Cardiovasc Intervent Radiol (2008) 31:595–603
DOI 10.1007/s00270-007-9291-3

CLINICAL INVESTIGATION

Radiofrequency Ablation of Renal Tumors with an Expandable Multitined Electrode: Results, Complications, and Pilot Evaluation of Cooled Pyeloperfusion for Collecting System Protection

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Received: 5 September 2007 / Accepted: 28 December 2007 / Published online: 5 February 2008

Abstract The objective of this study was to retrospectively evaluate the results of radiofrequency ablation (RFA) of renal tumors with an impedance-based system using an expandable multitined electrode. Twenty-two patients (30 tumors) were treated with RFA over a 7-year period, percutaneously (16 tumors) or intraoperatively (14 tumors). Follow-up imaging was performed at 1–3, 6, and 12 months and yearly thereafter. Twenty-seven of 30 tumors (19/22 patients) showed no residual tumor on the first imaging control. Two residual tumors were successfully ablated by a second RFA procedure. Our mean follow-up period was 35 months (range, 3–84 months). Two tumors that had been completely ablated based on imaging criteria recurred 11 and 48 months after RFA. One was treated by partial nephrectomy. The other one was not treated because the patient developed bone metastases. One patient had nephrectomy because of an RFA-induced ureteropelvic junction stricture. Nine patients (11 sessions) had a pyeloperfusion of cooled saline during RFA. None developed symptomatic complications, even though in three patients the ablation zone extended to the closest calyx (3–5 mm from the tumor). We conclude that RFA of renal tumors is promising, but serious complications to the collecting system must be taken into consideration. Prophylactic per-procedural cooling of the collecting system is feasible but needs further assessment.

Keywords Radiofrequency ablation · Renal cell carcinoma · Imaging guidance · Ureteral perfusion

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Introduction

Radiofrequency ablation (RFA) is being used increasingly to treat small renal masses in patients who are not ideal for surgery [1–16]. However, most series published in the literature have limited follow-up, and the medium-term (>2-year) efficiency of the technique needs evaluation. The recurrence rate of tumors that showed complete ablation on early imaging studies is still unknown. Several RFA devices are commercially available, and whether or not these devices give equivalent results is controversial [7, 17–20]. Although the complication rate seems low [21, 22], some severe thermal injuries to the collecting system have been reported [10, 23, 24]. To date, it is unclear whether or not there is a minimal distance to respect between the tumor and the collecting system when selecting patients for RFA [1]. Prophylactic

procedures such as intraoperative cooling of the collecting system have not been assessed.

The purpose of this study is to retrospectively review our 7-year experience with renal tumor RFA and to report our preliminary results with intraoperative pyeloperfusion.

Materials and Methods

Study Population

From June 2000 to June 2007, 22 consecutive patients (30 renal tumors) underwent RFA at our institution. The patients' mean age was 64 years (range, 32–78 tears). Indications for RFA included high surgical risk ($n = 4$), solitary kidney ($n = 15$), chronic renal failure ($n = 3$), hereditary predisposition to multiple renal cell carcinomas (RCCs; $n = 10$), and/or patient refusal of surgery ($n = 3$). All but one patient with a solitary kidney had a history of contralateral radical nephrectomy for RCC. Six patients had had nephron-sparing surgery for tumor on the ipsilateral or contralateral kidney.

Five patients had preexisting metastases that had been surgically removed. At the time of the RFA, four or five patients had no residual metastases; one patient had persistent lung metastases that had shown no evolution over a 1-year period.

Definitions

Exophytic tumors extended into the perirenal fat but not into the sinus fat; parenchymal tumors were limited to the parenchyma; central tumors had an extension into the renal sinus.

Persistent tumor was defined as any remaining portion of enhancing tumor seen on the first postoperative imaging examination. Recurrent tumor was defined as any new enhancing portion after initial imaging demonstrated complete tumor ablation.

An ablation session is the sum of ablations performed during the same anesthesia, regardless of the number of tumors treated. The primary technical success rate was the proportion of completely ablated tumors after the first ablation session. The secondary technical success rate was the proportion of completely ablated tumors, whatever the number of RFA sessions needed. The clinical success rate was the proportion of tumors that showed no persistent/recurrent tumor at the end of follow-up (whatever the number of RFA sessions performed) without the need for other types of treatment (e.g., surgery).

RFA Procedure

All treatments were performed under general anesthesia. Nineteen patients had only one tumor treated with RFA, in one ($n = 17$) or two ($n = 2$) sessions. Three patients had three ipsilateral tumors treated during the same session. Two of the 22 patients underwent a second RFA for a new ipsilateral ($n = 1$) or contralateral ($n = 1$) tumor, 46 and 52 months after the first RFA. Thus, 26 RFA sessions were conducted.

Whenever possible, an ultrasound (US)-guided (6 patients, 6 tumors, 8 sessions) or CT-guided (10 patients, 10 tumors, 10 sessions) percutaneous approach was chosen. An intraoperative approach was chosen in 8 patients (14 tumors, 8 sessions) because of an anterior tumor ($n = 3$) or because of multiple tumors, some of which needing surgical resection ($n = 5$); in that case, RFA was done under intraoperative US guidance or direct vision.

All 18 percutaneous treatments were performed by two radiologists with 15 ($n = 17$) and 2 ($n = 1$) years of experience in interventional radiology. Five intraoperative RFAs were performed by the most experienced radiologist and a staff urologist. Three intraoperative procedures were performed by staff urologists alone.

A percutaneous or intraoperative biopsy was obtained before treatment in 22 tumors, using an 18-G biopsy gun. In the remaining cases, no biopsy was performed because the patient had multiple tumors and a malignant histology had been obtained from another tumor of the same kidney (clear-cell RCCs in all cases).

We used a 15-G umbrella-shaped expandable multitined RFA electrode powered by a 200-W generator (LeVeen needle electrode, RF-3000 generator; Boston Scientific, Natik, MA, USA). The diameter of the tine array was chosen to create a thermal lesion that would extend at least 5 mm beyond the tumor. Ablation started at 30 W (2-cm electrodes), 40 W (3-cm electrodes), 50 W (3.5-cm electrodes), or 80 W (4-cm electrodes), with an increase of 10 W/30 s to a maximum of 60 W (2 cm), 80 W (3 cm), 90 W (3.5 cm), or 130 W (4 cm), or until a rapid increase in impedance (roll-off) was detected. After a 30-s period of rest, the ablation cycle was started again at 70% of the power at which the impedance roll-off had been obtained. The power was gradually increased (10 W/30 s) until a second impedance roll-off. Then the electrode was carefully removed.

Pyeloperfusion Technique

After patient 8, all patients with at least one tumor located within 10 mm of the collecting system (9 patients, 14

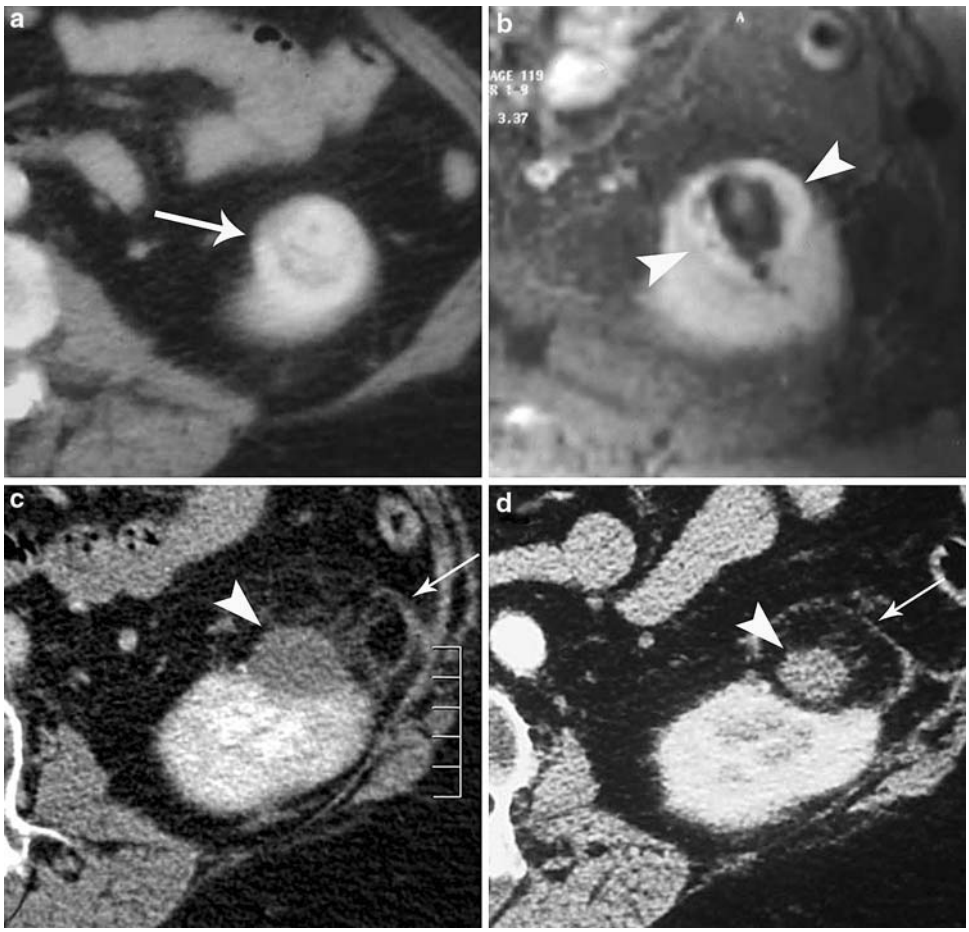

Fig. 1 Images obtained in a 65-year-old patient with a history of right radical nephrectomy for renal cell carcinoma and surgery for subsequent metastases (liver, right renal fossa, left adrenal). (**a**) Contrast-enhanced CT image showing a new 35-mm tumor of the lower pole of the left kidney (arrow). This tumor was treated by US-guided percutaneous RFA. (**b**) Fat-saturated gadolinium-enhanced MR image obtained 2 days after the ablation procedure showing residual enhancing tumor tissue on the periphery of the treated area (arrowheads). A second US-guided percutaneous RFA was performed 4 months later. (**c**) Contrast-enhanced CT image obtained 3 months after the second ablation session showing complete devascularization of the tumor (arrowhead). A fibrotic halo was visible in the fat surrounding the tumor (arrow), probably marking the boundary of the treatment-induced fat necrosis. (**d**) Contrast-enhanced CT image obtained 25 months after the second ablation session. The tumor was still devascularized (arrowhead) and had involuted (20 mm). The fibrotic halo located in the fat around the tumor was still visible (arrow)

tumors, 11 sessions) underwent a prophylactic pyeloperfusion with refrigerated (+4°C) saline containing no contrast medium. In 8 patients (13 tumors, 10 sessions), the cooled saline was directly perfused through a retrograde ureteral catheter placed the same day or the day before the ablation by the referring urologist, with a bladder catheter allowing perfusate drainage. In one patient with a preexisting ureteral JJ stent, the cooled saline was perfused through the bladder catheter. A correct reflux of perfusate into the renal pelvis through the JJ stent (distension of the collecting system) was monitored by US during the procedure. In all patients, the saline bag was placed approximately 1 m above the patient level and the perfusion was operated under gravity. It was started after the RFA needle had been placed in the tumor. The RFA generator was started 5 min after the start of the pyeloperfusion, which was maintained during the whole period of heating and stopped 2–3 min after the end of the ablation procedure. Approximately 1 liter of saline was needed. The ureteral catheter was removed the following day. In two patients with an RFA-induced urinary fistula, the ureteral catheter was replaced by a JJ ureteral stent.

Follow-up

Follow-up imaging (contrast CT or gadolinium-enhanced MRI) was performed at 1–7 days, 1–3 months, 6 months, and 12 months and yearly thereafter. The choice between CT and MRI was mostly dictated by the renal function of the patients.

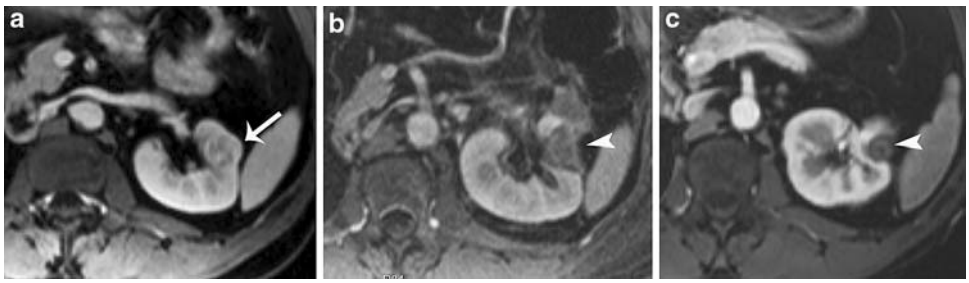

Fig. 2 Images obtained in a 51-year-old patient with history of right radical nephrectomy for renal cell carcinoma and surgical resection of a solitary metastasis of the left adrenal gland. (**a**) Fat-saturated gadolinium-enhanced MR image showing a new 24-mm tumor of the lateral midpole of the left kidney (arrow) that was treated with open intraoperative RFA because it could not be reached percutaneously. The tumor was 9 mm from the renal pelvis. (**b**) Fat-saturated gadolinium-enhanced MR image obtained 4 days after RFA showing a wedge-shaped devascularized ablation zone with no residual enhancing tumor element (arrowhead). (**c**) Fat-saturated gadolinium-enhanced MR image obtained 11 months after RFA. The ablated tumor is visible as a 13-mm nonenhancing nodule. At that time, the patient had severe renal insufficiency with retraction of the renal pelvis and dilation of the calyces (not shown). The renal function could not be improved by a ureteral stent. Several episodes of pyelonephritis occurred, further decreasing renal function, and the patient had to undergo left nephrectomy 22 months after RFA. Microscopic examination of the specimen showed chronic pyelonephritis. No residual tumor was found in the ablated zone

Statistical Analysis

Change in serum creatinine level before and 30 days after RFA was analyzed using a two-tailed paired Student's *t* test; $p < 0.05$ was considered significant.

Results

Tumor Characteristics

The mean diameter of the tumors was 21 ± 10 mm (range, 5–44 mm). Fourteen tumors were exophytic, 13 parenchymal, and 1 central. Preoperative biopsy ($n = 22$) showed 12 Fuhrman grade 1–2 ($n = 11$) or grade 3 ($n = 2$) clear-cell RCCs, 1 papillary RCC, 1 oncocytoma, and 7 nondiagnostic findings.

RFA Results

Twenty-seven tumors (19/22 patients) showed no persistent tumor on the first follow-up imaging control. Thus, the primary technical success was 90% (per-tumor analysis) or 86.4% (per-patient analysis).

Two of the three persistent tumors (diameter: 35 and 44 mm) had been treated by US-guided percutaneous RFA and successfully underwent a second US-guided ablation 4 months later (Fig. 1). The third patient had a solitary kidney with seven tumors. Six were surgically removed and one 20-mm tumor was treated with intraoperative RFA. Imaging control showed persistent tumor on the periphery of the ablation zone. This tumor was not retreated since further CT examinations showed eight new tumors in the kidney. The patient is currently awaiting therapeutic decision. Thus, the secondary technical success rate was 96.7% (29/30, per-tumor analysis) and 95.4% (21/22, per-patient analysis).

The mean follow-up was 35 ± 23.1 months (range, 3–84 months). Of the 29 tumors that had shown complete necrosis after one or two RFA sessions, 2 tumors (initial diameter: 28 and 35 mm) recurred 11 and 48 months after ablation. One was not treated because of the onset of bone metastases. The second one was treated by partial nephrectomy. The specimen showed a Fuhrman grade 3 clear-cell RCC.

Thus, the clinical success rate was 90% (27/30, per-tumor analysis) or 86.4% (19/22, per-patient analysis) at the end of follow-up.

Four patients developed one ($n = 2$), two ($n = 1$), and eight ($n = 1$) new asynchronous homolateral ($n = 3$) or contralateral ($n = 1$) tumors in locations that had not been treated with RFA. Two tumors were successfully treated by a second RFA session in two patients.

No patient was lost for follow-up. No metastasis appeared in the patients who had no history of metastasis at treatment, but one patient died of unrelated cause 57 months after RFA. Of the five patients with preexisting metastases, one died of metastatic dissemination 38 months after RFA. New metastases appeared in two patients who were still alive 66 and 58 months after RFA. The last two patients, who had had surgical resection of solitary metastases before RFA, remained free of metastatic disease at the end of follow-up, i.e., 36 and 26 months after RFA.

RFA Complications

The mean serum creatinine level was 112.7 ± 47.1 μmol/L before the RFA procedure and 130 ± 51 μmol/L 1 month afterward ($p > 0.1$).

Table 1 Complications to the collecting system during procedures with and without pyeloperfusion of cooled saline

Pt no.	Guiding method	Pyelo-perfusion	Tumor diameter (mm)	Distance between tumor and CS (mm)	Closest part of CS	CS injury at control imaging	Technical success	Follow-up (mo)	Clinical success
1	Intraop	No	35	19	Calyx	No	Yes	84	Yes
2[a]	Intraop	No	15	2	Calyx	No	Yes	84	Yes
3	Intraop	No	28	8	Calyx	No	Yes	66	No (LR)
		No	20	5	Calyx	No	Yes	66	Yes
		No	12	14	Calyx	No	Yes	66	Yes
4[b]	Percut (US)	No	35	7	Calyx	No	Yes	32[c]	Yes
5	Percut (CT)	No	35	6	Calyx	No	Yes	48	No (LR)
6	Percut (US)	No	44	11	Calyx	No	Yes	52[d]	Yes
7	Intraop	No	24	9	Renal pelvis	Yes: nephrectomy	Yes	22	Yes[e]
8	Intraop	No	20	5	Infundi-bulum	No	No	36	No (TF)
9[a]	Intraop	Yes	8	9	Calyx	No	Yes	58	Yes
			7	14	Calyx	No	Yes	58	Yes
			5	10	Renal pelvis	No	Yes	58	Yes
10	Intraop	Yes	21	6	Calyx	No	Yes	36	Yes
11	Percut (CT)	No	26	11	Calyx	No	Yes	27	Yes
12[b]	Percut (US)	Yes	40	8	Calyx	No	Yes	22	Yes
13	Intraop	Yes	13	5	Calyx	No	Yes	26	Yes
			10	5	Calyx	No	Yes	26	Yes
			6	15	Calyx	No	Yes	26	Yes
2[a]	Percut (US)	Yes	14	6	Calyx	No[f]	Yes	33	Yes
14	Percut (CT)	No	22	11	Calyx	No	Yes	27	Yes
15	Percut (US)	Yes	23	3	Infundi-bulum	No	Yes	23	Yes
16	Percut (US)	Yes	24	10	Calyx	No	Yes	19	Yes
17	Percut (CT)	No	26	11	Calyx	No	Yes	12	Yes
18	Percut (CT)	No	20	11	Calyx	No	Yes	12	Yes
9[a]	Percut (CT)	Yes	10	5	Calyx	Yes: asymptomatic	Yes	12	Yes
19	Percut (CT)	No	17	11	Calyx	No	Yes	7	Yes
20	Percut (CT)	No	10	16	Calyx	No	Yes	7	Yes
21	Percut (CT)	Yes	35	3	Calyx	Yes: asymptomatic	Yes	3	Yes
22	Percut (CT)	Yes	24	<1	Calyx	Yes: asymptomatic	Yes	4	Yes

Note. CS, collecting system; Pt, patient; percut, percutaneous; intraop, intraoperative; LR, late recurrence; TF, technical failure

[a] Patients who underwent two RFA sessions for asynchronous tumors

[b] Patients for whom the destruction of the tumor necessitated two RFA sessions

[c] Deceased (from metastases)

[d] Deceased (from unrelated cause)

[e] No residual tumor found on the nephrectomy specimen

[f] No injury of the collecting system, but chronic pain at the ablated site, probably due to partial necrosis of the dorsal muscles during the procedure

One patient had chronic pain at the ablated site, probably because of partial necrosis of the dorsal muscles during the procedure. Another patient, with a 24-mm tumor of the lateral midpole of the left kidney developed, in the months following the ablation, a severe renal insufficiency due to ureteropelvic junction (UPJ) obstruction that necessitated radical nephrectomy (Fig. 2).

Among the patients who had an intraoperative pyeloperfusion, postprocedural CT examinations showed the destruction of a neighboring calyx in one patient and a

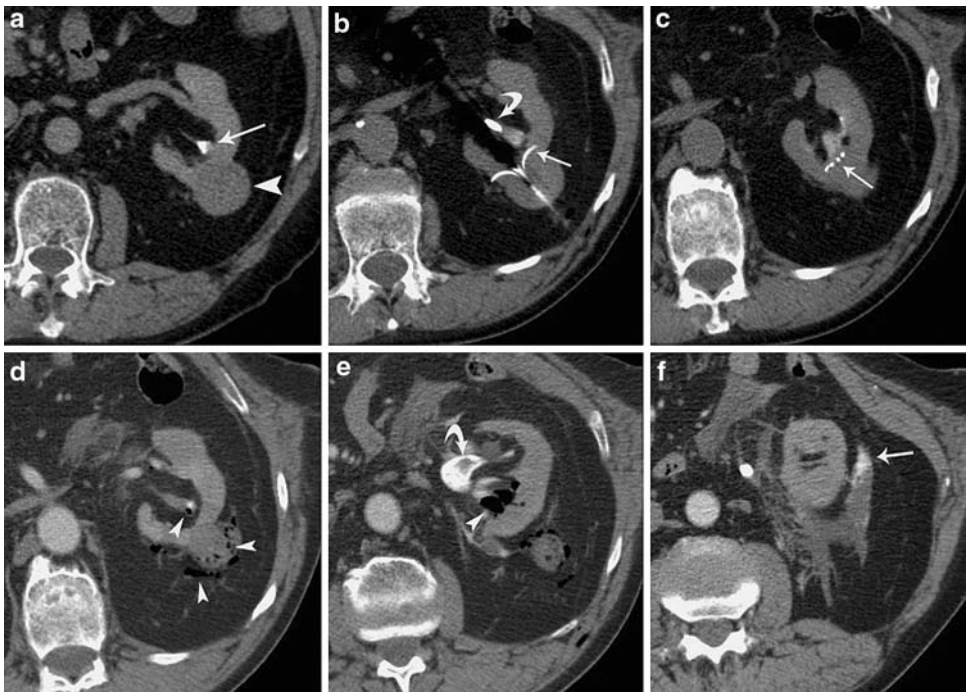

Fig. 3 Images obtained in a 76-year-old patient with chronic renal failure and a 35-mm exophytic tumor of the left kidney. (**a**) Contrast-enhanced CT image showing the tumor (arrowhead), which was located 3 mm from the closest calyx (arrow). (**b**), (**c**) Contrast-enhanced CT images showing the RFA electrode placed in the tumor. The electrode tines were approximately 2 mm from two different calyxes (arrows). A perfusion of cooled saline was done during the ablation through a ureteral catheter placed in the closest infundibulum (b; curved arrow). (**d**), (**e**), (**f**) Contrast-enhanced CT images obtained immediately after the RFA showing a urinary fistula with contrast medium in the peripnephretic fat (f; arrow). Gaz bubbles produced by vaporization of tissue during the procedure are present within the tumor, in the perinephretic fat, in the sinusal fat, and in one of the calyces close to the electrode (arrowheads). Small clots are visible in the renal pelvis (curved arrow). The patient remained asymptomatic. The ureteral catheter was replaced by a JJ stent and the urinary fistula had totally disappeared on a CT examination obtained 10 days later (not shown)

calyceal fistula in two patients (Table 1). These fistulas disappeared 1 week after placement of a JJ stent (Fig. 3). The three patients remained asymptomatic.

Discussion

Many studies have already established the short-term effectiveness of renal tumor RFA using open, laparoscopic or percutaneous approaches (Table 2). Although no 5-year survival rate has been published yet, our results, with a mean follow-up of 35 months, further validate these good medium-term results.

Besides these good overall results, our series brings additional light to the existing literature in three different fields. First, tumor recurrences can occur in areas apparently totally ablated. Most of the RFA failures reported so far are technical failures, i.e., lack of total destruction of the tumor. However, some studies with longer follow-up have reported a few instances of recurrences of contrast-enhancing tumor tissue in areas that seemed totally devascularized on early imaging controls [7, 8, 25]. Our results confirm the possibility of late recurrences, emphasizing the need for strict and prolonged imaging follow-up.

Second, the clinical results obtained with the LeVeen electrode are in line with those published with the other commercially available devices. To date, most of the reported RFA procedures have used the (temperature-based) RITA or the (impedance-based) Radionics system. Preliminary experimental data suggested that the use of the expandable multitined LeVeen electrode might result in skip areas of viable tissue in the ablated volume [26, 27]. Although other experiments did not confirm this finding [28–31], clinical experience with the LeVeen electrode is more limited than that with the other systems. To our knowledge, only one series using this device exclusively has been published (20 patients, mean follow-up of 24 months), with primary technical, secondary technical, and clinical success rates of 80% (16/20), 90% (18/20), and 90% (18/20), respectively [12]. These results are in line with ours and with what has been reported with the other systems.

Third, RFA can induce severe injury to the collecting system. Besides asymptomatic hydrocalices, mild ureteral strictures, urinary leaks, and transient hematuria [2, 4, 7,

Table 2 Radiofrequency ablation of renal tumors: recently published clinical series

Author [ref no.]	Year	Pt no.	Tumors	RFA sessions	Guiding method	Device	Mean tumor diameter (mm)	Primary tech success[a]	Secondary tech success[b]	Clinical success[b]	Mean follow-up (mo)	Comments
Farrel [3]	2003	20	35	35	CT/US/ intraop	Radionics / RITA	17 (9–36)	35/35[d]	35/35[d]	35/35[d]	9 (1–23)	
Mayo-Smith [4]	2003	32	32	38	CT/US	Radionics	26 (10–50)	26/32[d]	31/32[d]	31/32[d]	9 (1–36)	
Zagoria [6]	2004	22	24	27	CT	Radionics	35 (10–70)	18/22[e]	20/22[e]	20/22[e]	7 (1–35)	
Hwang [24]	2004	17	24	24	CT/laparo	Radionics	22 (12–28.5)	ND	ND	23/24[d]	14.5 (11–23)	Only hereditary tumors
Gervais [1]	2005	85	100	125	CT/US	Radionics/RITA	32 (11–89)	67/100[d]	90/100[d]	90/100[d]	27.6 (ND–72)	
Matsumoto [7]	2005	91	109	112	CT/laparo	RITA	24 (8–47)	107/109[d]	109/109[d]	60/60[e,f]	19.5 (12–33)[f]	
Varkarakis [8]	2005	46	56	62	CT	RITA/Boston	22 (10–40)	50/56[d]	55/56[d]	53/56[d]	27.5 (12–48)	
Ahrar [9]	2005	29	30	34	CT	Radionics/RITA	35 (15–65)	25/30[d]	28/30[d]	23/24[d]	10 (1–33)	24 pts available for follow-up
Weizer [10]	2005	24	32	27	CT	Radionics/RITA	24	18/23[e]	21/23[e]	21/23[e]	11.7 (1–28)	23 pts available for follow-up
Sabharwal [11]	2006	11	18	22	CT/intraop	RITA/Boston	20 (10–43)	14/18[d]	18/18[d]	18/18[d]	10.9 (1–24)	
Veltri [5]	2006	31	44	47	US	RITA	27 (14–50)	38/44[d]	39/44[d]	39/44[d]	14 (3–34)	
Arzola [12]	2006	23	27	22	CT	Boston	27 (9–60)	16/20[e]	18/20[e]	18/20[e]	24 (7–53)	20 pts available for follow-up
Breen [15]	2007	97	105	ND	CT/US	Radionics/RITA	32 (11–68)	83/105	95/105	95/105	16.7 (1–76)	

Note. Pt, patient; tech, technical; laparo, laparoscopic; intraop, intraoperative; ND, not determined

[a] Primary technical success rate: number of tumors (or patients) with complete tumor necrosis by imaging criteria at the end of the first ablation session

[b] Secondary technical success rate: number of tumors (or patients) in which complete tumor necrosis by imaging criteria was achieved, whatever the number of RFA sessions needed

[c] Clinical success rate: number of tumors (or patients) with complete tumor necrosis by imaging criteria at the end of the follow-up session, without the need for other types of treatment

[d] Per-tumor analysis

[e] Per-patient analysis

[f] Analysis of the 60 patients with more than 1 year of follow-up

10, 14, 15, 23, 24], three cases of severe renal pelvis injury have been published [10, 23, 24]. One occurred after laparoscopic RFA of a tumor adherent to the ureter and could be treated by open surgery [24]. Interestingly, the two others were exactly to the same as the complication we report: they also occurred after ablation of a tumor located anteriorly, on the medial midpole of the kidney, close to the renal hilum, and necessitated nephrectomy [10, 23]. Therefore, we think that tumors located in that part of the kidney should be contraindicated for RFA and treated with other means.

Whether preoperative pyeloperfusion of cooled serum can prevent these severe complications remains undetermined since, to our knowledge, this technique has not been assessed. Our preliminary experience suggests that it is easy to implement and only slightly increases the procedure duration. Shortly after the aforementioned RFA-related UPJ obstruction occurred, we decided to perform a prophylactic pyeloperfusion for all tumors within 10 mm of the collecting system. This attitude remains questionable. On one hand, despite pyeloperfusion, the ablation zone extended to the closest calyx (located 3–5 mm from the tumor) in three patients (Table 1). Thus, pyeloperfusion does not appear to be an absolute protection when the collecting system is within close range ($\leq$5 mm) of the tumor. On the other hand, a mild UPJ stricture has been reported after RFA (without pyeloperfusion) of a tumor located 14 mm from the UPJ [2]. Protective measures might thus be needed even when the collecting system is more than 10 mm from the tumor. In fact, heat diffusion in normal tissues around the tumor depends on many factors including the position of the electrode tines, the diameter of the tine array (influencing the power used), and the blood perfusion of the tumor and surrounding renal parenchyma. These multiple parameters make it difficult to define the distance beyond which there is no risk for the collecting system. It is also important to consider the part of the collecting system the tumor is close to. Destruction of calyces usually remains asymptomatic [2] but injury to the renal pelvis or the ureter might irreversibly impair the function of the entire kidney. Therefore, the protective efficiency of pyeloperfusion and its indications remains to be defined.

Our study has several limitations. First, it is retrospective. The guiding methods used to place the electrode varied greatly over the 7-year period of the study and the RFA ablations were done by operators with varying expertise and training. However, we did not observe any clear impact of the guiding method or operator experience on the treatment outcome. Particularly, the two late recurrences occurred after RFA procedures done by the most experienced operator under CT guidance (n = 1) and by an experienced staff urologist intraoperatively (n = 1). Second, even if our average follow-up period is long compared to the other published studies', the number of treated tumors is small, which limits the significance of our results. Third, the high rate (7/22) of inconclusive percutaneous biopsies, which leave the patients without any definitive histological diagnosis, remains an issue. This point comes as no surprise since the percentage of nondiagnostic biopsies can be up to 21%, even when the samples are taken directly from the tumor under direct vision [32], and remains a limitation of many series of renal tumors RFA in which nondiagnostic biopsy rates of 3–35% have been reported [1, 4, 7, 8, 11, 12].

In conclusion, renal tumor RFA with LeVeen electrodes seems to be an efficient technique, the results of which fall within the range of what has been reported with other RFA devices. Compliance to a strict imaging follow-up protocol remains essential to detect delayed recurrences. Tumors located next to the renal hilum should not be treated with RFA because of high risks of thermal injury to the renal pelvis. Prophylactic pyeloperfusion of cooled serum might be a way to reduce the risk of collecting system injury, but this procedure needs further evaluation.

References

1. Gervais DA, McGovern FJ, Arellano RS et al (2005) 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 185:64–71
2. Gervais DA, Arellano RS, McGovern FJ et al (2005) Radiofrequency ablation of renal cell carcinoma: part 2. Lessons learned with ablation of 100 tumors. AJR 185:72–80
3. Farrell MA, Charboneau WJ, DiMarco DS et al (2003) Imaging-guided radiofrequency ablation of solid renal tumors. AJR 180:1509–1513
4. Mayo-Smith WW, Dupuy DE, Parikh PM et al (2003) Imaging-guided percutaneous radiofrequency ablation of solid renal masses: techniques and outcomes of 38 treatment sessions in 32 consecutive patients. AJR 180:1503–1508
5. Veltri A, Calvo A, Tosetti I et al (2006) Experiences in US-guided percutaneous radiofrequency ablation of 44 renal tumors in 31 patients: analysis of predictors for complications and technical success. CardioVasc Interv Radiol 29:811–818
6. Zagoria RJ, Hawkins AD, Clark PE et al (2004) Percutaneous CT-guided radiofrequency ablation of renal neoplasms: factors influencing success. AJR 183:201–207
7. Matsumoto ED, Johnson DB, Ogan K et al (2005) Short-term efficacy of temperature-based radiofrequency ablation of small renal tumors. Urology 65:877–881
8. Varkarakis IM, Allaf ME, Inagaki T et al (2005) Percutaneous radio frequency ablation of renal masses: results at a 2-year mean followup. J Urol 174:456–460, discussion 460
9. Ahrar K, Matin S, Wood CG et al (2005) Percutaneous radiofrequency ablation of renal tumors: technique, complications, and outcomes. J Vasc Interv Radiol 16:679–688
10. Weizer AZ, Raj GV, O'Connell M et al (2005) Complications after percutaneous radiofrequency ablation of renal tumors. Urology 66:1176–1180

11. Sabharwal R, Vladica P (2006) Renal tumors: technical success and early clinical experience with radiofrequency ablation of 18 tumors. CardioVasc Interv Radiol 29:202–209
12. Arzola J, Baughman SM, Hernandez J et al (2006) Computed tomography-guided, resistance-based, percutaneous radiofrequency ablation of renal malignancies under conscious sedation at two years of follow-up. Urology 68:983–987
13. Clark TW, Malkowicz B, Stavropoulos SW et al (2006) Radiofrequency ablation of small renal cell carcinomas using multitined expandable electrodes: preliminary experience. J Vasc Interv Radiol 17:513–519
14. Memarsadeghi M, Schmook T, Remzi M et al (2006) Percutaneous radiofrequency ablation of renal tumors: midterm results in 16 patients. Eur J Radiol 59:183–189
15. Breen DJ, Rutherford EE, Stedman B et al (2007) Management of renal tumors by image-guided radiofrequency ablation: experience in 105 tumors. CardioVasc Interv Radiol 30:936–942
16. Gebauer B, Werk M, Lopez-Hanninen E et al (2007) Radiofrequency ablation in combination with embolization in metachronous recurrent renal cancer in solitary kidney after contralateral tumor nephrectomy. CardioVasc Interv Radiol 30:644–649
17. Zelkovic PF, Resnick MI (2003) Renal radiofrequency ablation: clinical status 2003. Curr Opin Urol 13:199–202
18. Desai MM, Gill IS (2002) Current status of cryoablation and radiofrequency ablation in the management of renal tumors. Curr Opin Urol 12:387–393
19. Hacker A, Vallo S, Weiss C et al (2005) Minimally invasive treatment of renal cell carcinoma: comparison of 4 different monopolar radiofrequency devices. Eur Urol 48:584–592
20. Rehman J, Landman J, Lee D et al (2004) Needle-based ablation of renal parenchyma using microwave, cryoablation, impedance- and temperature-based monopolar and bipolar radiofrequency, and liquid and gel chemoablation: laboratory studies and review of the literature. J Endourol 18:83–104
21. Johnson DB, Solomon SB, Su LM et al (2004) Defining the complications of cryoablation and radio frequency ablation of small renal tumors: a multi-institutional review. J Urol 172:874–877
22. Wah TM, Irving HC (2007) Acute tubular necrosis following radiofrequency ablation of a renal cell carcinoma. CardioVasc Interv Radiol (in press)
23. Johnson DB, Saboorian MH, Duchene DA et al (2003) Nephrectomy after radiofrequency ablation-induced ureteropelvic junction obstruction: potential complication and long-term assessment of ablation adequacy. Urology 62:351–352
24. Hwang JJ, Walther MM, Pautler SE et al (2004) Radio frequency ablation of small renal tumors: intermediate results. J Urol 171:1814–1818
25. Uribe PS, Costabile RA, Peterson AC (2006) Progression of renal tumors after laparoscopic radiofrequency ablation. Urology 68:968–971
26. Rendon RA, Kachura JR, Sweet JM et al (2002) The uncertainty of radio frequency treatment of renal cell carcinoma: findings at immediate and delayed nephrectomy. J Urol 167:1587–1592
27. Rehman J, Landman J, Sundaram CP (2002) Re: The uncertainty of radio frequency treatment of renal cell carcinoma: findings at immediate and delayed nephrectomy. J Urol 168:2128–2129, author reply 2129–2130
28. Gill IS, Hsu TH, Fox RL et al (2000) Laparoscopic and percutaneous radiofrequency ablation of the kidney: acute and chronic porcine study. Urology 56:197–200
29. Crowley JD, Shelton J, Iverson AJ et al (2001) Laparoscopic and computed tomography-guided percutaneous radiofrequency ablation of renal tissue: acute and chronic effects in an animal model. Urology 57:976–980
30. Hsu TH, Fidler ME, Gill IS (2000) Radiofrequency ablation of the kidney: acute and chronic histology in porcine model. Urology 56:872–875
31. Gulesserian T, Mahnken AH, Schernthaner R et al (2006) Comparison of expandable electrodes in percutaneous radiofrequency ablation of renal cell carcinoma. Eur J Radiol 59:133–139
32. Dechet CB, Zincke H, Sebo TJ et al (2003) Prospective analysis of computerized tomography and needle biopsy with permanent sectioning to determine the nature of solid renal masses in adults. J Urol 169:71–74