parameters (power with and without control, tissue temperature, saline enhancement) for 1, 3, 5 and 9 minutes in healthy perfused ex vivo porcine tissue. Each treatment parameter was repeated 5 times. Maximum vertical, long-axis and short-axis diameters of the macroscopic lesion were measured and lesion volumes/ shapes were calculated.
Results: Lesion volumes increased significantly with the pre-selected tissue temperature and saline enhancement. Saline enhancement created larger, but irregular shaped lesions. The impedance-based system created lesion volumes that were predictable by treatment time and generator power. Lesions were unpredictable when uncontrolled generator power was applied. The created lesion shape was dependent on the selected electrode configuration.
Conclusions: The currently available monopolar RFA systems offer different specific technical features to control tissue ablation. Detailed knowledge of the specific characteristics of each RF system is necessary to provide a higher chance of successful clinical outcome by complete and reliable ablation.

Keywords: Radiofrequency (RF) ablation; Kidney; Renal cell carcinoma; Experimental study

1. Introduction

Small renal masses are discovered incidentally at increasing rates through the widespread use of radiographic imaging modalities [1]. The natural history of these masses that are discovered at an early stage is often of slow growth and low metastatic risk [2,3]. Depending on the individual clinical situation, currently available treatment options include surgical excision by radical or partial open/laparoscopic nephrectomy, watchful waiting and investigational energy-based minimally-invasive ablation techniques. These techniques have the potential of avoiding open or laparoscopic surgical morbidity and better preser-

* Corresponding author. Present address: Department of Urology, University Hospital Mannheim, Theodor-Kutzer-Ufer 1-3, 68135 Mannheim, Germany. Tel. +49 621 383 2629; Fax: +49 621 383 1923.
E-mail address: axel.haecker@chir.ma.uni-heidelberg.de (A. Häcker).

0302-2838/$ – see front matter
doi:10.1016/j.eururo.2005.06.010

ELSEVIER

ving renal function. Examples of these techniques are Cryotherapy, Microwave Thermal Therapy, Interstitial Laser, High Intensity Focused Ultrasound (HIFU) and Radiofrequency Ablation (RFA).

The mechanism of RFA is heat-based tissue destruction using alternating electrical current at very high frequency (>400.000 Hz) delivered through an electrode inserted into the tumor. Different electrode systems have been developed, including single probes such as elongated, internally cooled and saline-enhanced electrodes, and multi probes such as array, bipolar, clustered cooled and expandable electrodes. Energy is applied under temperature or impedance-based monitoring.

Although RFA has already been used in clinical practise, variables affecting the coagulative effect of RFA are incompletely evaluated. Animal studies and small clinical series have mainly demonstrated feasibility and safety [4–6]. Systematical investigations are rare with a large variability in the ablation protocols.

The aim of our study was to investigate the ablation algorithms of four different commercially available monopolar RF systems under similar conditions in a standardized perfused kidney tissue model.

2. Materials and methods

2.1. Ex-vivo tissue model of perfused porcine kidneys

The standardized model of the isolated perfused ex vivo porcine kidney was used and previously described in detail [7,8]. Kidneys were removed from pigs within 5 minutes after slaughtering and were immediately perfused with cold (4 °C) sodium chloride (0.9%) solution through the intubated renal artery (10 F catheter). Organs were stored at 4 °C when the effluent from the renal vein ran clear. During the trials the kidneys were continuously perfused with sodium chloride (0.9%) solution at 37 °C by a roller pump. The perfusion pressure was set to 110–130 cm H_2O (measured by a water column) resulting in a perfusion rate of 60–100 ml/min. The kidney and the grounding pad were placed in a plastic basin filled with saline solution (0.9%) controlled at 37 °C with the groundling pad approximately 30 cm distant to the electrode [9].

2.2. Radiofrequency devices, settings and protocols of delivery

The RF electrodes were inserted and (in case of expandable electrodes) deployed in the center of the renal parenchyma perpendicular to the surface of the kidney. Each parameter setting was repeated 5 times. Treatment times were 1, 3, 5 and 9 minutes each in all cases. The deployment diameter of 2.0 cm for expandable electrodes and the electrode sizes for non expandable electrodes were selected on the basis of the anatomic characteristics of porcine kidneys and previous protocols developed for RFA of these kidneys [6,10]. The technical data of the four devices are presented in Table 1.

2.2.1. Multitine monopolar dry electrode - impedance-based system (Fig. 1a)

Two different treatment regimes were performed: first, without impedance control, power output was set constant at 20, 40 or 60 W. Secondly, an impedance-based treatment algorithm was performed, which is described in details elsewhere [11]. Briefly, power output was initially set at 20 W and was increased automatically in 10 W increments until an uncontrolled impedance rise occurred (called ‘‘roll-off’’). Power was reapplied after 30 s with 50% of the power at which the impedance rose. The procedure was determined until the next uncontrolled impedance rise occurred.

2.2.2. Multitine monopolar dry electrode - temperature-based system (Fig. 1b)

Energy was delivered until the average of four temperature thermocouples at the tips of the prongs of 70°, 90°, 110° and 120°

Table 1
Technical characteristics of the RF systems

Technical data	RF 3000[a]	RITA 1500[b]	HiTT 106[c]	COOL TIP[d]
Max. power output (W)	200	150	60	250
Frequency (kHz)	480	460	375	480
Monitoring of ablation	Impedance	Temperature	Impedance	Impedance
Electrode type	Monopolar dry expandable 8-tine needle	Monopolar dry expandable 3-tine needle	Monopolar wet non-expandable single needle perfusion	Monopolar dry non-expandable single needle internally cooled
Needle diameter (mm)	2.5	2.2	1.6	1.6
Active electrode (Model)	LeVeen	Starburst	EZ 708-15	Cool-Tip
Configuration	Umbrella	Christmas tree	Straight	Straight
Tip				
Length (cm)	NA	NA	1.5	1.0
Diameter (cm)	2.0	2.0	NA	NA

Note: NA = not applicable.
[a] Boston Scientific, Natic, Mass., USA.
[b] RITA Medical System, Mountain View, Calif., USA.
[c] Integra, formerly Berchtold, Tuttlingen, Germany.
[d] Radionics, Burlington, Mass., USA.