Published in final edited form as:

BJU Int. 2013 May ; 111(6): 997–1005. doi:10.1111/j.1464-410X.2012.11608.x.

Radiofrequency ablation of renal tumours with clinical, radiographical and pathological results

Jose A. Karam^{*}, Kamran Ahrar[†], Raghunandan Vikram[‡], Claudio A. Romero^{*}, Eric Jonasch[§], Nizar M. Tannir[§], Priya Rao[¶], Christopher G. Wood^{*}, and Surena F. Matin^{*}

^{*} Department of Urology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

[†]Section of Interventional Radiology, Department of Diagnostic Imaging, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

[‡]Department of Diagnostic Imaging, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

[§]Department of Genitourinary Medical Oncology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

[¶]Department of Pathology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

Abstract

- To evaluate our experience with radiofrequency ablation (RFA) for renal masses and to report on clinical, radiological and post-RFA biopsy results.
- The study collected clinical, radiological and pathological data from 150 consecutive patients who were treated with RFA of a renal mass between 2002 and 2008 at a tertiary referral centre.
- Post-ablation biopsies were performed in patients with non-involuting lesions or suspicion of recurrence on imaging.
- Comparisons were performed using the Mann–Whitney *U*-test.
- Survival was estimated using the Kaplan–Meier method.
- Renal malignancy was found in 72.1% of patients based on the initial diagnostic biopsy.
- Median tumour size was 2.6 cm, 22.7% of patients had a solitary kidney, and most were central tumours.
- The mean follow-up period was 40.1 months.
- There was no recurrence in 96.7% of the entire cohort.
- Cancer-specific survival for 106 patients with sporadic, localized, biopsy proven renal malignancy was 100% at 38.5 months.
- Biopsies were obtained in 43 patients for a median of 21 months after RFA.
- Among 38 patients who had biopsy for non-involuting, non-enhancing zones of ablation, three (7.9%) were positive.

- Short-term cancer-specific survival after RFA remains excellent and most cases are successful based on a combination of imaging and post-ablation biopsies performed almost 2 years after treatment.
- There were four out of 150 (2.7%) patients who had recurrences with tissue confirmation; one of these patients was detected on imaging and three (2%) were radiologically occult.
- The absence of enhancement in the setting of non-involuting lesions is not always a guarantee of a successful ablation.

Keywords

cryoablation; CT; follow-up; kidney cancer; MRI; radiofrequency ablation; renal ablation; renal cell carcinoma; renal biopsy; survival

Introduction

Surgical excision remains the reference standard for the curative treatment of small renal masses [1]. Ablative therapy with either cryoablation or radiofrequency ablation (RFA) has been proposed as a minimally-invasive, renal function-preserving therapy in patients who may be poor candidates for surgery [1–8]. One of the criticisms of published studies on ablative therapy is the lack of tissue-based outcome data because most studies are based only on radiographical assessment [1]. We reviewed our experience with RFA for renal masses and evaluated the clinical, radiographical and post-ablation biopsy results.

Patients and methods

Institutional review board approval was obtained for the present retrospective study. Patients with a renal mass who underwent RFA between 2002 and 2008 were included. All patients, including those with familial genetic syndromes, metastatic disease [9] and multiple tumours, were included as part of this intent-to-treat analysis. Recorded data included standard demographic variables; imperative vs elective indications for nephron sparing; tumour variables, including size, centrality (exophytic, central), nephrometry score and size of ablation zone; the results of pre- and post-ablation biopsies (tumour histology and grade); post-ablation time to biopsy, indication for biopsy and the number of cores taken; and clinical and radiographical follow-up, as well as the survival status, of those with localized RCC. R.E.N.A.L. nephrometry scoring [10] and measurement of the zone of ablation were performed by a single radiologist (RV).

In most cases, a diagnostic biopsy of the renal mass was performed using an image-guided, coaxial technique. In rare cases of a high probability of RCC, such as genetically proven von Hippel Lindau syndrome or histologically proven metastatic RCC, biopsies were omitted. The standard for performance of a diagnostic biopsy evolved at our institution during the study period: in some of the very early cases in 2002–3, biopsies were omitted; between 2003 and 2009, they were performed immediately before proceeding with the ablative procedure, within the same setting. More recently, we perform biopsies in a separate setting, await the results, and then proceed with ablation if biopsy confirms or suggests malignancy. Our biopsy sampling technique has also evolved over the study period. In our earlier experience, we relied on fine-needle aspiration biopsy, whereas, more recently, we routinely obtain core biopsy samples. A definitive diagnosis is rendered more readily from a core biopsy compared to fine-needle aspiration. In addition, core biopsy samples allow for determination of the subtype and nuclear grade of the tumour.

RFA was performed laparoscopically for anterior or medial tumours that were considered to be unsafe to approach percutaneously. Otherwise, a percutaneous approach was performed under CT guidance. Our RFA technique has been previously described in detail [9,11,12]. For percutaneous RFA, the patient was placed under general anaesthesia and, using a 200-W impedance-based device (Cooltip™; Covidien, Mansfield, MA, USA), one or more electrodes were positioned in the tumour using CT guidance. Sequential overlapping ablations were performed as indicated by the size and location of the tumour until the tumour was considered to be completely ablated, in accordance with the manufacturer's protocol and based on imaging. Contrast was frequently given at the end of the ablation procedure to perform a preliminary assessment of adequate ablation. Additional overlapping ablations were performed if the margins of ablation zone were deemed inadequate. In some patients in whom the colon was in close proximity, hydro-dissection was performed by injecting a relatively non-ionic fluid (5% dextrose) in a plane between the kidney and the colon. For cases involving laparoscopic RFA, such as anterior tumours or those close to the renal hilum or ureter, a transperitoneal laparoscopic approach was utilized. The patient was placed in modified flank position, and a three-port approach was used with the guidance of intra-operative ultrasonography to perform the initial targeting. The rest of the procedure was similar to that of the percutaneous approach.

Follow-up was performed in accordance with a systematic protocol that has been reported previously [13]. Patients were followed up at 1 month and, if the findings were favourable, at 6 months and then every 6 months thereafter for at least the first 2 years. After 2 years, individualized follow-up at 6 or 12 months was based on radiographical and biopsy findings. For example, a patient with a fully involuted zone of ablation or one with negative post-ablation biopsies may be followed annually, whereas a patient with a non-involuting lesion continues to be followed semi-annually. CT using a renal mass protocol (i.e. non-contrast followed by triphasic post-contrast imaging with thin cuts of the kidney) was performed preferentially; alternatively, for those with reduced kidney function, MRI using a dedicated renal mass protocol was performed. The senior author (SFM) and interventional radiologist (KA) of the present study separately reviewed images at the point-of-care, independently and in addition to the radiologist of record. A study radiologist (RV) reviewed all imaging for nephrometry scores and for measurement of the zones of ablation. Patients with confirmed RCC or suspected RCC on diagnostic biopsy had additional follow-up with chest X-ray and laboratory chemistry, as is standard follow-up for T1 RCC at our institution.

Patients who were evaluated after the 6-month period whose zones of ablation had non-involution were recommended to have multisite-directed percutaneous core biopsies of the zone of ablation. This procedure was started routinely in 2006 and 2007. Zones of ablation with no enhancement that had undergone significant involution were not considered to represent an adequate risk for the patient to undergo biopsy because this situation satisfies all the standard criteria for successful ablation (i.e. lack of enhancement plus involution) and also increases the possibility of a sampling error as a result of a much smaller radiological target (Figs 1 and 2).

The post-ablation biopsy technique was considered carefully. If the lesion was > 3 cm, the procedure consisted of multisite-directed biopsies performed in four quadrants plus the central part of the tumour. Tumours that were < 3 cm underwent more limited sampling; thus, at least three or more cores were attempted in all cases. Whenever possible, core samples were preferentially obtained, with or without fine-needle aspiration, similar to the pretreatment diagnostic biopsy approach.

Estimated GFR was calculated using the Modification of Diet in Renal Disease formula [14]. Central tendencies are reported as both the means and medians. Comparisons were

performed using the Mann–Whitney *U*-test for non-parametric independent variables, or using the Wilcoxon signed-rank test for related non-parametric variables. Survival was estimated using the Kaplan–Meier method. Analysis was performed using SPSS, version 19 (IBM, Armonk, NY, USA) with $\alpha = 0.05$.

Results

Table 1 shows demographic, tumour, procedure and follow-up data for the 150 consecutive patients who underwent RFA. A primary renal malignancy (RCC or oncocytic neoplasm) was found in 72.1% of patients. The median tumour size was 2.6 cm, 22.7% of patients had a solitary kidney and most had central tumours. Most patients had a percutaneous approach. .

Of 150 patients, 145 (96.7%) patients remain without any evidence of local residual/recurrent tumours or metastatic disease at median radiological and clinical follow-up periods of 26.8 and 40.1 months, respectively. In patients with two kidneys, median estimated GFR was 67.8 mL/min/1.73 m² before RFA and 58.6 mL/min/1.73 m² at a median of 23 months after RFA ($P = 0.001$). For patients with a solitary kidney, median estimated GFR was 52.8 mL/min/1.73 m² before RFA and 42.9 mL/min/1.73 m² at a median of 24 months after RFA ($P = 0.008$). Overall, 43 patients underwent post-RFA biopsy. Indications for post RFA biopsy included non-involution ($n = 38$), enlarging lesion ($n = 3$), enhancement ($n = 1$) and enhancing and enlarging lesion ($n = 1$). The median diameter and volume of the zone of ablation in those patients who underwent biopsy were significantly larger than in those who did not undergo biopsy (2.65 cm vs 1.9 cm [$P = 0.011$] and 6.3 cm³ vs 2.6 cm³ [$P = 0.001$], respectively) and this was not related to initial tumour size (2.7 cm vs 2.5 cm, respectively, $P = 0.651$). Table 2 shows the results of the post-RFA biopsy in these 43 patients. The median (range) number of biopsy cores obtained was three (1–6 per patient). Biopsies were obtained a median of 21 months after RFA. A total of five (11.6%) biopsies were positive in the 43 patients (Table 3). Of the 38 patients with non-enhancing and non-involuting zones of ablation, three (7.9%) had viable cancer cells on post-RFA biopsy (Fig. 3). Only one patient with an enhancing zone of ablation had cancer on a biopsy performed 27 months after RFA; in this patient, the zone of ablation was also enlarging. There was one patient with a recurrence after previous partial nephrectomy in a solitary kidney and attempted open cryoablation elsewhere who had pre-existent severe kidney disease (estimated GFR = 20) that precluded gadolinium contrast, The patient underwent post-ablation biopsy on suspicion of new multifocal disease developing in areas away from the site of ablation and is not considered as an RFA failure.

Salvage therapies in the five patients with a positive biopsy consisted of partial nephrectomy in two patients (Figs 4 and 5), repeat RFA in one (with no residual malignancy on a second set of biopsies performed after salvage RFA), observation (per patient request) in one patient with an oncocytic neoplasm, and nephrectomy in the patient with severe kidney disease and new multifocal RCC. Pathology in the latter case showed no viable cancer in the zone of ablation. All these patients remain without radiological evidence of local progression or metastatic disease. Mean (range) cancer-specific survival for all patients with biopsy-proven, sporadic localized primary renal malignancy ($n = 106$) was 100% at 38.5 (2–81 months).

Discussion

We report the second largest study incorporating post-ablation tissue evaluation after RFA. The high technical and clinical success rates reported in the present study compare favourably with those of previous studies [3,5,7,8,15]. Overall, 93.7% of patients remain

without evidence of residual tumour or recurrence at the ablation site. The most notable finding in the present study is that we identified a subgroup of patients who may be at a higher risk of recurrence, albeit small, compared to the entire cohort. Specifically, patients with non-enhancing and non-involuting lesions undergoing multisite-directed biopsies at a mean of 24 months after RFA had a 7.9% risk of showing evidence of residual neoplasm. No patient had biopsies before 7 months, thus precluding the potential criticism that biopsies may have been performed too early after ablation. In almost all of the biopsies, and in the two cases of salvage partial nephrectomy, the presence of viable cells was obvious and was confirmed by secondary pathology review by another dedicated urologic pathologist. Overall, RFA remains associated with favourable oncological outcomes in patients who were considered to be high risk for surgery, although the data obtained in the present study show that the limitations of radiological imaging need to be recognized.

To the best of our knowledge, only three other studies have reported results of systematically performed post-ablation biopsies, with contrasting results. Weight *et al.* [16] performed percutaneous biopsies 6 months after RFA, showing six (46.2%) patients with positive biopsies out of 13 patients who had no enhancement on post-treatment MRI or CT. Although the study by Weight *et al.* [16] showed significant selection bias in those who underwent cryoablation vs RFA and the use of MRI, which has more subjective methods for assessment of enhancement, it nevertheless suggests the fallibility of radiographical enhancement as the sole determinant of ablative success. By contrast, Raman *et al.* [17] reported 19 patients who underwent post-RFA core biopsies 1 year after treatment, where no patient had any viable cancer. However, the selection of the 19 patients from the larger series was not described. The results of the present study appear to lie inbetween these two studies because the radiological reliability that we observed was markedly better than that suggested by Weight *et al.* [16], although not perfect as suggested by Raman *et al.* [17]. Davenport *et al.* [18] reported on 25 patients out of their experience of 72 patients who had systematic biopsies at 2 months, none of whom was found to have a positive biopsy because the study selected for those who had successful treatment; however, out of their remaining 47 patients who were not described further, two had recurrence based on imaging and two (4.3%) had recurrence based on biopsy results [18].

These data, when taken together with the results of other studies showing enhancement without evidence of recurrent cancer [19,20], support the notion that imaging, although largely reliable, is still subject to quantifiable false-negative and false-positive results and is not infallible. Previous ablate-and-resect studies have been reported [21] that suggest incomplete ablation after RFA, although these studies have been subject to the criticism that RFA appears to acutely preserve cellular architecture and that time-dependent physiological mechanisms such as necrosis and apoptosis were not allowed to take place [22,23]. Given the limitations of radiographical imaging, the data obtained in the present study highlight the issue of whether zones of ablation that do not involute after 6–12 months should undergo systematic core biopsies to ensure the absence of viable malignancy, even if there is no detectable enhancement on imaging. Given that no other reliable marker exists for recurrent RCC, continued radiographical surveillance should be maintained in this population and, at the least, biopsy considered, because tissue confirmation remains the *sine qua non* of RCC management.

The present study has several limitations. It is a retrospective study subject to inherent biases, particularly with respect to patient selection and recall bias. We did not systematically biopsy every patient, instead focusing on patients who had little or no involution of the site of ablation. The larger size and volume of zone of ablation between those who underwent biopsy and those who did not supports this approach but, nevertheless, the results may have been different if we had tried to biopsy every patient. Systematic post-

ablation biopsy in all patients does not appear to be feasible, particularly for those lesions that shrink, and some centres which have this in the past are reconsidered this strategy [18]. Of the three patients with non-involuting tumours, two underwent partial nephrectomy. It is unclear whether radiological evidence of recurrence would have developed with a longer follow-up.

In conclusion, RFA remains a viable option for the treatment of high-risk patients with a small renal mass. However, the absence of enhancement in the setting of non-involuting lesions does not guarantee a successful ablation, and a small but quantifiable number of these cases will harbour viable cancer cells. These data suggest that patients with non-involuting, non-enhancing zones of ablation should be followed up closely with imaging studies and also that multisite-directed core biopsies 6 months or more after ablation should be considered to provide additional evidence that the treatment is successful.

Acknowledgments

Sunita Patterson reviewed the manuscript for grammatical and editorial content. This research was supported in part by the National Institutes of Health through MD Anderson's Cancer Center Support Grant, CA01667.

Abbreviations

RFA radiofrequency ablation

References

1. Campbell SC, Novick AC, Belldgrun A, et al. Guideline for management of the clinical T1 renal mass. *J Urol*. 2009; 182:1271–9. [PubMed: 19683266]
2. Altunrende F, Autorino R, Hillyer S, et al. Image guided percutaneous probe ablation for renal tumors in 65 solitary kidneys: functional and oncological outcomes. *J Urol*. 2011; 186:35–41. [PubMed: 21571336]
3. Tracy CR, Raman JD, Donnally C, Trimmer CK, Cadeddu JA. Durable oncologic outcomes after radiofrequency ablation: experience from treating 243 small renal masses over 7.5 years. *Cancer*. 2010; 116:3135–42. [PubMed: 20564644]
4. Raman JD, Raj GV, Lucas SM, et al. Renal functional outcomes for tumours in a solitary kidney managed by ablative or extirpative techniques. *BJU Int*. 2010; 105:496–500. [PubMed: 19681900]
5. Aron M, Kamoi K, Remer E, Berger A, Desai M, Gill I. Laparoscopic renal cryoablation: 8-year, single surgeon outcomes. *J Urol*. 2010; 183:889–95. [PubMed: 20089263]
6. Raman JD, Hall DW, Cadeddu JA. Renal ablative therapy: radiofrequency ablation and cryoablation. *J Surg Oncol*. 2009; 100:639–44. [PubMed: 20017159]
7. Levinson AW, Su LM, Agarwal D, et al. Long-term oncological and overall outcomes of percutaneous radio frequency ablation in high risk surgical patients with a solitary small renal mass. *J Urol*. 2008; 180:499–504. [PubMed: 18550123]
8. Zagoria RJ, Traver MA, Werle DM, Perini M, Hayasaka S, Clark PE. Oncologic efficacy of CT-guided percutaneous radiofrequency ablation of renal cell carcinomas. *AJR Am J Roentgenol*. 2007; 189:429–36. [PubMed: 17646471]
9. Karam JA, Ahrar K, Wood CG, et al. Radio frequency ablation of renal tumors in patients with metastatic renal cell carcinoma. *J Urol*. 2010; 184:1882–7. [PubMed: 20846689]
10. Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. *J Urol*. 2009; 182:844–53. [PubMed: 19616235]
11. Booth J, Matin SF, Ahrar K, Tamboli P, Wood CG. Contemporary strategies for treating nonhereditary synchronous bilateral renal tumors and the impact of minimally invasive, nephron-sparing techniques. *Urol Oncol*. 2008; 26:37–42. [PubMed: 18190828]

12. Ahrar K, Matin S, Wood CG, et al. Percutaneous radiofrequency ablation of renal tumors: technique, complications, and outcomes. *J Vasc Interv Radiol*. 2005; 16:679–88. [PubMed: 15872323]
13. Matin SF, Ahrar K, Cadeddu JA, et al. Residual and recurrent disease following renal energy ablative therapy: a multi-institutional study. *J Urol*. 2006; 176:1973–7. [PubMed: 17070224]
14. Levey AS, Coresh J, Greene T, et al. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med*. 2006; 145:247–54. [PubMed: 16908915]
15. Gervais DA, McGovern FJ, Arellano RS, McDougal WS, Mueller PR. Radiofrequency ablation of renal cell carcinoma: part 1, Indications, results, and role in patient management over a 6-year period and ablation of 100 tumors. *AJR Am J Roentgenol*. 2005; 185:64–71. [PubMed: 15972400]
16. Weight CJ, Kaouk JH, Hegarty NJ, et al. Correlation of radiographic imaging and histopathology following cryoablation and radio frequency ablation for renal tumors. *J Urol*. 2008; 179:1277–81. [PubMed: 18280507]
17. Raman JD, Stern JM, Zeltser I, Kabbani W, Cadeddu JA. Absence of viable renal carcinoma in biopsies performed more than 1 year following radio frequency ablation confirms reliability of axial imaging. *J Urol*. 2008; 179:2142–5. [PubMed: 18423723]
18. Davenport MS, Caoili EM, Cohan RH, et al. MRI and CT characteristics of successfully ablated renal masses: Imaging surveillance after radiofrequency ablation. *AJR Am J Roentgenol*. 2009; 192:1571–8. [PubMed: 19457820]
19. Matin SF. Determining failure after renal ablative therapy for renal cell carcinoma: false-negative and false-positive imaging findings. *Urology*. 2010; 75:1254–7. [PubMed: 20299082]
20. Javadi S, Matin SF, Tamboli P, Ahrar K. Unexpected atypical findings on CT after radiofrequency ablation for small renal-cell carcinoma and the role of percutaneous biopsy. *J Vasc Interv Radiol*. 2007; 18:1186–91.
21. Klingler HC, Marberger M, Mauermann J, Remzi M, Susani M. 'Skipping' is still a problem with radiofrequency ablation of small renal tumours. *BJU Int*. 2007; 99:998–1001. [PubMed: 17437433]
22. Anderson JK, Baker M, Jaffers O, Pearle MS, Lindberg GL, Cadeddu JA. Time course of nicotinamide adenine dinucleotide diaphorase staining after renal radiofrequency ablation influences viability assessment. *J Endourol*. 2007; 21:223–7. [PubMed: 17338624]
23. Hsu TH, Fidler ME, Gill IS. Radiofrequency ablation of the kidney: acute and chronic histology in porcine model. *Urology*. 2000; 56:872–5. [PubMed: 11068326]

FIG. 1.

Axial CT images of the left kidney (**A**) showing a solid, enhancing mass (arrowheads), with a maximum diameter of ≈ 2 cm. A small cyst is seen on the lateral border of the left kidney (arrow). Core biopsy of the solid mass showed RCC, clear cell type, nuclear grade 2. The patient underwent percutaneous CT-guided radiofrequency ablation. Follow-up CT images at 1 month (**B**), 6 months (**C**), 12 months (**D**), 22 months (**E**) and 46 months (**F**) showing gradual involution of the ablation zone. Incidentally, the cystic lesion along the lateral border of the kidney gradually enlarged until 22 months after ablation (**E**), and was no longer seen at 46 months after ablation (**F**).

FIG. 2.

Axial CT images of right kidney in a different patient (**A**) showing a 3.7-cm mass (arrowheads) in the anterior aspect of the kidney with close proximity to the colon. The patient underwent laparoscopic biopsy and radiofrequency ablation of the tumour. Pathology showed RCC, clear cell type. Follow-up CT at 1 month (**B**) showing an initial involution of the ablated tumour to 2.5 cm (arrowheads). Follow-up images at 8 months (**C**) and 13 months (**D**) showing no further involution of the ablation zone. Percutaneous biopsy of the ablation zone at 13 months showed necrotic tissue with no viable tumour.

FIG. 3.

Axial CT images of three patients with non-enhancing zones of ablation and biopsy proven recurrences. **A**, Pre-ablation image (Table 3, patient 2) showing a right 2.6-cm renal mass, and images at 6 and 12 months showing some regression of the perinephric fat halo but minimal to no involution of the non-enhancing zone of ablation. **B**, Pre-ablation image (Table 3, patient 3) showing a 1.5-cm left renal mass, and images at 1 and 6 months showing no involution of the non-enhancing zone of ablation. **C**, Pre-ablation image (Table 3, patient 4) showing a 2.2-cm left renal mass, and images at 6 and 12 months showing minimal involution of the non-enhancing zone of ablation

FIG. 4. Tissue specimens from a patient 3 (Table 3). **A**, Hematoxylin and eosin-stained core biopsy. **B**, Resected partial nephrectomy specimen. **C**, Section showing that most of the tumour (> 95%) is infarcted and composed of hyalinized tumour. **D**, Focally viable tumour was noted, composed of closely packed tubules and spindle cells of low nuclear grade, consistent with residual viable mucinous tubular spindle cell carcinoma.

FIG. 5. Tissue specimens from patient 4 (Table 3). **A**, Hematoxylin and eosin-stained core biopsy. **B**, Resected partial nephrectomy specimen. **C**, Section showing the interface between viable renal parenchyma (upper left) and infarcted tumour (bottom right). More than 95% of the tumour was infarcted. **D**, A small amount of residual viable clear cell RCC was identified, which showed features compatible with Fuhrman nuclear grade 2.

TABLE 1

Patient demographic, tumour, procedure and follow-up characteristics

Characteristic	Value
Age (years)	
Median (range)	68.5 (24–85)
Mean (SD)	66.5 (11.9)
Sex, <i>n</i> (%)	
Male	97 (64.7)
Female	53 (35.3)
Race, <i>n</i> (%)	
White	123 (82.0)
Black	9 (6.0)
Asian	4 (2.7)
Hispanic	14 (9.3)
Tumour location, <i>n</i> (%)	
Right kidney	75 (50.0)
Left kidney	75 (50.0)
Tumour characteristic, <i>n</i> (%)	
Exophytic	60 (40.0)
Central	90 (60.0)
Tumour diameter before RFA (cm)	
Median (range)	2.6 (0.9–7.1)
Mean (SD)	2.7 (1.2)
Nephrometry score, <i>n</i> (%)	
4	14 (9.3)
5	12 (8.0)
6	31 (20.7)
7	20 (13.3)
8	29 (19.3)
9	19 (12.7)
10	15 (10.0)
11–12	0 (0.0)
Missing	10 (6.7)
Median (range)	7 (4–10)
RFA technique, <i>n</i> (%)	
Percutaneous	130 (86.7)
Laparoscopic	20 (13.3)
Indication for RFA/nephron sparing, <i>n</i> (%)	
Imperative	55 (36.7)
Elective	95 (63.3)
Solitary kidney, <i>n</i> (%)	
Yes	34 (22.7)

Characteristic	Value
No	116 (77.3)
Pre-RFA renal biopsy histology, <i>n</i> (%)	
RCC	
Clear cell	76 (50.7)
Papillary	13 (8.7)
Chromophobe	1 (0.7)
Oncocytic neoplasm	18 (12.0)
Benign	
Angiomyolipoma	2 (1.3)
Oncocytoma	1 (0.7)
Other malignancy	6 (4.0)
Other	
No cancer/non-diagnostic	10 (6.7)
No biopsy done	23 (15.3)
Disease grade on diagnostic biopsy, <i>n</i> (%)	
1–2	64 (42.7)
3–4	9 (6.0)
Not reported	77 (51.3)
Radiographical follow-up (months)	
Median (range)	25.0 (0–76)
Mean (SD)	26.8 (21.9)
Clinical follow-up (months)	
Median (range)	38.0 (2–95)
Mean (SD)	40.1 (21.1)

RFA, radiofrequency ablation.

TABLE 2

Post-ablation biopsy results ($n = 43$)

Characteristic	Value
Cores taken at post-RFA biopsy, n (%)	
Fine-needle aspiration only	2 (4.6)
1	9 (20.9)
2	3 (7.0)
3	12 (27.9)
4	6 (14.0)
5	9 (20.9)
6	2 (4.6)
Post-RFA biopsy, n (%)	
Positive for neoplasm	5 (11.6)
Enhancement on imaging	1 (5.3)
Non-involution	3 (7.0)
Negative for neoplasm	38 (88.4)
Indications for post-RFA biopsy, n	
Enhancing lesion,	1
Number positive	0
Enlarging lesion	3
Number positive	0
Enhancing and enlarging lesion	1
Number positive	1
Non-involuting lesion	38
Number positive	3
Time to biopsy (months)	
Median (range)	21 (7–76)
Mean (sd)	24.3(16.1)

RFA, radiofrequency ablation.

TABLE 3
Characteristics of tumours and patients with post-RFA biopsies positive for malignancy

Number	Type of RFA	Size of tumour before RFA (cm)	Nephrometry score	Pre-RFA histology/grade	Indication for post-RFA biopsy	Time from RFA to positive biopsy (months)	Post-RFA histology/grade	Treatment of recurrence	Time from repeat biopsy/treatment to last imaging (months)	Status
1	Percutaneous	2.8	7p	Not done	Enlarging and enhancing nodule in ablation bed	27	Clear cell RCC/1	Repeat RFA	45	Alive, NED
2	Laparoscopic	2.6	10a	Oncocytic neoplasm	Failure to shrink	28	Oncocytic neoplasm	Observation	27	Alive, NED
3	Percutaneous	1.5	6p	Mucinous tubular and spindle cell carcinoma	Failure to shrink	13	Mucinous tubular and spindle cell carcinoma	Partial nephrectomy (viable tumour, negative margins)	38	Alive, NED
4	Percutaneous	2.2	9p	Clear cell RCC/2	Failure to shrink	9	Clear cell RCC/2	Partial nephrectomy (viable tumour, negative margins) (Fig. 4)	27	Alive, NED
5	Percutaneous	3.8	5a	Clear cell RCC	Non-contrast indication, new multifocal disease	7	Clear cell RCC	Radical nephrectomy (multifocal RCC with no viable tumour in zone of ablation, negative margins) (Fig. 5)	8	Alive, NED

NED, no evidence of disease; RFA, radiofrequency ablation.