Percutaneous thermal ablation for small renal masses

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Dr Konstantinos Katsanos
Dr Shahzad Ilyas
Professor Andreas Adam

Department of interventional radiology,
Guy’s and St Thomas’ Hospitals NHS Foundation Trust,
King’s Health Partners, London

katsanos@med.upatras.gr
konstantinos.katsanos@gstt.nhs.uk

Introduction
Renal cell carcinoma (RCC) is among the ten most common tumours in men and women. Evolution of imaging modalities, accompanied by extensive screening and imaging surveillance for other diseases, has led to an increased number of small renal tumours being detected incidentally at earlier stages. More than 80% of small renal masses (SRM) are proven to be renal cell carcinoma classified as stage cT1a; ie localised small renal tumours with a maximal diameter smaller than 4cm; and nephron-sparing treatments (NST) are nowadays the accepted standard of care, provided that a healthy kidney segment may be safely preserved. Active surveillance may be an initial management option for patients with significant comorbidities and limited life expectancy, however, partial nephrectomy (PN) is considered the gold standard treatment for SRMs and should be offered to all patients amenable to safe surgical treatment.

Recent guidelines indicate that percutaneous thermal ablation may also be considered a valid alternative treatment option as long as a complete ablation can reliably be achieved. This review gives a brief overview of percutaneous thermal ablation techniques focusing on their main technical aspects and application techniques for curative ablation of small renal cell carcinoma. The authors also provide a critical narrative of the relevant medical literature, with an emphasis on long-term outcomes of comparative effectiveness research, and appraise the percutaneous methods compared to surgery in the context of both long-term oncologic outcomes and of preservation of renal function.

Percutaneous thermal ablation
Percutaneous ablation is a minimally-invasive, image-guided procedure, usually performed under conscious sedation. The modality most commonly employed for imaging guidance is computed tomography (CT); this provides excellent visualization of adjacent organs and permits accurate electrode placement. Ultrasound guidance avoids the use of ionising radiation but does not demonstrate adjacent bowel loops as clearly as CT. MRI guidance is expensive and cumbersome. Patient preparation typically involves correction of any underlying coagulopathy if necessary and overnight starving to allow for safe administration of intravenous conscious sedation. Access planning and local anaesthesia of the skin and subcutaneous tissues is performed under aseptic conditions. The main advantage of the percutaneous image-guided method is the ability to control every step of the procedure, re-adjust needle/electrode placement, choose another access point or even abandon the procedure if deemed unsafe. The immediate outcome of percutaneous ablation is demonstrated clearly on cross-sectional imaging, usually a contrast-enhanced CT examination performed on the following day. The extent of the ablation is demonstrated clearly on such studies. Non-enhancing areas represent coagulated tissue and the appearances on imaging have been shown to correspond to histological necrosis (figure 1).

In line with the principle of R0 surgical excision, an R0 ablation with enough tissue margin to minimise the risk of residual tumour or early recurrence is advocated at all times. One of the main goals of percutaneous renal ablation is its nephron-sparing nature. The aim is to achieve complete ablation of the tumour with an adequate margin to ensure that all malignant cells have been destroyed. Regular imaging follow-up enables early detection and timely retreatment of recurrent tumours. The amount of normal renal parenchyma lost during percutaneous ablation is significantly smaller than after partial nephrectomy.

Radiofrequency ablation
Radiofrequency ablation (RFA) was first reported in liver tumours in the 1990s and is the most widely used and studied method for the treatment of small renal masses. RFA uses an alternating current (460-500kHz) delivered via electrodes of different sizes and shapes. It requires the use of grounding pads on the skin to allow the creation of a closed electrical circuit between the body and the RFA generator. Circulation of the alternating current causes high frequency agitation of the ionic molecules contained within the tissues, thus generating frictional heat. Temperatures between 60°C and 100°C produce immediate cell death by protein denaturation and coagulative tumour necrosis. However, when the temperature exceeds 100°C, water vaporises and tissue adjacent to the electrode may carbonise, thus reducing the electrical conductance of tissues and increasing impedance. The efficacy of RFA has also been limited by adjacent high flow vascular structures, producing the so-called ‘heat-sink’ phenomenon. The curative tumour ablation zone must correlate with the target mass lesion and ideally include a 0.5-1cm margin of healthy tissue around the target lesion to minimise the risk of future recurrence; ie an R0 ablation effect.

Microwave ablation
There has been increasing interest in the use of microwave ablation (MWA) for the treatment of SRMs and several recent publications on this subject. MWA was developed to overcome the major limitations of RFA; ie the heat-sink phenomenon and the dependence of coagulation on the electrical properties of the tissues. MWA uses an electromagnetic wave...
(915-2,450MHz) through an electrode-antenna that causes the tissue water molecules to rotate, re-orientate and increase their kinetic energy resonating with the applied waves, thus generating heat and increasing tissue temperature to nearly 100°C. No grounding pads are necessary and larger areas of coagulation are created than with RFA. MWA operates independently of any electrical current convection and is not limited by tissue impedance, desiccation or char- ring and heat-sink phenomena. The most recent microwave generators employ a frequency of 2,450MHz, which produces more homogeneous and more spherical ablation results without the more oblong ‘rat-tail’ areas of first-generation 915MHz devices. It in addition, internally cooled antenna shafts have been developed that increase efficacy at higher energies without collateral damage.

Clinical outcomes

Assessed clinical evidence to-date originates mostly from single-arm observational cohort studies or comparative unmatched studies with population-based comparator groups. There are some large case series as well, together with some relevant meta-analyses based on these studies and with only one randomised controlled trial in the case of MWA. Overall, surgical (open, laparoscopic or robotic) partial nephrectomy may provide five-year survival of more than 90% with minimal damage to normal renal parenchyma.

It has been shown that image-guided ablation of small renal tumours may be performed successfully, with significantly shorter hospital stay, or even as a day-case procedure. Patients have a faster recovery time and there is better preservation of kidney function compared to PN. For example, long-term data following open or laparoscopic PN of 894 small T1a RCCs from a single centre retrospective study have shown a five-year recurrence-free survival of 97.9% and 97.1% for laparoscopic and open PN respectively. Another single-centre retrospective series of radiofrequency ablation in 185 patients with small renal tumours reported a five-year recurrence-free survival of 96.1% for T1a lesions. Pantelidou et al, who retrospectively examined freedom from local recurrence and/or remote metastasis in a cohort of 63 RFA versus 63 RPN cases, documented that local recurrence was numerically (not significantly) higher in the RFA group (6.8% vs 1.9%, p=0.13) without, however, any significant difference in terms of disease-free survival (adjusted HR: 0.6, 95% CI: 0.1-3.7, p=0.60).

A proportional rate meta-analysis of six cross-sectional studies including 587 patients with small renal tumours (mean size 2.5cm) treated with either thermal ablation (percutaneous or laparoscopic application of radiofrequency or microwave) or surgical nephrectomy (open or laparoscopic) documented that complication rate was significantly lower in the ablation group (7.4 vs 11%; RR: 0.65, 95% confidence interval [CI]: 0.31-0.97, p=0.04) and postoperative renal function was significantly worse in case of nephrectomy (mean difference of eGFR decline: -14.6ml/min/1.73m², 95% CI: 27.96 to -1.23, p=0.03). Local recurrence rate was identical in both groups (3.6 vs 3.6%; RR: 0.92, 95% CI: 0.4-2.14, p=0.79) and disease-free survival also was similar up to five years (HR: 1.04, 95% CI: 0.48-2.24, p=0.92).

Conclusion

In conclusion, renal cell carcinoma is a common cancer in both men and women and is being increasingly detected at earlier stages as an incidental small renal mass. Surgical partial nephrectomy has been the historical gold standard nephron-sparing treatment, with percutaneous ablation methods reserved for patients who are unfit for surgery because of advanced age, underlying comorbidities or already compromised renal function. Recent studies have demonstrated the long-term oncologic non-inferiority of percutaneous thermal ablation compared to surgical resection, coupled with foreshortened hospital stay, earlier return to normal activities, lower rate of complications and better preservation of renal function. Nonetheless, significant challenges and unmet clinical needs remain, as not all tumours are amenable to ablation or some may require to be targeted successfully. Although the level and quality of relevant clinical evidence remains low and further studies are needed, percutaneous ablation should be considered a suitable alternative to surgery in appropriately selected patients with small renal tumours.

References

Figure 1
(A) Elderly male patient with a mid-pole heterogeneously enhancing 3.5cm tumour of the right kidney proven to be clear cell carcinoma on biopsy. (B) Immediate post-ablation result following a 10-minute microwave ablation with a single antenna at 100W (Emprint, Medtronic). Note the non-enhancing area of ablation with significant tumour shrinkage compared to baseline (because of extensive dehydration) and a wide circumferential tissue margin without any site-related complications.

Figure 2
Baseline contrast-enhanced CT images (coronal reformats) of a male patient with bilateral incidental renal tumours. The right one is close to the renal mid-pole and is completely endophytic measuring nearly 2.5cm. In the left upper pole there were two tumours, the largest in the medial aspect measuring 3.0cm.
Figure 3
Post-operative contrast-enhanced CT images (coronal reformats) following percutaneous microwave ablation of the right endophytic lesion and robotic partial nephrectomy of the left upper pole (procedures were performed on separate occasions). Note the wedge-shaped non-perfusing area of ablation corresponding to the baseline target tumour in case of microwave (red asterisk) in the right kidney and the post-operative changes in the left kidney.