Radio-frequency Ablation and Cryoablation for Renal Cell Carcinoma

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Contents

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Abstract

Percutaneous tumor ablation has become one of the most prevalent treatment options for small renal cell carcinomas given continued favorable outcome and is already a treatment of choice for selected patients. Currently, the most common indications are elderly patients with small incidental tumors of unclear metastatic potential and high-risk surgical patients since this procedure has been shown to be safe in patients with multiple comorbidities. This chapter describes the indications, applicators, procedure, outcomes, and complications of percutaneous tumor ablation of renal cell carcinoma. Importantly, the technologies are continuously improving, and it is expected that patient selection and satisfaction will continue to expand and outcomes will continue to improve.

Radio-frequency ablation and cryoablation are treatments for focal malignancy where a needle applicator is advanced through the skin into the center of a tumor (guided by ultrasound, computed tomography, or magnetic resonance imaging) and then induces hot or cold cytotoxic temperatures that rapidly result in tumor death (Goldberg et al. 2000). Once reserved for nonsurgical patients, these minimally invasive treatment options have now expanded to include a larger spectrum of patients, fueled by continued favorable outcome studies, scarce complications, lower immediate morbidity and mortality than surgery, lower cost, outpatient capacity, and, importantly, patient satisfaction (McAchran et al. 2005; Onishi et al. 2007). These benefits must be balanced with the acknowledgement of the relative newness of these procedures which is accompanied by lack of long-term data and that there are challenges including the inability to treat large, centrally located tumors near the renal hilum and difficulties monitoring ablation. But even as initial outcome data is published, rapid technological advancements and improvements in technique evoke even greater promise for success going forward.

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1 Indications

According to the American Cancer Association, there are approximately 50,000 new cases of renal cell carcinoma diagnosed each year in the United States, an incidence that has more than doubled since 1950 (Jemal et al. 2008). Most of these are incidentally detected on high-resolution diagnostic imaging for unrelated indications. Many of these incidentally noted RCCs are T1a tumors (less 4 cm in diameter limited to the kidney) and found in elderly patients who are generally poorer surgical candidates as they were imaged for other comorbid conditions (Jayson and Sanders 1998). In addition, the benefit of a total or partial nephrectomy (currently the most common treatment option) is unclear for these small, nonaggressive RCCs whose natural course may not affect patient longevity (Hollingsworth et al. 2006). Indeed, prior to the development of these minimally invasive procedures, conservative watchful waiting was often advocated, despite substantial patient anxiety (Chow et al. 1999). For these patients, percutaneous tumor ablation is an attractive option since it spares the significant morbidity of surgery while offering effective and potentially curative treatment option (Onishi et al. 2007). Lastly, from a public health perspective, tumor ablation is likely preferred over surgery for small RCC treatment at a societal willingness-to-pay threshold (Pandharipande et al. 2008).

Patients needing nephron-sparing treatment such as those with a single kidney, with bilateral RCCs, or with genetic predisposition to multiple tumors are good candidates even if initially they are also candidates for partial nephrectomy (Goldberg and Dupuy 2001). For example, patients with von Hippel-Lindau syndrome are excellent candidates, as alternative treatments to multiple partial nephrectomies for recurring RCCs are important to save nephrons and prolong the time to dialysis. Patients already on dialysis are also at increased risk for renal cell carcinoma and, given their renal failure, are often poor surgical candidates as well. Other risk factors for renal cell carcinoma which may lead to poor surgical candidacy include smoking and obesity (Cohen and McGovern 2005).

Other uses of ablation in the treatment of RCC have included local tumor recurrence after nephrectomy (McLaughlin et al. 2003), intractable tumor-related hematuria (Wood et al. 2001), palliation for lung and symptomatic bone metastases (Zagoria et al. 2001; Dupuy et al. 1998), and tumor debulking in conjunction with immunotherapy in patients with stage IV disease (Goldberg and Dupuy 2001). Again, each case should be reviewed on a case by case basis.

2 Patient Selection

Patients are usually jointly evaluated by a urologist and interventional radiologist, but practices may vary amongst different centers. Regardless, each practitioner must weigh best interests of the patient. Since one-quarter of patients with RCC will have metastatic disease at diagnosis which precludes local treatment and indicates a poor 5-year survival rate, the extent of disease should be well established with sufficient abdominal and nonabdominal imaging to verify the extent of local tumor and metastatic involvement (Cohen and McGovern 2005). In addition, pretreatment imaging is important for treatment planning which can be performed via ultrasound, magnetic resonance, or CT guidance (Goldberg et al. 2000). Important laboratory values include prothrombin time, partial prothrombin time, complete blood cell count, creatinine, and screening for intravenous sedation or anesthesia. A biopsy prior to the procedure is not imperative but should be strongly considered, because imaging does not always accurately differentiate benign from malignant disease (Silverman et al. 2006).

Tumor size and location are the two most important factors that govern whether RCCs can be successfully treated (Gervais et al. 2005a). Since heat exponentially decreases from the radio frequency or cryo source, large tumors (>5 cm) pose a significant challenge, especially since a 0.5–1.0-cm "ablation margin" surrounding the tumor is also preferred (Goldberg and Dupuy 2001). In general, RCC tumors that are 4 cm in diameter or less are ideal for ablation, with highly favorable success rates (>90 %) when performed by well-trained clinicians (Levinson et al. 2008). Most tumors smaller than 3 cm can also be successfully treated in a single session (Zagoria et al. 2004). Tumors between 3.0 and 4.0 cm in diameter can also be successfully treated with confidence, but multiple ablations and sessions may be required (Gervais et al. 2005b). Indeed, as implied above when describing therapy for VHL RCC, one of the benefits cited for RF ablation is the ability to perform minimally invasive repeated treatments.

The location of the tumor also influences ablation results. The easiest tumors to treat are exophytic as they are surrounded by heat-insulating perirenal fat (Liu et al. 2006; Ahmed et al. 2004). As a result, even large exophytic tumors are almost always successfully treated, with 70 % or more requiring only a single RF session (Hui et al. 2008). Parenchymal tumors may be more difficult to treat, but centrally located tumors represent a larger obstacle for successful ablation given with the surrounding vascular tissue which draws heat away from the tumor (i.e., the heat-sink effect) (Lu et al. 2002). As a result, central tumors larger than 3 cm have an increased risk of treatment failure (Ogan et al. 2002). Additional factors affecting ablation are the electrical and thermal conductivities of the tumor and surrounding tissues which influence the capacity for energy deposition and heat accumulation, respectively (Ahmed et al. 2008; Solazzo et al. 2005).

Contraindications may include a poor life expectancy of less than 1 year, multiple metastases, or difficulty for successful treatment due to size or location of tumor (Ahrar et al. 2005). In general, large tumors (>5 cm) or tumors in the hilum or central collecting system are not typically recommended for percutaneous tumor ablation (Atwell et al. 2007; Gervais et al. 2005b). In addition, tumors located so that thermal injury may occur to the proximal ureter, resulting in urine extravasation and urinoma production, are usually deferred until an intraureteral stent has been placed by a urologist (Johnson et al. 2003). However, the only absolute contraindications include irreversible coagulopathies or severe medical instability such as sepsis.

3 Procedure

The aim of percutaneous tumor ablation is to kill all viable malignant cells within a designated area including a 5–10-mm "ablative" margin of surrounding tissue, if possible, with the minimal damage of the adjacent tissues (Goldberg et al. 2000). The most well-studied techniques and those that received most attention are radio-frequency ablation and cryoablation, but some emerging energy sources such as microwave and high-intensity focused ultrasound show some promise but are only available in controlled experimental situations.

3.1 Radio-frequency Ablation

RF delivers a high-frequency (460–500 kHz) alternating current into the tumor by means of an RF applicator, a single thin needle (usually 21–14 gauge) that is electrically insulated along all but the distal 1–3 cm of the shaft, or an array of multiple such tines extending from a central cannula. The current produces resistive friction in the tissue that is converted into heat, analogous to heat production from an electrical resister in a circuit. Heat, in turn, induces cellular destruction and protein denaturation. Cell death occurs at temperatures higher than 50 °C with complete tumor necrosis being achieved at 60–100 °C (Goldberg et al. 2000). Most RF systems used for the kidney are monopolar, and the current is completed via grounding pads placed on the patient's thighs. Efforts to increase tumor ablation have led to the development of various RF applicators such as multitined applicators, cluster applicators, pulsed energy delivery, and others. Currently, there are three RF devices with 510-K Food and Drug Administration approval for soft tumor ablation (Valleylab Cool-tip™, Boulder, Colorado; Boston Scientific LeVeen®, Natick, Massachusetts; AngioDynamics StarBurst™, Queensbury, New York). No study has yet demonstrated a clear advantage of any one device, and new devices are sure to become available given increasing market demand.

3.2 Cryoablation

Cryoablation uses cooled cryoprobes to freeze and destroy tumor. Traditionally, given the large applicator size (up to 8-mm diameter, or 0.5 gauge) (Finley et al. 2008), it was almost always administered via laparoscope, but smaller applicators now enable percutaneous image-guided application (17 gauge) (Finley et al. 2008). Liquid nitrogen or argon is introduced into the probe in a controlled fashion, resulting in freezing of the surrounding tissues. The formation of ice crystals and subsequent thawing within a cell disrupts the cell membrane and other intracellular activities leading to cell death. Additional cells which are not directly killed may undergo apoptosis. A typical cryoablation session involves freezing, thawing, and refreezing which is particularly effective at mediating cellular disruption (Hoffmann and Bischof 2002; Rupp et al. 2002).

One cited benefit of cryoablation is the ability to visualize the ice ball in real time via CT or MR which allows the extent of cell death to be more reliably predicted (Edmunds et al. 2000). It is thought that complete cell death occurs 3 mm inside the edge of the ice ball with most operators extending the ice ball at least 5 mm beyond the tumor margin (Warlick et al. 2006). However, for RF ablation performed under CT guidance, a postprocedural scan with contrast will also often enable gross visualization of enhancing residual tumor which can then be re-treated (Goldberg et al. 2000). According to the most recent studies, cryoablation provides a safe and oncologically effective alternative to extirpative surgery for renal masses in patients with significant medical comorbidities (Kim et al. 2013). In patients with solitary kidneys, renal cryoablation is associated with superior perioperative outcomes compared to partial nephrectomy. Specifically, partial nephrectomy is not associated with greater loss of renal function than renal cryoablation regardless of the extent of tumor complexity (Panumatrassamee et al. 2013).

3.3 Emerging Technologies

Microwave energy is emerging as a potential source of heat for use in thermal ablation although the technology is still in its infancy with only small experimental series in patients (Liang et al. 2008; Clark et al. 2007). In contrast to radio frequency, within the tip of the inserted microwave applicator is an antenna for externally applied energy at 1,000–2,450 mHz. The deposited microwave energy results in rotation of polar molecules that is opposed by frictional forces which are then converted to heat (Carrafiello et al. 2008). One potential advantage of microwave over RF is greater energy deposition and higher temperatures, especially since microwave is not impeded by peri-applicator tissue charring like RF. The higher energy may also be more resilient to the heat-sink effect which can be an important obstacle for RF (Brace et al. 2007). As such, the technology is deserving of further consideration but requires further investigation as the efficacy and safety relative to more proven technologies are still to be determined (Liang et al. 2008).

High-intensity focused ultrasound is another emerging minimally invasive ablation tool with most research focused on fibroid treatment (Lenard et al. 2008). There has not yet been any well-documented investigation for the possible application for renal tumors. One theoretically attractive option is that cytotoxic heat accumulation is created via multiple high-intensity ultrasound waves delivered by a transducer on the skin without any physical penetration of the skin surface (Klingler et al. 2008).

3.4 Difficulties Comparing Modalities and Approaches

There is currently no conventional acceptance as to which modality is superior given insufficient data for even the two most widely used procedures: radio-frequency ablation vs. cryoablation. Cryoablation is almost always performed with laparoscopy owing to the large size of most applicators, and there is insufficient follow-up data for the more recently developed percutaneous cryoablation to be useful for comparison. On the other hand, it has been used longer so there is potentially more experience with that technique. Recognizing these differences, meta-analyses indicate that a second treatment session is necessary more often for percutaneous radio-frequency ablation than for laparoscopic cryoablation (primary efficacy rates of 87.1 and 94.8 %, respectively) (Kunkle and Uzzo 2008; Hui et al. 2008). However, the secondary efficacy rates after retreatment are similar (92 and 95 %, respectively, $p > 0.05$) (Hui et al. 2008). There is also no significant difference between metastatic progression (2.5 and 1.0 %, respectively, $p > 0.05$) (Kunkle and Uzzo 2008). However, meta-analysis does suggest that major complications may be lower in percutaneous radio-frequency ablation than laparoscopic cryoablation (3 % vs. 7 %, respectively) (Kunkle and Uzzo 2008). Additionally, other initial comparisons between percutaneous and laparoscopic cryoablation suggest that there may be higher overall complications, transfusion rates, analgesic use, and hospital stays with a laparoscopic approach compared to percutaneous treatment (40 %, 28 %, 17.8 mg, and 3.1 days vs. 22 %, 11 %, 5.1 mg, and 1.3 days, respectively, all $p < 0.05$) with similar failure rates at 1-year follow-up (4.2 and 5.3 %, respectively) (Finley et al. 2008). Further validation with randomized prospective data is necessary as these studies are small retrospective studies that cannot control for factors that may have influenced the choice of approach. An analysis of 5- and 10-year follow-up data will be helpful when available.

Regardless, we adhere to the notion that less invasive approaches should be preferred over more invasive in the setting of similar outcomes.

In conclusion, in the setting of RCC, percutaneous ablation procedures can be considered over laparoscopic ones, saving partial nephrectomy for cases when the first two approaches are not advised. However, comparing the individual percutaneous modalities (i.e., radio-frequency ablation and cryoablation) for definite advantages over each other is challenging, as both are being presently refined. Thus, the most important factors will continue to be proper patient selection and meticulous technique by experienced clinicians.

3.5 Adjuvant Therapy

Recent studies have demonstrated that the modification of tumor vessel density using antiangiogenic agents such as sorafenib (Nexavar®, Bayer HealthCare, Leverkusen, Germany) and sunitinib (SUTENT®, Pfizer Labs, New York, New York) increases the efficacy of RF coagulation. In one study, the administration of sorafenib prior to RF ablation markedly decreased microvascular density and led to significantly larger zones of RF-induced coagulation necrosis (Hakime et al. 2007). There is also the potential for combining treatment with radiation as has been examined in animal studies and in patients with lung cancer (Horkan et al. 2005; Dupuy et al. 2006). Although these methods are still in their investigational phase, there is promise for their rapid acceptance and adoption in standard clinical practice.

3.6 Biopsy Controversy

There is currently some debate about whether biopsy should be performed before ablation. For most institutions, pathologic confirmation of malignancy is a tacit or explicit requirement before any type of treatment is initiated, including thermal ablation, but some institutions are beginning to question whether a biopsy is always necessary (Beland et al. 2007). Additionally, ablation of the tumor will make pathologic examination of the tissue much more challenging if this is ever needed for future therapeutic considerations. The argument to not perform a biopsy is the need for two percutaneous procedures which are associated with increased costs and small but genuine procedural risks and that many tumors demonstrate imaging features that are highly suggestive of renal cell carcinoma perhaps making biopsy redundant (Herts and Baker 1995). In addition, even small amounts of hemorrhage associated with biopsy can potentially obscure the margins of the tumor which can increase the difficulty of the ablative procedure. Unlike laparoscopic surgery where port-site seeding is estimated to be 0.1 %, percutaneous tumor tract seeding has only been reported in a single case report (Castillo and Vitagliano 2008; Bush et al. 1977; Tanaka et al. 2008). To minimize the risks and costs, a biopsy can be easily performed immediately prior to ablation, but pathologic analysis cannot be rendered before tumor ablation commences.

3.7 Day of the Procedure

Regardless of the energy source, the percutaneous procedure is usually an outpatient procedure unless comorbid conditions require hospitalization or closer observation. Only conscious sedation is typically necessary for anesthesia, although some physicians and patients prefer general anesthesia. The patient is placed prone, and after local anesthesia is applied, the applicator is percutaneously advanced into the center of the tumor under image guidance (CT, ultrasound, or MR). Heat or cold is then applied for approximately 10–20 min as dictated per manufacturer recommendations. Depending upon the size and location of the tumor, the applicator may need to be readjusted and additional treatments administered. After the procedure, the patient is monitored for several hours and discharged home with oral analgesics for postprocedural pain with patients usually resuming to full activity in a couple of days. A laparoscopic approach is similar to other surgical laparoscopic procedures requiring general anesthesia. Patients are hospitalized at least overnight and may have slightly higher postprocedural pain (Finley et al. 2008).

4 Outcomes and Complications

4.1 Imaging Follow-Up

The success of percutaneous tumor ablation is assessed by postprocedural imaging, typically by computed tomography or MR starting 1 month after treatment. Imaging immediately following the procedure can be difficult to interpret, because peripheral inflammation may mimic the appearance of viable tumor. On computed tomography, viable tumor is usually nodular and maintains its enhancement (>10-HU postcontrast injection), whereas successfully ablated tumor loses its attenuation, consistent with coagulation necrosis (Gervais et al. 2005a, b). It has also been noted that tumors usually decrease in size immediately after ablation by about 20 %, while many continue to involute over time (Ganguli et al. 2008). Very rarely does the zone of ablation enlarge because of liquefactive necrosis (Merkle et al. 2005). The area of nonenhancement itself may be larger than the original tumor as the zone of ablation is expected to be larger than the tumor to allow for an “ablative margin.” Recurrent tumor will usually manifest as peripheral nodular or peripheral crescent enhancement (Gervais et al. 2005a, b). Subsequent follow-up imaging is usually performed at 3–6, 12, 18, and 24 months after ablation, and yearly thereafter.

Many patients who undergo percutaneous tumor ablation have renal insufficiency which is often a large contributing factor in deciding to undergo tumor ablation since it limits destruction to vital normal renal parenchyma. For these patients, follow-up imaging is often performed with MR to limit the toxicity of iodinated contrast administered with CT. Yet, unenhanced imaging is almost never sufficient for evaluation of recurrent tumor.

Current thinking is that even if the eGFR is estimated to be very low which may place the patient at risk for nephrogenic systemic fibrosis (Wertman et al. 2008), the risk-benefit ratio still usually favors proceeding with MR imaging with gadolinium rather than CT with iodine-based contrast agents (Geoffrey et al. 2007). Again, residual or recurrent tumor usually manifests as abnormal nodular or crescent enhancement with gadolinium. Immediate postablation MR imaging may demonstrate smooth rim peripheral enhancement secondary to surrounding hyperemia. Unenhanced T1 and T2 signal may be variable and complex due to hemorrhage, coagulated protein, and liquefactive necrosis (Merkle et al. 2005).

4.2 Imaging Pitfalls

During ablation, gas is formed without and about the tumor as a by-product of tissue coagulation (Fig. 1). This may be visualized on immediate postprocedural imaging and should not be mistaken for bowel injury. In addition, hydrodissection is occasionally employed prior to ablation to protect the adjacent organs from heat injury. This involves infusing sterile water into the surrounding tissue to create a barrier between the adjacent organs and the ablative zone (Fig. 2). This should not be mistaken for hemorrhage or bowel injury.

Follow-up imaging also commonly demonstrates inflammatory stranding within the surrounding perirenal fat which should not be confused with residual tumor. Over time, a thin soft tissue halo may also appear within the surrounding fat due to encapsulation of fat necrosis which should not be interpreted as recurrent tumor (Fig. 1) (Gervais et al. 2003). More recently, it has also been observed that enhancing inflammatory nodules do rarely appear (<2 % of the time) after percutaneous ablation which may mimic tumor seeding of the applicator tract (Lokken et al. 2007). Real tumor tract seeding is exceeding rare and has only ever been reported once after radio-frequency ablation of RCC (Mayo-Smith et al. 2003). Instead, a new enhancing nodule within or adjacent to the

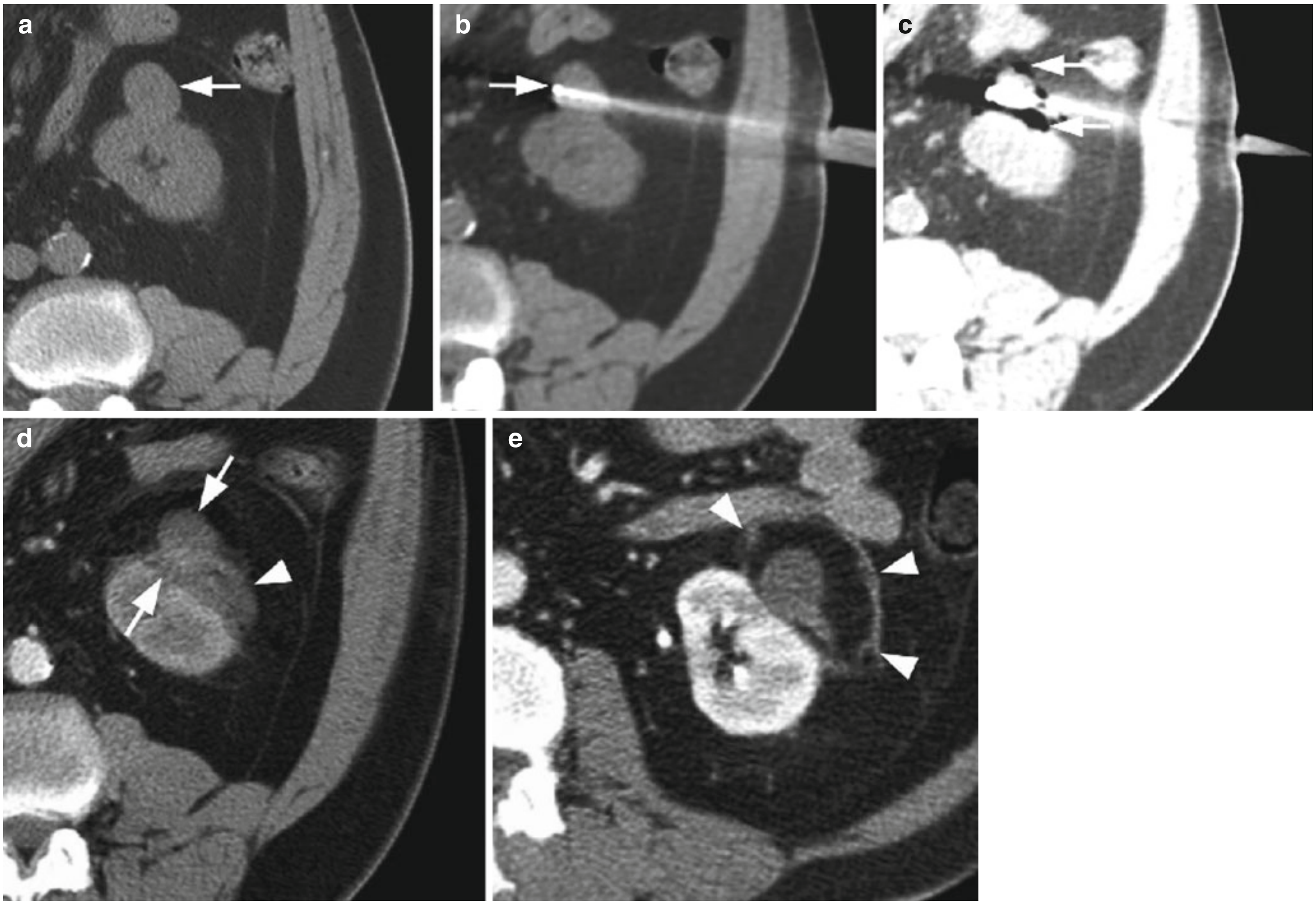

Fig. 1 Successful radio-frequency ablation of renal cell carcinoma. (**a**) Noncontrast CT demonstrates exophytic 2.5-cm tumor (*arrow*); (**b**) positioning of RF applicator with tip at distal end of tumor (*arrow*); (**c**) gas (*arrows*) is produced during ablation secondary to high-temperature coagulation; (**d**) immediate contrast-enhanced CT demonstrates nonenhancement of the tumor with a small surrounding "margin" of nonenhancement of the adjacent kidney (*arrows*) and small clinically insignificant perinephric hemorrhage (*arrowhead*); (**e**) 2 years after ablation, contrast-enhanced CT follow-up demonstrates continued nonenhancement of the tumor with a characteristic fat "halo" in the perirenal fat (*arrowheads*), suggesting complete treatment

applicator track is more likely to represent chronic inflammation containing histiocytes, granulation tissue, and fibrosis. These will usually appear as either a ring-enhancing nodule or ill-defined tram-tracking enhancement appearing 3–52 months after ablation (Lokken et al. 2007). Nodular enhancement along the ablated tumor margin, however, should be treated with suspicion for recurrence.

4.3 Outcomes

Results vary depending upon the modality (cryoablation vs. radio frequency) and applicator type (single vs. multitine), but meta-analyses across all percutaneous approaches yield a secondary effectiveness rate (i.e., no evidence of recurrence after multiple treatments is necessary) greater than 90 % for tumors smaller than 4 cm which is not significantly different than surgical treatment at 1 year (Hui et al. 2008).

4.3.1 Outcomes for Radio-frequency Ablation

Some midterm data is becoming available demonstrating recurrence-free survival rate of approximately 90 % at 5 years for tumors smaller than 4 cm (Levinson et al. 2008). Additionally, as technology and the learning curve have markedly progressed since treatment was performed for these initial survival data, future studies are expected to be as good or better. Again, treatment success is dependent upon size and location (exophytic vs. central) with near 100 % recurrence-free disease possible with selected tumor sizes (<4 cm) with larger tumors associated with increased risk of recurrence.

4.3.2 Outcomes for Cryoablation

Data is very limited for percutaneous cryoablation (Fig. 3), but short-term success (1 year) also appears to be excellent with success rates consistently above 95 % (Atwell et al. 2008). In addition, technical success was achieved with tumors ranging up to 7 cm, though the same principle of selecting tumors less than 4 cm still applies for optimal

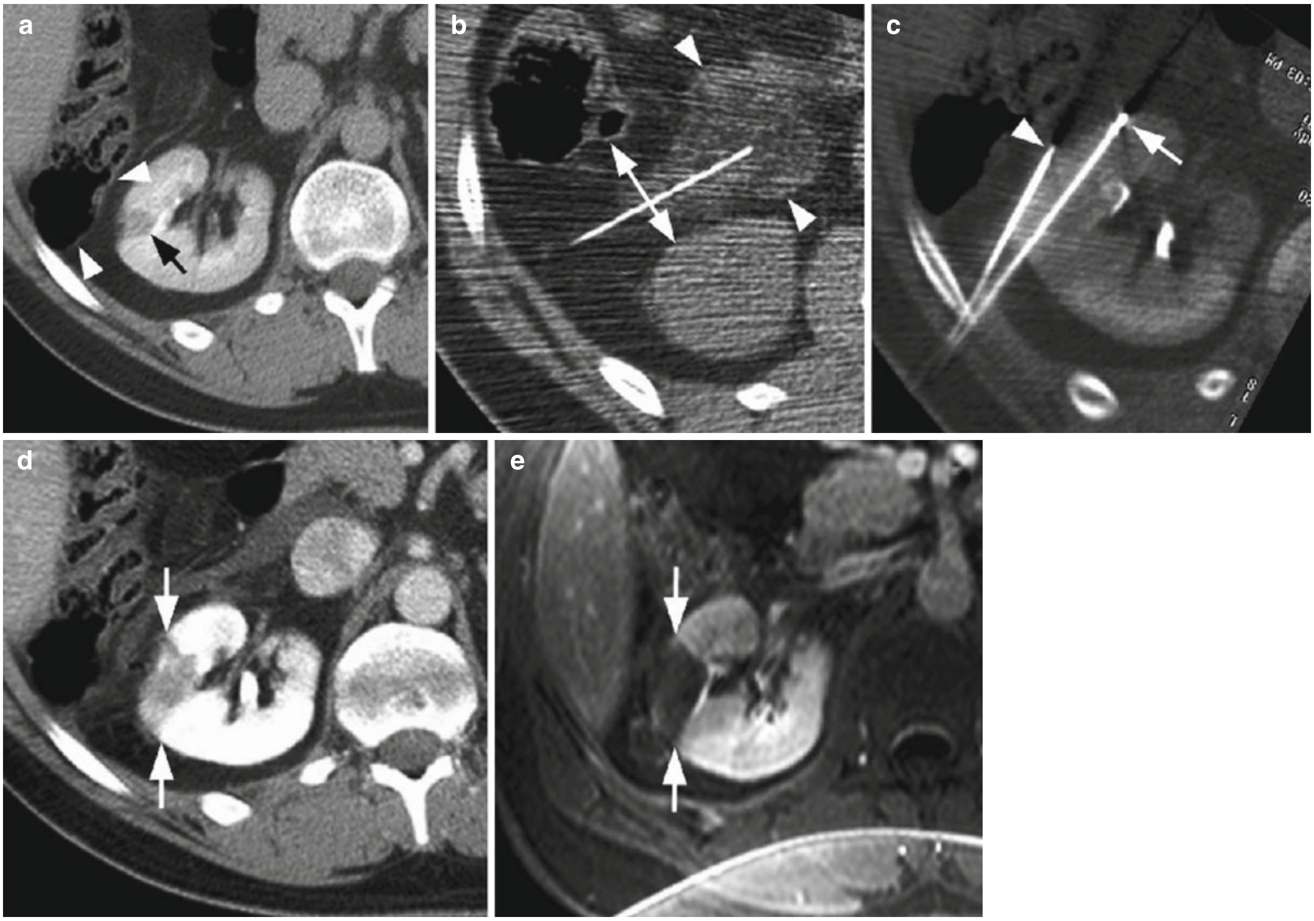

Fig. 2 The use of hydrodissection in thermal ablation to protect adjacent structures in a patient with multiple RCCs. (**a**) The colon (*arrowheads*) is closely approximated to the 1.3-cm tumor in the right kidney (*black arrow*), risking thermal injury; (**b**) 5 % dextrose in water (*arrowheads*) is injected into the perirenal fat which successfully separates the colon from the kidney (*double-headed arrow*); (**c**) applicator needle (*arrow*) is positioned into the tumor with the aid of a guiding needle (*arrowhead*); (**d**) immediate postablation CT demonstrates the ablative zone about the tumor (*arrows*); (**e**) 6-month follow-up MR with gadolinium demonstrates no recurrent tumor enhancement (*arrows*). A second 1.5-cm RCC in the right lower pole was also successfully treated during the same session (not shown)

results (Stein and Kaouk 2007). Again, 5- and 10-year follow-up outcome data will be helpful with the caveat that current treatments will likely be superior given continuously technological improvements.

When comparing the outcomes of laparoscopic to percutaneous cryoablation at the same center, the procedural outcomes are demonstrably superior for percutaneous cryoablation including lower complications and transfusions (22 % vs. 40 %, respectively), shorter hospital stays (1.3 vs. 3.1 days, respectively), and lower narcotic use (5.1 vs. 17.8 mg, respectively). It should be noted that the complication rates reported in this series were higher than the accepted complication rate for percutaneous cryoablation (around 3 %) (Hui et al. 2008). Regardless, in short-term follow-up (13 months), cancer-specific survival is similar for percutaneous and laparoscopic cryoablation (100 and 100 %, respectively), and initial treatment failure was also not significantly different at 5.3 % (1/19) and 4.3 % (1/24), respectively.

4.4 Complications

The average complication rate is less than 5 % for both radio frequency and cryoablation, but almost none result in long-term morbidity. Radio-frequency ablation and cryoablation are both effective in the treatment of renal masses measuring 3 cm or smaller (Atwell et al. 2013). Major complications with either procedure are infrequent. Meta-analyses demonstrate a major complication rate of 3 % for percutaneous treatment vs. 7 % in the surgical treatment group (7 %; $p < 0.05$) which is the accepted clinical understanding (Hui et al. 2008; Johnson et al. 2004). The most common complications include perinephric hematoma, pneumothorax, nerve injury, and pain. Central tumors and tumors within the lower pole also run the risk of ureteral or ureteropelvic injury. A few case reports have documented nephrectomies that were necessary after ureteral injury or obstruction, but again, this is compared to oncologic treatment that could have included nephrectomy itself.

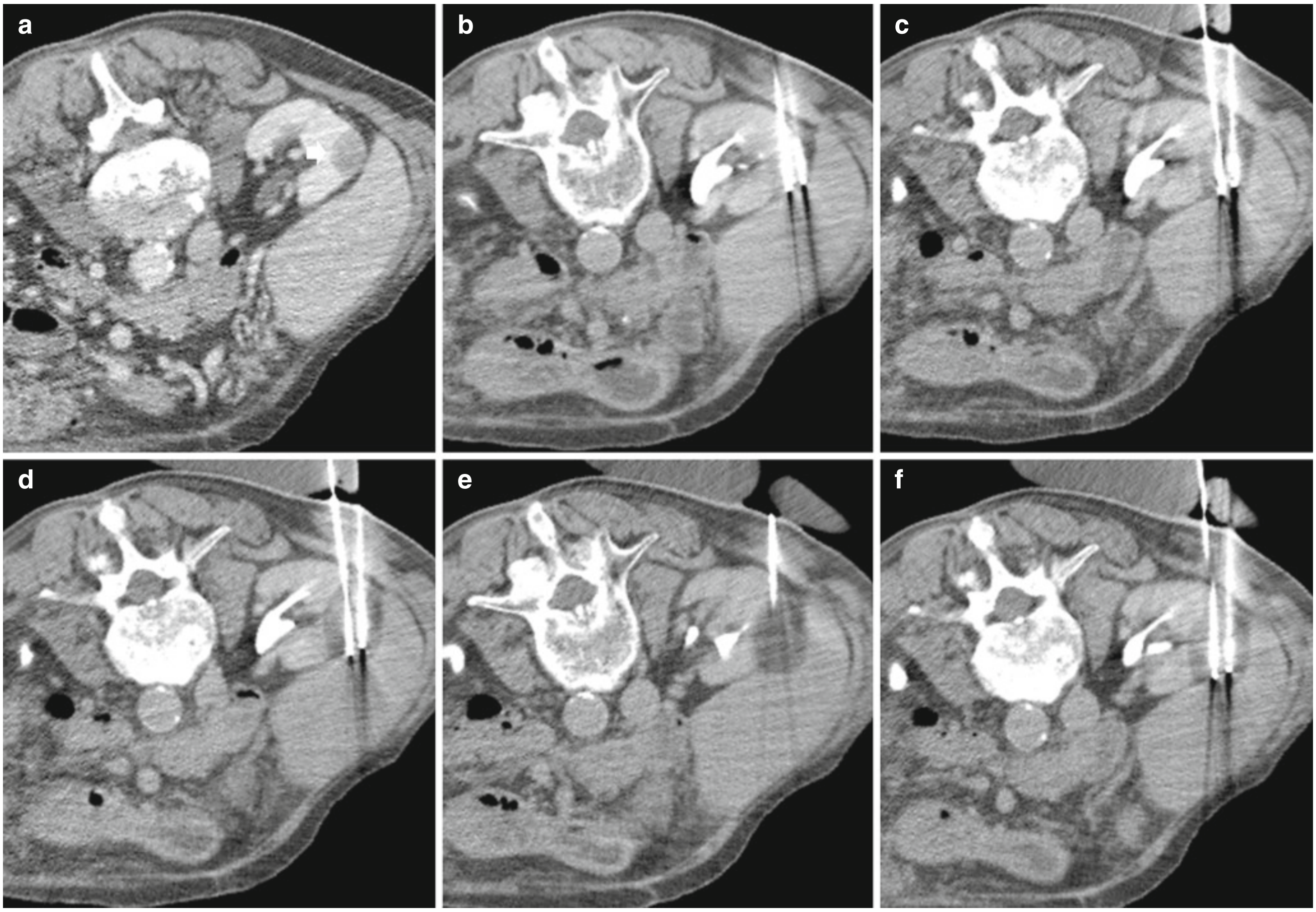

Fig. 3 The use of cryoablation in a patient with papillary RCC. (**a**) A small hypodense solid renal tumor (*arrow*) is evident in the right kidney (patient in prone position); (**b**) two needles are inserted in the mass. (**c**–**f**) progressive increase of the ice ball after two cycles of freezing and thawing

It is also important to note that the very low complication rate associated with RF ablation is reported in patients who were already deemed too high risk for surgical intervention because of advanced age or medical comorbidities. Thus, even in high-risk patients, percutaneous tumor ablation is associated with a very low complication rate.

Conclusion

Minimally invasive treatments for renal cell carcinoma such as percutaneous tumor ablation will undoubtedly become more prevalent as outcomes continue to be favorable and should be considered a viable treatment option for selected patients. Currently, the most common indications are elderly patients with small incidental tumors of unclear lethal potential and all high-risk surgical patients as this procedure has been shown to be safe in patients with multiple comorbidities. Multiple modalities are available, but the most common are RF and cryoablation which are likely similar in efficacy but still lack sufficient long-term data. These technologies are continuously improving, and it is expected that, as a result, patient selection and satisfaction will continue to expand.

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