Radiofrequency ablation of renal tumors in the solitary kidney

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KRAMBECK AE, FARRELL MA, CALLSTROM MR, ATWELL TD, CHARBONEAU JW, CHOW GK, DIMARCO DS, PATTERSON DE. Radiofrequency ablation of renal tumors in the solitary kidney. The Canadian Journal of Urology. 2008;15(4):4163-4168.

Objectives: *Radiofrequency ablation (RFA) is a minimally invasive therapy aimed at maximal preservation of renal function in the nonsurgical renal mass patient. We evaluate our experience with RFA of renal tumors in the solitary kidney.*

Patients and methods: *A retrospective review of all patients with a solitary kidney treated with RFA for renal mass was performed. Two radiologists reviewed all images. From December 2001 to June 2006, 55 renal tumors were treated with RFA in 30 patients with a solitary kidney. Percutaneous approach was used in 44 tumors (26 patients) and intraoperative open approach in 11 tumors (4 patients). Average mass size was 2.0 cm (1.2-5.4). Biopsy performed prior to ablation in 14 tumors showed renal cell carcinoma in 12 (86%) and was non diagnostic in 2 (14%).*

Results: *There were no major post procedural complications. Initial technical success was noted in 98% of tumors in 97% of patients. Average follow-up with contrast enhanced CT or MRI was 25 months (3-47) in 26 patients (50 tumors) and showed local tumor control in 100%. No difference in preoperative and postoperative calculated creatinine clearance was noted (p = 0.072). There was no difference in systolic (p = 0.102) and diastolic (p = 0.790) blood pressure pre and post ablation.*

Conclusions: *RFA of renal masses in the solitary kidney appears to be a safe, minimally invasive alternative to open surgical resection in properly selected patients. Local tumor control was achieved with no adverse effects on renal function and blood pressure in this series.*

Key Words: kidney neoplasm, radiofrequency ablation, percutaneous ablation, blood pressure, renal function

Introduction

The successful surgical treatment of small (< 5 cm) localized renal masses with open partial nephrectomy has lead to search for effective minimally invasive therapies that can deliver similar oncologic results with less morbidity.[1-5] Laparoscopic partial nephrectomy is a less invasive approach associated with a more rapid recovery than open surgery and equivalent oncologic control.[6,7] Unfortunately, this procedure often requires hilar vessel clamping, can result in significant blood loss, and is technically demanding. Furthermore, patients with multiple renal masses, or who have undergone prior partial nephrectomy represent treatment challenges with not only minimally invasive surgical techniques, but also open resection.

To address these challenges, image guided percutaneous ablation has been developed using multiple energy sources including radiofrequency ablation (RFA) and cryotherapy.[8,9] Percutaneous ablation is technically easier than laparoscopic partial nephrectomy, has potential of less blood loss, and does

Accepted for publication May 2008

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not require vessel clamping. Percutaneous cryoablation has been evaluated and found to be safe in patients with a solitary kidney.[10] Although multiple series have demonstrated the feasibility of RFA for the treatment of small renal tumors,[9,11-13] studies focusing on local tumor control and impact on renal function in patients with a solitary kidney are limited.[14] We review our experience with RFA in patients with a solitary kidney and report its effect on renal function and blood pressure.

Materials and methods

Patient selection

After institutional review board approval, we identified 30 patients with a solitary kidney who underwent imaging-guided RFA for 55 renal tumors from the period December 2001 to June 2006.

Tumor characteristics

Patients with a solitary kidney and contrast enhancing renal masses on computed tomography (CT) or magnetic resonance imaging (MRI) were candidates for RFA. Masses had a presumptive diagnosis of malignancy based on imaging. Percutaneous biopsy of the mass prior to RFA was performed only if technically feasible after placement of the ablation device.

Tumors were classified into three groups: exophytic, intraparenchymal, or central. Central tumors extended into the renal pelvis. Exophytic tumors had > 50% of the volume outside the renal capsule. Intraparenchymal tumors had < 50% of the tumor volume outside the renal capsule.

Preprocedural assessment and RFA protocol

All patients were initially evaluated by a urologist to determine eligibility for RFA. Preferentially lesions were treated with US guidance. All patients were assessed with ultrasound imaging; if the lesion was suboptimally visualized then CT guidance was used. CT monitoring was also used in tumors > 3 cm in diameter or in close proximity to the ureter or bowel. An intraoperative approach through a flank or subcostal incision was used for multiple tumors undergoing combined surgical resection and RFA or if there was potential of injury to adjacent organs. The decision to perform intraoperative RFA was based on urologic surgeon's preference. A radiologist was present for the intraoperative procedures to perform the RFA portion of the case.

Percutaneous procedures were performed under general anesthesia with overnight hospital observation by a urology team. Two RFA devices, RITA XL electrode (RITA Medical Systems, Mountain View, CA) or the Cool-tip™ electrode (Valleylab, Boulder, CO), were used with previously described techniques.[11,15] The device used depended on the radiologist's preference; however, the majority were treated with the Cool-tip™ electrode. Each tumor was treated with the intention of providing at least a 0.5 cm tumor-free margin, which required some tumors to be treated with overlapping ablations. All tumors were treated in single sessions.

Postprocedural care and imaging assessment

Major complications were defined as grade 3 or greater using the National Cancer Institute's Common Terminology Criteria for Adverse Events v3.0 (CTCAE). A follow-up contrast-enhanced CT or MRI was typically performed within 4 hours but no later than 48 hours of the ablation procedure to determine technical success. Non-contrast and contrast-enhanced arterial and nephrographic phase CT scans were obtained. Gadolinium enhanced MRI was performed for patients with decreased renal function. Technical success was defined as non-enhancing tissue completely incorporating the original tumor site. Based on the prior work of Matin SF et al, technical failure was defined as enhancement in the tumor ablation zone within 3 months of the procedure.[16] No postprocedural biopsies were performed. Continued follow-up by a urologist included either CT or MRI, chest x-ray, serum creatinine and urologist visit every 3-6 months for 2 years, then every 6 months for 2 years, and then yearly thereafter. Local tumor progression was defined as increase in tumor size and/or evidence of contrast enhancement on imaging beyond 3 months of the RFA procedure.

Statistical analysis

Creatinine clearance was calculated using the Cockroft-Gault formula.

Comparisons of pre and postoperative serum creatinine, creatinine clearance and blood pressure were evaluated using a paired two-sample t-test. P values less than or equal to 0.05 were considered statistically significant.

Results

Mean patient age at RFA was 63.5 years (range 27-90). There were 12 females and 18 males. Mean weight was 96 kg (range 39-155). Multiple comorbidities were noted in 20 (67%), and 12 (40%) were of advanced age (> 65 years). American Society of Anesthesia score ranged from 2-4 (mean 2.8). Multiple renal tumors were noted in 11 patients (37%). The reason for solitary kidney and health conditions contributing to RFA selection rather than surgical resection, are listed in Table 1.

TABLE1. **Patient features undergoing radiofrequency ablation (RFA)**

Reason for solitary kidney	**n = 30**	**%**
Nephrectomy for RCC	25	83.3
Congenital solitary	2	6.7
Transplant kidney	2	6.7
Nephrectomy for liposarcoma	1	3.3
Contributing factors		
Prior partial nephrectomy[a]	12	40.0
Metastases at presentation[b]	7	23.3
Von Hippel Lindau	3	10.0
Birt Hogg Dubé syndrome	1	3.3

[a]Prior partial nephrectomy in the solitary kidney.

[b]Metastasis was resected in six patients and two patients received immunotherapy

Tumor characteristics are summarized in Table 2. Percutaneous ablation was performed in 26 of the 30 (87%) patients, 2 (7%) were treated intraoperatively only, and 2 (7%) underwent a combination of percutaneous and intraoperative ablation. Ultrasound guidance was used for 24 of 55 ablations (44%) and combined CT and US guidance was used for 31 ablations (56%). All intraoperative RFA procedures were performed under ultrasound guidance. Preprocedure needle biopsy was performed on 14 tumors; 12 (86%) renal cell carcinoma (RCC) and 2 (14%) nondiagnostic. All 26 patients treated solely percutaneously were discharged home the following day.

On immediate post treatment imaging, technical success was noted in 54 of 55 tumors (98%) in 29 of 30 patients (97%). Residual enhancement immediately post

TABLE 2. **Characteristics of treated tumors**

Tumor characteristic	**Mean**	**Range**
Size (cm)	2.0	1.2-5.4
Location	**n = 55**	**%**
Right	30	54.5
Left	23	41.8
Transplant	2	3.6
Exophytic	18	32.7
Intraparenchymal	31	56.4
Central	6	10.9
Upper pole	15	27.3
Mid pole	18	32.7
Lower pole	22	40.0
Anterior kidney	33	60.0
Posterior kidney	22	40.0

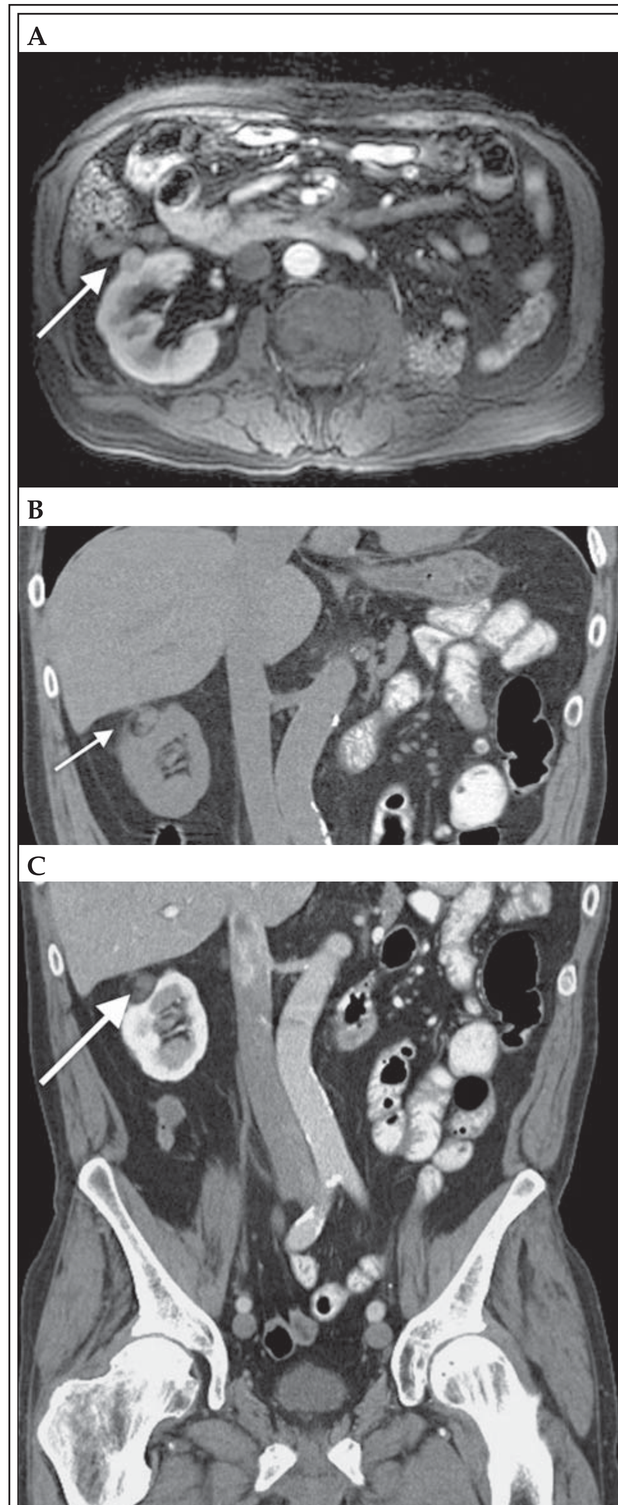

Figure 1. A) Ultrasound if tumor near renal vein (arrow). B) Immediate post ablation CT shows an enhancing rim (arrow). C) CT at 14 months shows interval enlargement. This was subsequently successfully treated with repeat percutaneous RFA.

treatment was seen after treating a central 2.4 cm tumor in one patient, Figure 1. This patient was successfully retreated with RFA 15 months later by performing overlapping ablations.

Of the 29 patients with a technically successful RFA, one patient with two tumors was lost to follow-up. Three patients with single tumors did not have a contrast enhanced CT or MRI for evaluation. For the remaining 25 patients, follow-up ranged from 3-47 months (mean 25). On follow-up examination 10 of 25 (40%) patients had contrast-enhanced CT and 15 (60%) gadolinium enhanced MRI. Local tumor progression was not noted, giving a local control rate of 100%.

No major acute complications were noted. Perirectal and peritoneal drop metastases were noted in 1/25 (2%) patient. The patient had previously undergone a contralateral nephrectomy and ipsilateral partial nephrectomy for recurrent RCC. Metastases were noted 9 months after most recent RFA. This case has been previously published.[17]

At most recent follow-up, serum creatinine and blood pressure measurements were available for 24 of 30 (80%) patients. Average time from RFA to follow-up creatinine was 4.3 months (range, 0.03-15.0) and blood pressure measurements was 4.8 months (range, 0.03-22.0). There was no significant difference in pre and post ablation serum creatinine, creatinine clearance, systolic or diastolic blood pressure Table 3. Although no patient required dialysis, one patient with pre-existing renal insufficiency prior to RFA eventually underwent a native nephrectomy and living-related renal transplant for imminent renal failure. At last follow-up, 5 of 30 patients (17%) had died, with one death from RCC progression.

Discussion

Although overall most solid renal masses (85%) are malignant, prior studies have demonstrated that small lesions < 3.5 cm can be managed conservatively with little risk of disease progression,[18] as most small lesions are low grade malignancies. Furthermore, almost half < 1 cm in diameter are benign.[19] Conservative management is often chosen in patients with small renal masses at high risk of renal insufficiency due to multiple comorbidities or prior renal surgery. Watchful waiting; however, may not be a realistic option for patients with enlarging masses, multiple tumors, a genetic predisposition to recurrent renal neoplasms, or those who cannot tolerate the psychologic stress associated with conservative management.

Since its introduction by Zlotta et al in 1997 for the treatment of renal masses in vivo, RFA has become a realistic treatment option in select patients.[9] This minimally invasive therapy has found a role in patients with multiple comorbidities who are poor

TABLE 3. **Features pre and post radiofrequency ablation (RFA)**

	Mean	**Range**	**P-value**
Follow-up (months)	4.3	0.03-15.0	
Serum creatinine (mg/dl)			0.079
Preoperative	1.47	0.70-2.50	
Postoperative	1.57	0.70-3.80*	
Calculated creatinine clearance (ml/minute) **		0.072	
Preoperative	61.5	20.7-145.8	
Postoperative	58.4	22.6-145.8	
Systolic blood pressure (mm Hg)			0.102
Preoperative	136	100-176	
Postoperative	143	103-210	
Diastolic blood pressure (mm Hg)			0.790
Preoperative	78	60-96	
Postoperative	78	50-98	

*One patient underwent preemptive native nephrectomy with living-related renal transplant for imminent renal failure

**Creatinine clearance calculated based on Cockroft-Gault formula surgical candidates, those with limited renal function, and patients with multiple RCC tumors or genetic predispositions such as von Hippel-Lindau disease or familial type RCC.[20] One benefit of RFA is that it does not require renal vascular clamping, which can contribute to renal insufficiency in the high risk patient. Many authors have demonstrated the efficacy and safety of RFA for the treatment of renal tumors although only intermediate length follow-up (< 3 years) has been reported.[11-13,15,20] Overall, reported treatment success rates, defined as no residual enhancement on follow-up CT or MRI imaging, range from 79% to100%.[11-13,15,20]

Our current study found residual enhancement in one tumor immediately post treatment, with a corresponding 98% technical success rate. Due to its proximity to the renal hilum, this initial ablation was performed with one placement of a 3 cm exposed electrode in order to avoid ureteral injury. The residual tumor was successfully treated with RFA 15 months following the initial ablation. A combination of vascular perfusion mediated cooling and inadequate number of overlapping ablations led to this initial treatment failure. Convection heat loss at the RFA needle tip with resulting decrease in coagulative necrosis can result in RFA failure when tumors near major vascular structures.[21]

An important point of this study is that despite the high risk cohort of patients with a solitary kidney, there was no significant increase in serum creatinine or creatinine clearance post ablation. A previously published study demonstrated an overall 13% decrease in creatinine clearance in 12 patients with a solitary kidney treated with RFA for a renal mass.[14] These results are comparable to a contemporary open partial nephrectomy series reporting 8.1% new onset chronic renal insufficiency for all patients treated, with 2.1% of those patients requiring dialysis.[22] Another study focusing on laparoscopic partial nephrectomy noted a 4.1% rate of transient abnormal renal function and 2.0% chronic renal insufficiency rate.[23] Our results with RFA of solitary kidneys demonstrate comparable intermediate renal preservation. None of our patients required hemodialysis; however, one patient with underlying renal insufficiency eventually underwent renal transplant for imminent renal failure. The lack of hilar vessel clamping and minimal effect on normal surrounding parenchyma most likely account for the success rates achieved with this treatment approach.

Additionally, we found no significant difference in systolic and diastolic blood pressure post procedure compared to pre procedure measurements. Similar findings have been observed with open partial nephrectomy[24] and laparoscopic cryoablation.[25] The short term safety of this treatment modality is further demonstrated by these results, even in patients with limited renal reserves. Although no major complications occurred, one patient developed intraperitoneal drop metastases on interval follow-up.[16] Since this patient had aggressive grade 3 recurrent RCC, metastatic disease cannot be ruled out. This patient subsequently died from metastatic disease.

We do recognize certain limitations of this study. Creatinine clearance was calculated, since iothalamate clearance tests are not routinely performed for patients with renal masses at our institution. Histologic diagnosis of most of the ablated tumors was not obtained. We based our decision not to biopsy renal masses on previous work demonstrating the inaccuracy of renal lesion needle biopsy.[26] Instead, the decision to treat was based on interval growth on serial imaging, patients' preference, a history of RCC or genetic predisposition to RCC. Another study limitation is that our criterion for success was lack of enhancement on abdominal imaging. We did not biopsy any lesions after ablation. Others have demonstrated that extent of tumor necrosis after RFA is closely correlated with findings on enhanced CT and MRI.[27] Finally, follow-up in this cohort is not adequate to demonstrate oncologic efficacy. Local tumor progression after RFA have been reported as late as 31 months[12] and therefore, 5-10 year follow-up is necessary for this cohort before confident treatment outcomes can be determined.

In conclusion, RFA of renal masses in the solitary kidney is a safe, minimally invasive alternative to open surgical resection in properly selected patients. There were no major complications or adverse effects on renal function and blood pressure in this high risk cohort. In addition, with intermediate length follow-up we were able to demonstrate a high local tumor control rate. ☐

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EDITORIAL COMMENT

The authors present their institution's experience with radiofrequency ablation of small renal masses in solitary kidneys. The combined treatment group includes a majority of percutaneous RF approaches under the guidance of a team of radiologists and urologists. Technical success was 97% with one central tumor requiring re-treatment. The important aspects to this series are the team approach to this difficult patient group and the lack of procedural morbidity.

One criticism is the paucity of renal mass biopsies. Though renal tumor biopsy during percutaneous ablation therapy has been controversial in the past, pretreatment biopsy is experiencing a renaissance secondary to the exploration of potential molecular markers and directed treatment options for metastatic lesions.1 Renal masses 3 cm or less may be oncocytic or benign in as many of a third of cases. With accuracy of core needle biopsy substantially improved, biopsy may change tumor management2 in a number of cases some which may not need intervention and can be offered observation. Though technical success is truly admirable, one must remember that tumor biology and the knowledge to be able to treat recurrence or metastases of this potentially lethal cancer is a primary goal.

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