Laparoscopic and Percutaneous Ablative Techniques in the Treatment of Renal Cell Carcinoma

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Widespread use of computed tomography, ultrasound, and magnetic resonance imaging has led to an increase in detection of relatively small renal masses, and approaches to managing them have evolved in the last two decades. Indications for nephron-sparing surgery have expanded, and minimally invasive procedures, which can confer advantages over open surgery, are now available. Ablative techniques offer a combination of nephron-sparing and minimally invasive approaches. Ablative techniques include cryoablation, radiofrequency ablation (RFA), and high-intensity focused ultrasound (HIFU). Cryoablation and RFA have been relatively safe. HIFU has been associated with serious side effects in animal models, and is not yet acceptable for use in humans. Ablative techniques require long-term studies to confirm lasting efficacy. The best modality for tumor targeting, monitoring of therapy, and follow-up is still under investigation. Debate exists regarding the best method for ensuring adequate intraoperative tumor cryoablation. For minimally invasive ablative measures to gain a place as nephron-sparing approaches, they should show both equivalent efficacy and reduced morbidity relative to those of open partial nephrectomy. These techniques should currently be reserved for selected patients and should be compared to the evolving modality of laparoscopic partial nephrectomy.
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Key words: Renal cell carcinoma • Cryoablation • Radiofrequency ablation • High-intensity focused ultrasound • Laparoscopy

In 2001, 30,800 new cases of renal cell carcinoma (RCC) were diagnosed, and RCC accounted for 12,100 deaths.[1] Radical nephrectomy has been the gold standard for the management of renal tumors since Robson and colleagues reported greater survival in patients who underwent this procedure than in those who underwent simple nephrectomy.[2,3] However, the widespread use of abdominal computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) has led to an increase in the number of incidentally detected renal masses[4,5] and the last two decades have seen an evolution in the management of these renal lesions, with partial nephrectomy becoming widely used for smaller or peripherally located renal masses.[6] Watchful waiting in selected cases is occasionally offered as an option, based on data suggesting that small lesions (<3 cm) are slow-growing and may not pose a risk for progression and dissemination.[7]

Ablative techniques in renal surgery, though experimental, are evolving treatment modalities.[8] The appeal of these approaches follows two larger trends: the acceptance of a nephron-sparing approach to the management of renal malignancy and the demand for minimally invasive surgery.

Nephron-Sparing Surgery with Normal Contralateral Kidney

Prior to the extensive use of CT and other imaging modalities, RCCs less than 3 cm in diameter accounted for approximately 5% of cases.[9] Currently, 10%–40% of renal tumors are discovered when less than 3 cm in size. Reluctance to perform radical nephrectomy for small bilateral tumors or small unilateral tumors in patients with a solitary kidney and/or compromised renal function led to the development of nephron-sparing surgery.[10,11] Over time, the indication for nephron-sparing surgery has been extended to include patients with renal masses and a normally functioning contralateral kidney.[12] Large series studies have confirmed similar 5-year cancer-specific survival rates between partial and radical nephrectomy. Local recurrence rates in patients treated with partial nephrectomy have ranged between 2% and 3%.[6,13–16]

Minimally Invasive Techniques in Urologic Surgery

Laparoscopic surgery is the most recent addition to the armamentarium of surgical approaches in urology for both benign and malignant disorders. The benefits of the laparoscopic approach have been well documented and include decreased morbidity, decreased hospitalization time, and earlier return to full activity.[8] Laparoscopic radical nephrectomy should be considered an oncological equivalent to the open radical nephrectomy. Percutaneous approaches have also been used to treat malignancy in patients who are not candidates for, or who refuse, open surgery.[17]

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Ablative Techniques in Renal Surgery

Ablative techniques in renal surgery represent the ability to combine the minimally invasive approach of laparoscopy with nephron-sparing surgery. Small renal tumors are especially good targets for ablation via laparoscopy, because these lesions are usually located in the renal cortex and are often unifocal. Ablative renal surgery is potentially less morbid than open partial nephrectomy, which may be associated with greater intraoperative and postoperative blood loss as well as postoperative urinoma formation.

This review focuses on three of the better-studied methods: cryoablation, radiofrequency ablation (RFA), and high-intensity focused ultrasound (HIFU). Cryosurgery is the oldest of these treatment modalities. It began as early as 1845 when James Arnott[18] hypothesized that freezing temperatures could be used to destroy tissue. The materials used to convey the therapy have evolved since Arnott's time; cryotherapy came to involve solidified carbon dioxide and liquid nitrogen. The application remained limited to the treatment of accessible lesions such as those on the skin and cervix until a century later when, in 1961, Cooper[19] made improvements in the apparatus used to deliver cryotherapy. In the urologic field, cryotherapy was directed at the treatment of prostate cancer and benign prostatic hyperplasia throughout the 1960s but was abandoned due to unacceptable rates of local complications. Onik and colleagues[20] renewed interest in cryosurgery as a treatment for malignancies in the 1980s and are credited with confirming the ability of ultrasound to monitor tissue destruction through the freezing process.

Cryosurgery represents an improvement in the age-old application of cold for destruction of tissue. It is particularly suited to treatment of RCC relative to prostate cancer in that the kidney is in a more favorable location for treatment than the prostate, with less risk to adjacent structures, and small RCCs are usually unifocal as compared to the multifocality of prostate cancer.

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RFA and HIFU, developed in the 1990s, are newer modalities that rely on thermotherapy for tissue destruction. Thermotherapy refers to tissue damage taking place at temperatures above 45°C. Investigation into the application of RFA to RCC followed its successful use in the treatment of other conditions including hepatocellular carcinoma,[21] osteoid osteoma,[22] undesirable endometrium,[23] as well as myocardial aberrant conductive pathways.[24]

These minimally invasive ablative techniques for renal masses differ fundamentally in their mechanisms of tissue destruction and tumor ablation. However, progress in each of these approaches was made possible by advances in imaging capabilities. The success of CT, ultrasound, and MRI in monitoring the delivery of therapy and the posttreatment radiographic appearance of the treated lesions has been instrumental in advancing the clinical utility of minimally invasive ablative procedures.

Cryosurgery

Cryobiology

Cryosurgery causes tissue destruction by both immediate and delayed mechanisms.[25] The immediate freezing of tissue causes ice crystals to form in the extracellular space and inside the microvascular bed, leading to an increase in the extracellular osmotic power. Water is drawn into the extracellular space, giving rise to a cytotoxic hyperosmotic intracellular environment. Rapid freezing also results in cytotoxic intracellular ice crystal formation. During the thaw phase, circulation is restored, but damage to endothelial cells leads to porous blood vessels with subsequent edema formation, vascular occlusion, and thrombosis. Failure of the microcirculation results in further tissue necrosis. Achieving cytotoxic freezing temperatures is essential for successful cancer eradication. Uchida and colleagues[17] froze renal cancer cell lines for 60 minutes at −5°C to −30°C and found that 96% of RCC cells survived when cooled to above −10°C, whereas only 15% survived when cooled to below −20°C. Experimental and clinical reports in the treatment of non-urological malignancies show that tissue temperatures as low as −40°C to −50°C are required to induce complete cell death.[25] Therefore, adequate margins are obtained by a proper location of the −40°C isotherm at the tumor's margin. Campbell and colleagues[26] studied mongrel dogs using 3.4 mm cryoprobes in order to correlate the intrarenal temperatures with the sonographic appearance of the cryolesion. They found that the cryolesion—frequently described as an "iceball"—needed to extend at least 3.1 mm beyond the sonographic edge of the tumor to ensure adequate cooling of the tissue to at least −20°C. Gill and colleagues[27] routinely extend the iceball 1 cm beyond the tumor edge. Some investigators have speculated on the possibility of achieving even lower tissue temperatures by occluding the renal artery during cryoablation. Campbell and associates,[26] however, could not demonstrate a practical advantage of renal-artery occlusion in a canine model.

Achieving cytotoxic freezing temperatures is essential for successful cancer eradication.

Most investigators advocate repeating the freeze/thaw cycle in order to ensure adequate cell death in renal tissue. The rationale for repeating the freeze/thaw cycle stems from evidence for increased cytotoxicity in prostate and hepatocellular carcinoma. No direct comparison of single versus repeat freeze/thaw cycles in the treatment of RCC has been published yet.

The gross and microscopic appearance of cryoablated renal tissue has been studied in canine models.[28] Four hours following treatment, the tissue is grossly hemorrhagic with a sharp demarcation between treated and untreated tissue, corresponding to vascular congestion, intratubular and interstitial hemorrhage, and early nuclear pyknosis. At 8 days, a central region of coagulative necrosis and a 2-mm–thick area of sublethal injury are evident; at 3 months, the region of necrosis is absorbed, and a 1- to 1.5-mm–thick fibrosis layer corresponds to the area of sublethal injury. Untreated tissue remains normal both in the ipsilateral and contralateral kidneys. These findings were also well studied and confirmed in a porcine model.[29] In humans some of the ablated areas, especially in exophytic lesions, become autoamputated a few months following ablation.

Equipment

The cryoprobe is the device used to deliver the freezing temperatures necessary for tissue destruction. It is a vacuum-insulated instrument that becomes cool when circulated with a cryogen such as liquid nitrogen (−195°C). Alternatively, in more recently developed applications, argon gas is allowed to expand at the probe tip using the Joule-Thompson principle, in which pressurized gas is permitted to depressurize through a narrow nozzle located at the tip of the probe and cool the surrounding tissue to −187°C (Figure 1).

Probes are available in a variety of models and diameters (1.5–8 mm) suitable for open, laparoscopic, and percutaneous use. Larger probes are capable of creating larger lesions.[30] However, one potential area of con-

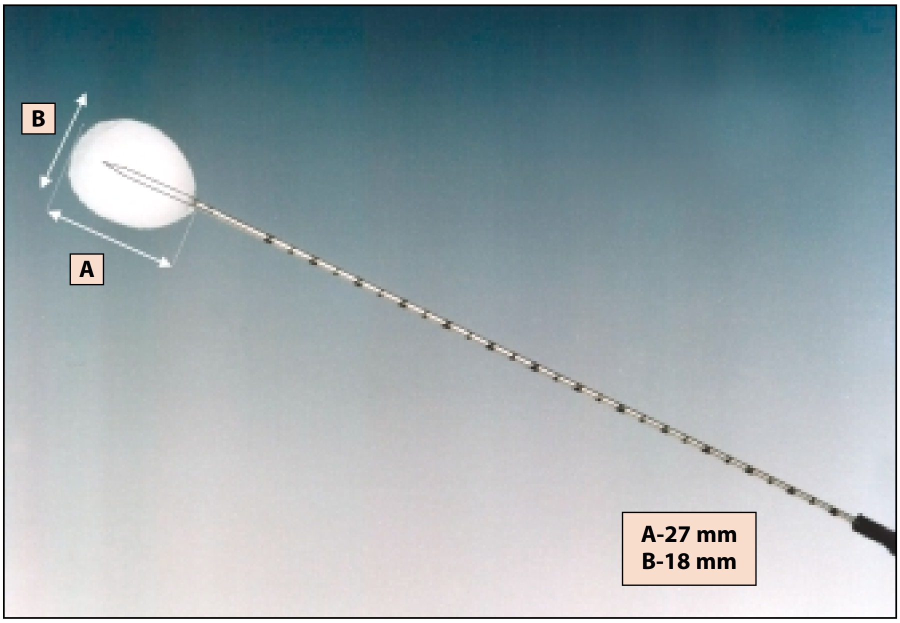

Figure 1. *Typical cryoprobe showing iceball dimensions*

cern revolves around the use of the standard, larger cryoprobes of 3 to 8 mm, noted to cause renal capsular and parenchymal fractures, which can result in significant bleeding. At UCLA, we have been using ultrathin, 1.5-mm state-of-the-art, third-generation cryoprobes (Galil Medical, Yokneam, Israel) for selected patients with small renal tumors. It is possible to simultaneously use multiple 1.5-mm cryoprobes, which are the same size as 17-gauge needles. This approach is based on an iceball geometry in which a 9-mm radius is achieved at 5 minutes of continuous freezing, and a 13-mm radius is achieved at 10 minutes of continuous freezing, with the lethal −20°C isotherm located at a radius of 7 mm and 10 mm, respectively. The leading edge of the iceball that is seen on ultrasound, which achieves a freezing temperature of only 0°C, is just 2–3 mm beyond the −20°C zone, allowing a comfortable margin of error if one freezes 5–10 mm beyond the tumor margin on ultrasound. Spacing the probes at 10-mm intervals generates one large iceball created by the confluence of individual, overlapping iceballs. These ultrathin probes, which are currently available for open cryosurgery, are being developed for percutaneous and laparoscopic approaches.

Techniques

Open. We recently published our technique for open renal cryosurgery in a patient with Von Hippel Lindau disease,[30] and a multisegment, internet-based video tutorial of this surgical technique can be viewed at http://www.elsevier.com/locate/urologyonline. With the patient in a flank position, the kidney is exposed using an extraperitoneal, extrapleural approach. An intraoperative frozen needle biopsy of the lesion is obtained. Real-time B-mode ultrasonography using a 7.5 MHz linear array probe is used with color-flow Doppler to assess tumor size, depth of the parenchymal lesion, and the mass relationship to the collecting system and major vessels. Multiple cryoprobes are placed at 1-cm intervals along the periphery, base, and center of the tumor in order to form a wedge-shaped lesion. Tip positioning is guided by ultrasound. Cryoablation is initiated by producing tip temperatures reaching −180°C. Freezing continues until the iceball is advanced 10 mm beyond the tumor edge. Ultrasound is used to confirm normal blood flow to the surrounding kidney and obliteration of flow to the ablated lesion. Following a second freeze-thaw cycle, the probe tracts are inspected to ensure hemostasis.

Laparoscopic. The laparoscopic technique, shown in Figure 2, resembles the open approach, but uses instruments modified for laparoscopy, including an intraoperative, laparoscopic ultrasound probe.[31,32] The choice between a transperitoneal and retroperitoneal approach is dictated by the location of the lesion and surgeon preference. The retroperitoneal approach offers the advantage of a decreased risk of bowel injury and the formation of adhesions. However, blunt dissection in this approach is associated with an increased risk for bleeding.[33]

Percutaneous. The percutaneous approach uses the Seldinger technique to position sheaths in the kidney under ultrasound, CT, or MRI guidance in the vicinity of renal lesions. Cryoprobes are then placed through these sheaths and cryoablation is initiated. Uchida and colleagues[17] were the first to report the clinical application of cryoablation to RCC using a percutaneous technique with ultrasound guidance. Technical difficulties in monitoring the size of the iceball have been reported.[34]

Monitoring

Intracorporeal ultrasonography is used for both laparoscopic and open approaches, whereas open MRI is used for percutaneous cryoablation. Ultrasound can detect renal tumors, reliably guide a cryoprobe to the tar-

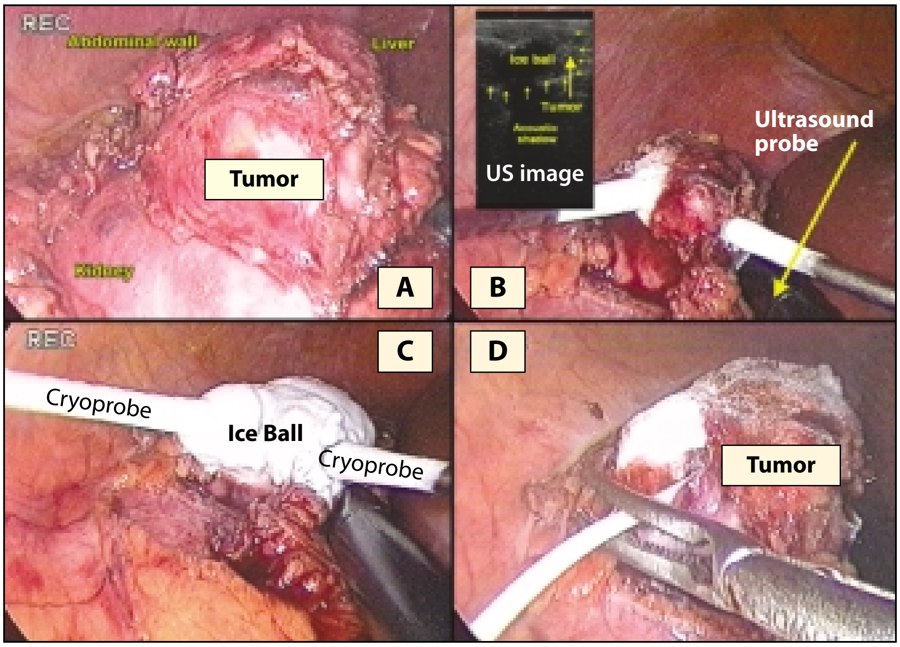

Figure 2. *Laparoscopic cryoablation demonstrating:* (A) *Exposed exophytic lesion,* (B) *Cryoprobes with ultrasound probe actively freezing tumor,* (C) *Freezing complete,* (D) *Insertion of fibrin glue for hemostasis.*

get lesion, and capture the characteristic change in appearance of cryotreated tissue. The cryolesion appears as a hypoechoic area with a hyperechoic rim that expands as the freezing process goes on. At the time of thawing, the hyperechoic rim disappears. Animal studies have shown excellent correlation between the lesion's ultrasonographic image and its diameter measured by calipers (Figure 2).[20,28]

Radiofrequency Ablation

Mechanism of Action

Radiofrequency (RF) energy can be used to rapidly create highly localized lesions via a *temperature-based* or an *impedance-based* system. Both systems rely on the creation of a closed electrical circuit. The cytotoxic mechanism in both involves desiccation due to high intracellular temperatures. High-frequency current flows from a needle electrode to the surrounding tissue, resulting in ionic agitation, which leads to accelerated molecular friction, which produces heat. Heat induces immediate cellular damage, leading to coagulative necrosis. Energy returns to the RF generator via a return pad that completes the circuit.

The macroscopic and microscopic findings following RF treatment correlate.[35–37] Macroscopically, after RF treatment, kidneys demonstrate a gray-white area of necrosis surrounding a central cavity containing both areas of hemorrhage and necrotic debris. Clear demarcation exists between the induced lesion and the surrounding normal parenchyma. Shortly after RF ablation, intense stromal and epithelial edema with marked hypereosinophilia and pyknosis are present, accompanied by microvascular thrombosis and coagulative necrosis. Chronic lesions demonstrate dense fibrosis.

Technique

Temperature-based systems were the first to be introduced for renal-tissue RFA. Power ranging from 26W to 50W at a frequency ranging from 460 kHz to 500 kHz is delivered. Various devices have been used for RFA. Bipolar electrodes result in pillow-shaped or ovoid lesions. Monopolar needles are coupled with secondary hooks to create spherical lesions. An insulating shaft protects normal tissue. Tissue temperature measurements are made via thermocouples located at the tip of the needles. Electrode temperatures at approximately 100°C are generally required in order to assure temperatures of at least 60°C at the periphery of the ablated lesion.[36] Temperature-based systems are limited to a lesion diameter of 16 mm. Early tissue desiccation causing a rise in tissue impedance is responsible for this limitation. Multiprobe, hooked, and bipolar arrays; intraparenchymal saline injection; and internally cooled electrodes have all been developed to increase the size of the lesion created. In addition to the monopolar and bipolar devices described above, a probe with four needle tips or arrays with adjustable lengths can be used. Polascik and colleagues[38] introduced the modified technique of saline perfusion of tissue during RFA. This technique was found to prevent tissue desiccation, resulting in increased volumes of ablated tissue. In addition, RF with saline perfusion allowed tissue ablation to occur in a predictable manner.

Crowley and colleagues[37] introduced an impedance-based system to overcome the limitations of conventional RF and studied its effects in a porcine model. RF was delivered both laparoscopically and percutaneously with CT guidance. The procedures showed minimal morbidity and allowed monitoring and control of ablation. The resistance of the tissue surrounding the electrode is monitored as RF energy flows to the return pad. RF energy is applied until the tissue becomes desiccated, then acting as an insulator and blocking further flow of energy to the return pad, allowing the temperature at that particular location to rise and cause denaturation of intracellular proteins and cell death.

Monitoring
The ability to monitor the lesioning process during RFA using real-time ultrasound is debatable. Polascik and colleagues[38] as well as Zlotta and colleagues[35] reported that in a saline-infused RFA, a bubbling effect in the area of the treatment may be ultrasonographically imaged as an area of increased echogenicity. However, Crowley et al[37] found that ultrasound was not useful for intraoperative monitoring. Posttreatment lesions appeared as a distinct hyperechoic zone, an area of bright echogenic foci, or a heterogeneous area of mild hyperechogenicity.

High-Intensity Focused Ultrasound

Mechanism of Action
High-intensity focused ultrasound can induce tissue lesions in vivo by focusing energy onto a small volume of tissue, which causes tissue temperatures to rise to approximately 90°C. Lesions are created by two types of physical insults: thermal and cavitational. The thermal effect is caused by tissue absorption of the sound wave and the heat energy produced as the wave passes through tissue. It is obtained by using low ultrasonic intensities over long periods of exposure. Cavitation results from high peak intensities over brief exposure periods. Cavitation is caused by a process in which bubbles develop and acutely increase in size to the point at which resonance is achieved. When the bubbles suddenly collapse, high pressures ranging from 20,000 to 30,000 bars develop and damage nearby cells.[39] Theoretically, the focusing ability of HIFU prevents intervening tissues from thermal destruction.

Chapelon and colleagues[39] studied the effects of HIFU on rat and canine kidneys and demonstrated lesions consistent with coagulative necrosis or cavitation, depending on ultrasound duration and intensity. The lesion size also varied depending on the acoustic intensity and the number of firings. Adams and colleagues[40] noted that histologically, affected cells demonstrate pale eosinophilic cytoplasm and separation from one another. At the periphery of the lesions, areas of hemorrhage were noted in close proximity to normal-appearing tissue. Susani and colleagues[41] studied the gross and histologic effects of HIFU in two patients with RCC prior to nephrectomy and found the area of treatment was indistinguishable from the large area of tumor necrosis.

Technique
Ultrasound energy is delivered via a highly focused transducer. The transducer is composed of a piezoelectric element that both images and delivers therapy. The main theoretical advantage of the approach is that it may be done extracorporeally without direct contact between the effector probe and the lesion.

Monitoring
A limitation of HIFU is the difficulty in imaging lesions for the precise targeting of tissue destruction. Adams and colleagues[40] induced experimental VX-2 kidney tumors in a rabbit model. At the time of lesioning, it was impossible to accurately localize lesions for destruction. The investigators suggested integration of the HIFU technology with other imaging modalities such as duplex Doppler, CT, or MRI as a possible means of precisely localizing renal tumors. Other groups have similarly described the limitation of ultrasound in demonstrating detectable tissue changes during or following the creation of lesions.[42,43]

Are Ablative Techniques Safe?

Cryosurgery and RFA have been relatively safe. No worsening of renal function following these procedures has been reported. Hemorrhage, thrombosis, and urinary fistula formation are all potential risks of cryosurgery and RFA; however, few if any of these complications have been noted. The table shows reported complications of cryosurgery in clinical studies.

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Complications of RFA in clinical studies include incomplete ablation of a renal lesion, requiring multiple treatments to ablate the lesion completely,[36] and postoperative hemorrhage.[49] Complications of cryosurgery and RFA noted in animal models, but not in humans, include freezing of the collecting system in a dog without evidence of urinary leakage or hemorrhage,[28] secondary ureteropelvic junction stricture,[26] and urinoma after RFA.[37]

Cracking and bleeding of renal parenchyma during the thaw phase have been noted by some groups during open as well as laparoscopic cryoablation.[50] Electrocautery, surgical mesh, avitene plugs, thrombin-soaked gel foam, cellulose mesh, and argon beam laser application have all been

Table 1
Frequency of Complications of Cryoablation in Clinical Studies*

Complication	Perc	Open			Laparoscopic		Open/Lap
	Uchida et al 1995[17]	Delworth et al 1996[44]	Zegel et al 1998[45]	Rukstalis et al 2001[46]	Bishoff et al 1998[47]	Gill et al 2000[27]	Rodriguez et al 2000[48]
Urinary extravasation	0/2	0/2	0/6	0/29	0/9	0/32	0/7
Postoperative hemorrhage	0/2	0/2	0/6	0/29	0/9	0/32	0/7
Renal capsule fracture	0/2	0/2	0/6	4/29	0/9	0/32	0/7
Renal failure requiring dialysis	0/2	0/2	0/6	3/29	0/9	0/32	0/7
Liver laceration	0/2	0/2	0/6	0/29	0/9	1/32	0/7
Postoperative CHF	0/2	0/2	0/6	1/29	0/9	0/32	0/7
Pelvic vein thrombosis	0/2	0/2	0/6	0/29	0/9	0/32	1/7
Recurrence	0/2	0/2	0/6	1/29	0/9	0/32	0/7

*Values are expressed as frequency/n. Perc, percutaneous; Lap, laparoscopic; CHF, congestive heart failure.

used to establish hemostasis in laparoscopic procedures when cracking and bleeding have occurred. At UCLA we infuse fibrin glue into the probe tract while still frozen in order to prevent bleeding following thawing.

Animal models have shown HIFU to be associated with a number of adverse side effects that, for the time being, are serious enough to preclude safe application to human kidneys. Chapelon and colleagues[39] showed that in 13 of 16 dogs, abdominal organ lesions occurred following HIFU. This finding was believed to be due to misfocusing of the target organ. Some improvement was achieved using an ultrasound bidimensional scanner; however, a kidney lesion was obtained in only 10 of 16 animals, and six dogs suffered cutaneous burns. Adams and colleagues[40] noted a difficulty in tumor localization due to the movement of the kidney during ventilation. Watkin et al[42] also reported poor targetability of renal lesions while using HIFU; only 67% of total shots fired were detected in the target area. Moreover, no change in the ultrasound appearance of the treated area following HIFU was noted, making it difficult to evaluate the extent of destruction of renal lesions.

Oncological Efficacy of Ablative Techniques

Immediate postoperative and long-term efficacy are assessed by the radiographic appearance of lesions at various intervals. Rukstalis et al[46] define their radiographic response criteria as initial evidence of infarction and hemorrhage, subsequent obliteration or reduction in size of the renal mass, and absence of growth on radiologic follow-up examinations. Atypical enhancement on CT or MRI should not be considered a failure unless associated with persistence or growth of the mass. Gill, Novick, and associates[27] performed routine postcryoablation biopsies in order to confirm adequate treatment. In all 23 patients, no evidence of tumor was noted. Because of these consistent findings with their technique, the group essentially abandoned the practice of postoperative biopsy. Rukstalis et al[46] reported on one patient with an enhancing mass unchanged in size at 3 months following surgery. Biopsy showed a microscopic focus of grade 1 renal cell carcinoma and a repeat cryosurgery was eventually performed with a good local control.

RFA results are limited to feasibility studies and lack long-term follow-up. Gervais and colleagues[49] used percutaneous RFA with CT or ultrasound guidance to treat nine renal masses in eight patients. All patients had life expectancies less than 10 years and significant comorbidities. Those with metastatic disease were excluded. Seven of eight patients survived at least 6 months after surgery. Four lesions required multiple RFA treatments based on follow-up imaging that demonstrated evidence of residual tumor. At a mean follow-up of 10.3 months, seven of the nine tumors were completely eradicated.

Limitations

Ablative techniques do not generate pathologic specimens that allow accurate pathologic diagnosis and thus preclude accurate tissue diagnosis, staging, and grading, which are important for prognosis determination. Therefore, biopsy of perirenal fat and of the renal mass is promoted by some investigators and is performed at our institution. Reliability of such biopsies, however, has been called into question. Moreover, performing pretreatment biopsy during percutaneous procedures brings back to discussion the question of tract seeding.

Therefore, reliable freezing and complete eradication of tissue with achievement of adequate margins during the procedure need to be ensured. Debate exists over which of two techniques of intraoperative monitoring is preferable: use of thermocouples, as advocated by Kavoussi and Rodriguez[48] or following radiographic lesion appearance, as advocated by Gill and Novick.[27]

Concern for achieving negative margins has led some investigators to modify their techniques in order to obtain pathological specimens. Crowley and colleagues[37] describe the use of RFA-assisted laparoscopic partial nephrectomy in 10 patients. All ablated lesions were excised and sent for pathological evaluation, with negative margins reported in all cases. Other innovative modifications of ablative techniques are likely to follow. Currently we are not convinced that ablative measures followed by tissue removal has a role.

Conclusions

Minimally invasive modalities for the treatment of RCC are being introduced as new nephron-sparing approaches in an attempt to minimize operative time, morbidity, and time to full recovery. The majority of candidates are those with unifocal, small, peripheral lesions located away from the collecting system.

Few large series with long-term results confirming the curative efficacy of ablative techniques have been conducted. Cryosurgery is the most studied modality. RFA studies are mostly limited to small series of patients with short-term follow-up or to case reports. Due to its alarming complication rate in animal models, HIFU warrants further investigation and refinement prior to an attempt to use it for renal masses in a clinical setting. Optimization of treatment modalities and refinement of techniques is ongoing. Long-term studies are needed to confirm a durable response compared to partial and radical nephrectomy. Nevertheless, inclusion criteria based on size, location, and type of treatable lesions and patient selection are evolving.

Cryosurgery and RFA are generally reserved for exophytic lesions <4 cm. They also serve older patients with significant comorbidities. The role of percutaneous techniques is still unclear. Radiographic follow-up is essential. The best modality (ie, MRI, ultrasound, or CT) for tumor targeting, monitoring of therapy, and follow-up is still under investigation. Debate continues as to the best method of ensuring adequate intraoperative tumor cryoablation: use of thermocouples or monitoring radiographic appearance of the lesion. Finally, the role of follow-up biopsy to ensure complete eradication of the tumor needs further defining. For minimally invasive ablative measures to gain a place as nephron-sparing approaches,

Due to its alarming complication rate in animal models, HIFU warrants further investigation and refinement prior to use in a clinical setting.

Main Points

- Ablative techniques in renal surgery, such as cryoablation, radiofrequency ablation (RFA), and high-intensity focused ultrasound (HIFU), combine the minimally invasive approach of laparoscopy with nephron-sparing surgery.
- Cryoablation and RFA have been associated with few complications in clinical studies.
- HIFU has been associated with severe adverse effects in animal models, precluding use in humans prior to further investigation and refinement.
- The best modality—magnetic resonance imaging, ultrasound, or computed tomography—for tumor targeting, monitoring of therapy, and follow-up is still under investigation.
- Debate exists concerning whether use of thermocouples or monitoring radiographic appearance of the lesion is the optimal technique for ensuring adequate intraoperative tumor ablation.
- Long-term studies are needed to confirm a durable response of ablative techniques compared to partial and radical nephrectomy.
- At this time, these techniques should be reserved for selected patients and should be compared to the evolving modality of laparoscopic partial nephrectomy.

they should show both equivalent efficacy and reduced morbidity relative to those of open partial nephrectomy. At this time, these techniques should be reserved for selected patients and should be compared to the evolving modality of laparoscopic partial nephrectomy. ■

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