

# Percutaneous Radiofrequency Ablation of Renal Cell Carcinoma

Yi-You Chiou<sup>1,3</sup>, Jen-I Hwang<sup>2,3</sup>, Yi-Hong Chou<sup>1,3\*</sup>, Jia-Hwia Wang<sup>1,3</sup>, Jen-Huey Chiang<sup>1,3</sup>, Cheng-Yen Chang<sup>1,3</sup>

<sup>1</sup>Department of Radiology, Taipei Veterans General Hospital, <sup>2</sup>Department of Radiology, Taichung Veterans General Hospital, and <sup>3</sup>National Yang-Ming University School of Medicine, Taipei, Taiwan, R.O.C.

**Background:** Preliminary data regarding the use of percutaneous radiofrequency ablation (RFA) for the treatment of renal cell carcinoma (RCC) are encouraging, and show the technique to be associated with minimal morbidity. Thus, the current study was designed to evaluate the clinical applications, treatment efficacy, and complications of percutaneous RFA in RCC.

**Methods:** From February 2003 to February 2004, 12 consecutive patients with histopathologically proven RCC underwent imaging-guided percutaneous RFA. The mean age of the patients (8 men and 4 women) was 76 years (range, 56–87 years), and mean tumor diameter was 3.7 cm (range, 2.2–8.0 cm). The efficacy of RFA was evaluated with contrast-enhanced, dynamic computed tomography (CT) performed 1 month after treatment, and then every 3 months. A Radionics device with an internally cooled electrode was used in 7 patients, and a radiofrequency interstitial tissue ablation (RITA) device with an expandable needle electrode was used in 5. Complete necrosis was defined as a lack of contrast enhancement in the treated region on follow-up CT studies.

**Results:** Overall, 16 sessions of RFA were performed for 12 solitary renal tumors in 12 patients: 8 patients underwent a single RFA session, whereas 4 had 2 sessions. Dynamic CT after RFA showed complete necrosis in 9 of 12 tumors. In 3 patients with tumors of 4.5–8.0 cm in diameter, enhancement of residual tissue was observed after RFA treatment, thus indicating residual tumor. Complete tumor necrosis was seen in all 5 tumors (100%) of diameter  $\leq$  3.0 cm; 3 of 4 tumors (75%) of diameter 3.1–5.0 cm; and 1 of 3 tumors (33%) of diameter  $>$  5.0 cm. A big subcapsular hematoma, which was found in 1 patient after RFA, resolved completely within 10 months without treatment; no serious complications occurred in the other 11 patients.

**Conclusion:** Percutaneous RFA is effective in the treatment of RCC. It is most successful for tumors not larger than 3 cm in diameter, and has a satisfactory success rate in tumors of 3–5 cm in diameter. The rate of serious complications of RFA is low. Further studies are necessary to determine the long-term efficacy of RFA in RCC. [J Chin Med Assoc 2005;68(5):221–225]

**Key Words:** kidney, neoplasm, radiofrequency ablation, renal cell carcinoma

## Introduction

Although renal cell carcinoma (RCC) can be detected by flank pain and hematuria, the development of imaging techniques such as ultrasonography and computed tomography (CT) has led to an increased detection rate of small renal tumors.<sup>1</sup> Currently, almost 2-thirds of diagnosed renal cancers are incidental

findings in asymptomatic patients.<sup>2</sup> The traditional treatment for renal tumors is radical or partial nephrectomy,<sup>3,4</sup> and although laparoscopic nephrectomy is less invasive than traditional open nephrectomy,<sup>5</sup> all these procedures require hospital admission, general anesthesia and operation, along with the attendant risks and costs. For patients who are not candidates for surgery, or for those who refuse

\*Correspondence to: Dr. Yi-Hong Chou, Department of Radiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, R.O.C.

E-mail: yychiou@vghtpe.gov.tw • Received: October 7, 2004 • Accepted: January 26, 2005

surgery, minimally invasive thermal ablation techniques are a promising option. Although percutaneous radiofrequency ablation (RFA) for the treatment of RCC is a recent innovation, results from preliminary clinical series and animal studies are encouraging,<sup>6-11</sup> and show RCC to be technically feasible and to have minimal morbidity.<sup>12-23</sup>

In this study, we describe our experience of using percutaneous imaging-guided RFA in 12 patients with RCC and review the treatment's techniques, efficacy, and complications; to the best of our knowledge, no such study has yet been reported in Taiwan.

## Methods

### *Study participants*

From February 2003 to February 2004, 12 consecutive patients (8 men and 4 women; mean age, 76 years; age range, 56–87 years) who underwent percutaneous imaging-guided RFA for the treatment of RCC were evaluated for clinical outcome. This prospective study was approved by our institutional review board, and informed consent was obtained from all patients before the procedure. The study participants either refused surgery ( $n = 4$ ), or were not considered surgical candidates because of advanced age, comorbid conditions (5), or the presence of a solitary kidney (3).

All patients had their diagnosis confirmed by imaging-guided biopsy, performed either in advance or simultaneously with RFA. Biopsy results revealed RCC in all cases. Tumor size ranged from 2.2–8.0 cm (mean, 3.7 cm), with tumors classified into 3 groups depending on their diameter: 5 were  $\leq 3$  cm; 4 were 3.1–5.0 cm; and 3 were  $> 5$  cm.

### *Radiofrequency tumor ablation technique*

All patients were interviewed before the treatment by an experienced interventional radiologist, and were assessed with ultrasonography before the procedure to determine whether the tumor was amenable to ablation under ultrasound guidance. If the lesion was suboptimally visualized using ultrasonography, RFA was performed with CT guidance. Ablations were performed with ultrasonography in 8 patients and CT in 4. RFA was performed in 9 patients with meperidine and in 3 with conscious sedation (droperidol, midazolam, fentanyl) administered and monitored by anesthesiologists.

Two different RFA devices were used as described previously:<sup>24,25</sup> a radiofrequency interstitial tissue ablation (RITA) device (Rita Medical Systems, Mountain View, CA, USA), and a Radionics device

(Radionics, Burlington, MA, USA). With the RITA device, ablation was performed with an expandable needle electrode (Starburst<sup>TM</sup>, 2–3 cm; or Starburst<sup>TM</sup> XL, 3–5 cm). With the Radionics device, treatment was performed with either a cluster (3-prong, 2.5-cm active tip) or a single (2- or 3-cm active tip) needle electrode, depending on tumor size. Each tumor had 1–5 ablations per session, with the number depending on tumor size.

### *Imaging assessment after ablation*

After RFA, all patients underwent immediate follow-up ultrasonography or contrast-enhanced dynamic CT to evaluate the possibility of bleeding or fluid accumulation. The efficacy of RFA was evaluated by contrast-enhanced, dynamic CT performed 1 month after RFA, and then every 3 months. Treated tumors were assessed for residual enhancement and size changes. Complete necrosis was defined as a lack of contrast enhancement in the treated region on follow-up CT studies, and all follow-up images were also assessed for the development of new metastatic disease and ancillary peritumoral changes. Residual disease was defined as persistent enhancement in an area or areas of tumor after ablation, as determined at the 1-month follow-up study. Recurrent disease was defined as new tumor enhancement, after at least 1 imaging study had demonstrated complete eradication of enhancement. Assessment of images was performed in consensus by 2 experienced radiologists.

## Results

There were 16 sessions of RFA for 12 solid renal tumors in 12 patients: 8 patients had a single RFA session, and the other 4 had 2 sessions. Nine tumors were located in the right kidney and 3 in the left kidney. Five patients were treated with the RITA device, and 7 with the Radionics device. Of patients treated with the RITA system, 3 were treated with 2–3 cm active electrodes, and 2 with 3–5 cm active electrodes. Of the 7 patients treated with the Radionics system, 2 were treated with a 2-cm active-tip electrode, 4 with a 3-cm active-tip electrode, and 1 with a 2.5-cm cluster electrode.

The mean duration of follow-up was 14 months (range, 8–20 months). Post-treatment CT showed total necrosis in 8 of 12 tumors (67%) after 1 session of RFA treatment (Figure 1), and in 9 of 12 tumors (75%) after 2 sessions. Residual tumor was observed in 3 patients with tumors of 4.5–8.0 cm in diameter. Complete necrosis was seen in all small tumors

(diameter  $\leq 3.0$  cm), 3 of 4 medium tumors (3.1–5.0 cm), and 1 of 3 large tumors ( $> 5.0$  cm). No recurrent tumor was found in the 9 tumors with complete necrosis.

All patients tolerated RFA with no major complications. After the procedure, 1 patient developed a big subcapsular hematoma, but this resolved completely in 10 months without treatment (Figure 2), and 3 patients had pain or paresthesia around the puncture site for several days or weeks, but this resolved spontaneously. All patients were discharged with a prescription for pain medication (acetaminophen or nonsteroidal anti-inflammatory drug), but only 1 patient required analgesia for more than 7 days after RFA. No patients experienced the postablative

syndrome (pain, fever, malaise, and elevated white blood cell count) described after hepatic RFA, and no patients had antibiotics before, during or after RFA.

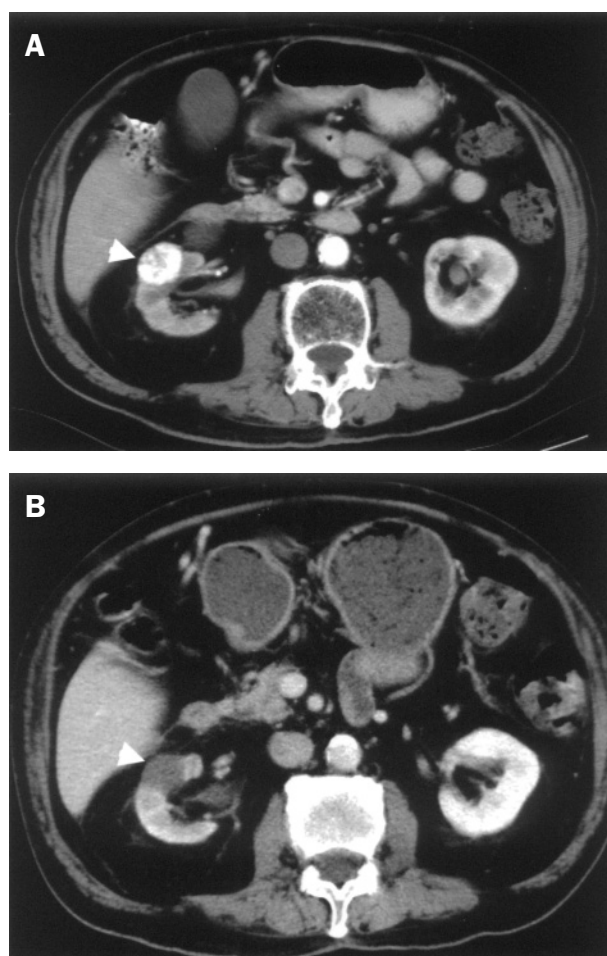
## Discussion

Percutaneous RFA has been used to ablate liver neoplasms with good outcome.<sup>26</sup> Radiofrequency thermal ablation works by converting radiofrequency waves into heat through ionic vibration. Alternating current passing from an electrode into the surrounding tissue causes ions to vibrate in an attempt to follow the directional current change. Thus, ionic friction generates heat in the tissue and not in the electrode itself. Increased current leads to more vigorous ionic motion and increased temperature over a period of time, eventually leading to coagulation necrosis and cell death. The purpose of RFA is to achieve local temperatures that are lethal to the targeted tissue. Generally, thermal damage to cells begins at 42°C; once above 60°C, intracellular proteins are denatured, the lipid layer melts, and irreversible cell death occurs.<sup>27</sup>

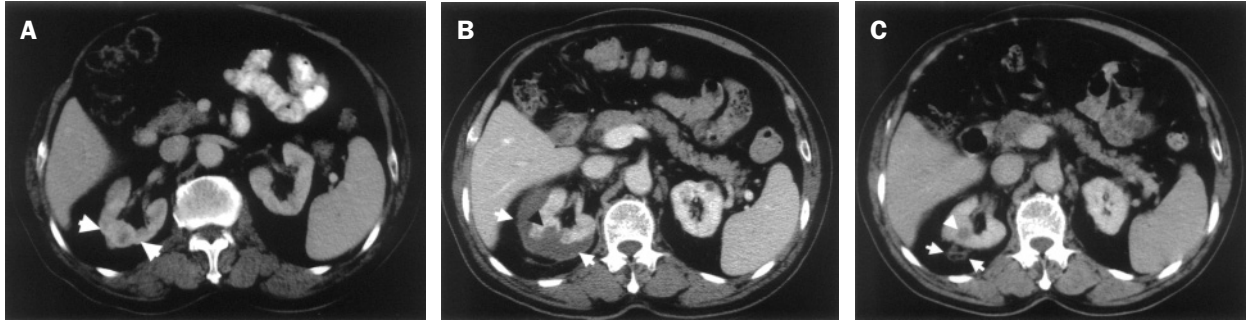
The traditional treatment for localized RCC is open, partial or radical nephrectomy,<sup>28</sup> but this is not ideal for all tumors because some patients are unable or unwilling to undergo surgery, or would have insufficient functional renal tissue remaining after such intervention.<sup>24</sup> Attention has recently focused on RFA as a minimally invasive option for RCC: various outcomes have been reported,<sup>14–19</sup> and the duration of hospital stay, costs, and risk of complications tend to be less for RFA than nephrectomy.

The success rate of RFA in treating RCC depends mainly on tumor size.<sup>15,17,18</sup> In our study, no small tumors had residual or recurrent tumor during follow-up CT scans. However, after a single session of RFA, residual tumor was found in all 3 patients with larger tumors (4.5–8.0 cm in diameter), and was still evident in 2 patients after the second session of RFA. These findings suggest that larger tumors are more difficult to eradicate completely with RFA. The presence of residual disease detected on follow-up scans does not necessarily indicate a poor outcome, because residual tumor can be re-treated and there appears to be no higher risk of systemic spread from foci of residual tumor. No patients in our series, or in other published series, developed detectable metastatic disease after incomplete renal tumor ablation.<sup>15–19</sup>

Other factors that may affect the success rate of RFA are tumor location and the surrounding tissue. Centrally located tumors are more difficult to treat successfully because of heat loss due to the large



**Figure 1.** Computed tomography scans from an 84-year-old man with biopsy-proven renal cell carcinoma of the right kidney: (A) a scan before radiofrequency ablation (RFA) shows a 2.5-cm enhanced soft tissue mass (arrowhead) in the anterior part of the middle pole of the right kidney; (B) a scan 4 months after RFA shows no enhancement of the mass (arrowhead), which had been treated with percutaneous ultrasound-guided RFA.



**Figure 2.** Computed tomography scans from a 79-year-old man with biopsy-proven renal cell carcinoma of the right kidney: (A) a scan before radiofrequency ablation (RFA) shows a 2.8-cm enhanced soft tissue mass (arrowheads) in the posterior part of the middle pole of the right kidney; (B) a scan 1 month after RFA shows no enhancement of the mass (black arrowhead), which had been treated with percutaneous ultrasound-guided RFA, and a big hematoma (white arrows) in the subcapsular area of the right kidney; (C) a scan 10 months after RFA shows decreased size of the mass (arrowhead) and no enhancement (note that the previous subcapsular hematoma completely resolved without treatment), and a small fat necrosis (arrows) was evident in the posterior aspect of the right kidney.

amount of vascularity in the central kidney. During RFA, heat loss occurs at the needle tip, mainly through convection by blood circulation.<sup>15,29,30</sup> Exophytic tumors, which are partially surrounded by avascular, perirenal fat, are easy to completely eradicate with RFA. Surrounding fibrosis, as seen in chronic renal disease,<sup>17</sup> is also expected to reduce thermal conduction and heat dissipation, thus improving the efficacy of RFA.

The rate of serious complications with RFA is low. Indeed, a major advantage of RFA is the ability to avoid tract bleeding and tumor seeding by coagulating the tract when the ablating electrode is withdrawn. Some studies have shown that RFA for RCC has a low complication rate (approximately 7–17%),<sup>15,24</sup> and our study identified a serious complication in only 1 of 12 patients (8%): a large subcapsular hematoma, which, nonetheless, was completely resolved without treatment 10 months after RFA. For several days or weeks after RFA in our study, 3 patients had local pain or paresthesia around the puncture wound, but these events resolved spontaneously, presumably because of only transient damage to intercostal or lumbar nerves in the affected dermatome. Other complications of RFA reported in the literature include infection, ureteral obstruction, and fistula, which can all be treated conservatively.<sup>16</sup>

One limitation of our study was that RFA outcomes were judged by contrast enhancement during follow-up CT studies.<sup>31</sup> Lack of such enhancement has generally been assumed to indicate a lack of viable tumor. Jacomides et al<sup>32</sup> performed tumor resection, secondary to RFA, in 5 of 17 laparoscopically treated RCC patients and found no residual tumor on histologic study. Matlaga et al<sup>33</sup> also found uniform tumor devitalization without viable tumor. In our experience,

it is crucial to choose a suitable ablation protocol and RFA electrode to create necrosis large enough to provide an adequate safety margin. We believe that a lack of contrast enhancement on CT indicates complete tumor eradication, but follow-up surveillance imaging is warranted because long-term results for renal tumor RFA are lacking; such follow-up scans should be used to detect local or metastatic lesions.

In conclusion, percutaneous imaging-guided RFA is a technique with rapidly increasing usefulness. It allows the safe and accurate treatment of renal tumors and, as a minimally invasive and nephron-sparing procedure, it is ideal for patients who are not good surgical candidates. The success of RFA for RCC is influenced primarily by tumor size. Indeed, RFA is a very promising technique that is most successful for tumors  $\leq 3$  cm in diameter, with satisfactory success against tumors 3.1–5.0 cm in diameter. Long-term follow-up data are still needed regarding local and systemic recurrence and survival after RFA, and will provide additional guidance in the initial selection of patients for this treatment.

## References

1. Jayson M, Sanders H. Increased incidence of serendipitously discovered renal cell carcinoma. *Urology* 1998;51:203–5.
2. Homma Y, Kawabe K, Kitamura T, Nishimura Y, Shinohara M, Kondo Y, Saito I, et al. Increased incidental detection and reduced mortality in renal cancer — recent retrospective analysis at eight institutions. *Int J Urol* 1995;2:77–80.
3. Uzzo RC, Novick AC. Nephron sparing surgery for renal tumors: indications, techniques and outcomes. *J Urol* 2001; 166:6–18.
4. Messerli FH, Grossman E. Management of small renal tumors: an overview. *Am J Med* 2001;110:558–62.

5. Gill IS. Retroperitoneal laparoscopic nephrectomy. *Urol Clin North Am* 1998;25:343-60.
6. Polascik TJ, Hamper U, Lee BR, Dai Y, Hilton J, Magee CA, Crone JK, et al. Ablation of renal tumors in a rabbit model with interstitial saline-augmented radiofrequency energy: preliminary report of a new technology. *Urology* 1999;53:470-2.
7. Merkle EM, Shonk JR, Duerk JL, Jacobs GH, Lewin JS. MR-guided RF thermal ablation of the kidney in a porcine model. *AJR Am J Roentgenol* 1999;173:645-51.
8. Aschoff AJ, Sulman A, Martinez M, Durek JL, Resnick MI, MacLennan GT, Lewin JS. Perfusion-modulated MR imaging-guided radiofrequency ablation of the kidney in a porcine model. *AJR Am J Roentgenol* 2001;177:151-8.
9. Miao Y, Ni Y, Bosmans H, Yu J, Vaninbrouck J, Dymarkowski S, Zhang H, et al. Radiofrequency ablation for eradication of renal tumor in a rabbit model by using a cooled-tip electrode technique. *Ann Surg Oncol* 2001;8:651-7.
10. Zlotta AR, Wildshutz T, Raviv G, Peny MO, van Gansbeke D, Noel JC, Schulman CC. Radiofrequency interstitial tumor ablation (RITA) is a possible new modality for treatment of renal cancer: *ex vivo* and *in vivo* experience. *J Endourol* 1997;11:251-8.
11. Collyer WC, Landman J, Olweny EO, Andreoni C, Kerbl K, Bostwick DG, Clayman RV. Comparison of renal ablation with cryotherapy, dry radiofrequency, and saline augmented radiofrequency in a porcine model. *J Am Coll Surg* 2001;193:505-13.
12. Corwin TS, Lindberg G, Traxer O, Gettman MT, Smith TB, Pearle MS, Cadeddu JA. Laparoscopic radiofrequency thermal ablation of renal tissue with and without hilar occlusion. *J Urol* 2001;166:281-4.
13. Crowley JD, Shelton J, Iverson AJ, Burton MP, Dalrymple NC, Bishoff JT. Laparoscopic and computed tomography-guided percutaneous radiofrequency ablation of renal tissue: acute and chronic effects in an animal model. *Urology* 2001;57:976-80.
14. McGovern FJ, Wood BJ, Goldberg SN, Mueller PR. Radiofrequency ablation of renal cell carcinoma via image-guided needle electrodes. *J Urol* 1999;161:599-600.
15. Gervais DA, McGovern FJ, Arellano RS, McDougal SW, Mueller PR. Renal cell carcinoma: clinical experience and technical success with radiofrequency ablation of 42 tumors. *Radiology* 2003;226:417-24.
16. Mahnken AH, Gunther RW, Tacke J. Radiofrequency ablation of renal tumors. *Eur Radiol* 2004;14:1449-55.
17. Zagoria RJ, Hawkins AD, Clark PE, Hall MC, Matlaga BR, Dyer RB, Chen MY. Percutaneous CT-guided radiofrequency ablation of renal neoplasms: factors influencing success. *AJR Am J Roentgenol* 2004;183:201-7.
18. Mayo-Smith WW, Dupuy DE, Parikh PM, Pezzullo JA, Cronan JJ. Imaging-guided percutaneous radiofrequency ablation of solid renal masses: techniques and outcomes of 38 treatment sessions in 32 consecutive patients. *AJR Am J Roentgenol* 2003;180:1503-8.
19. Farrell MA, Charboneau WJ, DiMarco DS, Chou GK, Xincke H, Callstrom MR, Lewis BD, et al. Imaging-guided radiofrequency ablation of solid renal tumors. *AJR Am J Roentgenol* 2003;180:1509-13.
20. Dupuy DE, Mayo-Smith WW, Cronan JJ. Image-guided biopsy and radiofrequency ablation of a renal mass. *Sem Intervent Radiol* 2000;17:373-9.
21. Yohannes P, Pinto P, Rotariu P, Smith AD, Lee BR. Retroperitoneoscopic radiofrequency ablation of a solid renal mass. *J Endourol* 2001;15:845-9.
22. Hall WH, McGahan JP, Link DP, deVere White RW. Combined embolization and percutaneous radiofrequency ablation of a solid renal tumor. *AJR Am J Roentgenol* 2000;174:1592-4.
23. de Baere T, Kuoeh V, Smayra T, Dromain C, Cabrera T, Court B, Roche A. Radiofrequency ablation of renal cell carcinoma: preliminary clinical experience. *J Urol* 2002;167:1961-4.
24. Pavlovich CP, Walther MM, Choyke PL, Pautler SE, Chang R, Linehan WM, Wood BJ. Percutaneous radio frequency ablation of small renal tumors: initial results. *J Urol* 2002;167:10-5.
25. Gervais DA, McGovern FJ, Wood BJ, Goldberg SN, McDougal WS, Mueller PR. Radio-frequency ablation of renal cell carcinoma: early clinical experience. *Radiology* 2000;217:665-72.
26. Rossi S, Di Stasi M, Buscarini E, Quaretti P, Garbagnati F, Squassante L, Paties CT, et al. Percutaneous RF interstitial thermal ablation in the treatment of hepatic cancer. *AJR Am J Roentgenol* 1996;16:759-68.
27. Scudamore C. Volumetric radiofrequency ablation: technical consideration. *Cancer J* 2000;6:316-8.
28. Robson CJ, Churchill BM, Anderson W. The results of radical nephrectomy for renal cell carcinoma. *J Urol* 1969;101:297-301.
29. Goldberg SN, Hahn PF, Tanabe KK, Mueller PR, Schima W, Athanasoulis CA, Compton CC, et al. Percutaneous radiofrequency tissue ablation: does perfusion-mediated tissue cooling limit coagulation necrosis? *J Vasc Interv Radiol* 1998;9:101-11.
30. Goldberg SN, Gazelle GS, Mueller PR. Thermal ablation therapy for focal malignancy: a unified approach to underlying principles, techniques, and diagnostic imaging guidance. *AJR Am J Roentgenol* 2000;174:323-31.
31. Rendon RA, Kachura JR, Sweet JM, Gertner MR, Sherar MD, Robinette M, Tsihlias J, et al. The uncertainty of radiofrequency treatment of renal cell carcinoma: findings at immediate and delayed nephrectomy. *J Urol* 2002;167:1587-92.
32. Jacomides L, Ogan K, Watumull L, Cadeddu JA. Laparoscopic application of radiofrequency energy enables *in situ* renal tumor ablation and partial nephrectomy. *J Urol* 2003;169:49-53.
33. Matlaga BR, Zagoria RJ, Woodruff RD, Torti FM, Hall MC. Phase II trial of radiofrequency ablation of renal cancer: evaluation of the kill zone. *J Urol* 2002;168:2401-5.