Percutaneous radiofrequency ablation of renal tumours: Technique and follow up

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Learning objectives

The aim of our exhibit is to outline the role of percutaneous radiofrequency ablation (RFA) in the management of renal tumours. We review the current literature regarding the technique using examples from cases referred to our interventional radiology service.

Learning objectives include:

1. To outline the patient selection criteria for RFA of renal tumours
2. To describe the technique employed
3. To illustrate the spectrum of US/CT/MR findings on follow-up imaging of renal tumors treated using percutaneous RFA
4. To review the complications associated with the procedure

Background

Renal Cell Carcinoma

- Renal tumours represent 3% of all human tumours (1). The incidence of renal cell carcinoma (RCC) in the US has increased by over 100% since 1950 (2). This has been accompanied by an increase in the 5 year survival rate for RCC from 34% in 1950 to 62% in 1996 (2).

- The increased incidence and improved survival are largely attributable to radiologic detection of early-stage disease (3).

- At the same time, there have been numerous advances in the curative treatment of RCC with the emergence of nephron-sparing surgeries including open and laparoscopic partial nephrectomy and laparoscopic complete nephrectomy(4,5).

- Some patients are, however, unsuitable for surgical resection and its inherent mortality and morbidities, in others with a predisposition to multiple bilateral renal malignancies, such as in Von Hippel Lindau disease, renal preservation is paramount. In such patients, ablation therapies such as cryoablation and radiofrequency ablation (RFA) are emerging as practical, safe, and effective alternatives to surgery (4,5).

- In addition, nonstandard indications for renal RFA have been described including transfusion dependant haematuria, pain control, palliation, preoperative tumour embolisaton and transitional cell carcinoma.
Radiofrequency Ablation

Principles

- RFA is a thermal ablation method that uses high frequency energy to induce cell death. A high frequency alternating current with a wavelength of 460-500kHz is emitted through a needle-electrode placed under imaging guidance within the targeted tissue (6). Grounding pads placed on the patient's thighs completes the electrical circuit.

- The alternating radiofrequency circuit agitates ions in the tissue surrounding the needle, creating frictional heat. As tissue temperatures increase between 60-105°C, there is an instantaneous induction of irreversible cellular damage referred to as coagulation necrosis (7).

- At temperatures between 50-60°C, coagulation is induced within minutes. Lower temperatures than 50°C are not used for RFA, because of prolonged heating times required.

- At temperatures greater than 105°C, cells boil, releasing gas vapour and causing tissue charring. This inhibits the dispersion of radiofrequency energy, decreasing the size of the ablation zone (6).

- RFA devices should ideally induce prolonged heating of target tissue with temperatures sustained between 50° and 105°C.

RFA Devices

- In percutaneous RFA, the energy is delivered into the target tissue using needle-like electrodes which range in diameter from 15 to 17 gauge.

- Three different radiofrequency devices are commonly used, each with different approaches to maximize the size of thermal ablation and monitoring for thermal destruction.

- Cool-tip radiofrequency ablation system (Radionics, Burlington, Mass.) consists of a single 17G needle-electrode or a unit of three electrodes in a triangular cluster. The system uses the synergisitic effects of internal cooling of the electrode and pulsed energy delivery to control the temperature near the probe and prevent gas vapourisation and tissue charring which limit energy dispersion (6). The system uses an impedance-controlled current monitoring the resistance of the tissue surrounding the electrode. RF energy is applied until the tissue becomes dessicated, thus acting as an insulator with a roll off in impedence.
The RITA (radiofrequency interstitial tissue ablation) system (Rita Medical Systems, Mountain View, Calif) contains numerous retractable electrode tines in a starburst configuration which are advanced into the target tissue to increase the area of ablation. This system is temperature-controlled, with thermocouples located at the tine tips to create a target temperature of 105°C.

- LeVeen device (Radiotherapeutics, Mountain View, Calif) is a multi-tine impedance controlled system.
Fig.: LeVeen Electrode (Radiotherapeutics, Mountain View, California) is a multi-tine electrode design

- The available radiofrequency devices use generators that deliver 150-200W of energy.

Efficacy of RFA
- Zlotta et al described renal RFA prior to open radical nephrectomy in 1997 (8). Percutaneous RFA for RCC under ultrasonic guidance was first described in the literature in 1999 (9). Current literature describes percutaneous access in 94% of renal RFA cases (10).
- Results from clinical series with relatively short term follow up have supported the efficacy of the procedure in carefully selected patients. In the largest study to date, RFA of 105 renal tumours in 97 patients was described (11). The mean patient age was 71.7 years with a mean tumoral size of 3.2cm (1.1-6.8cm). 83 (79%) of tumors were treated with a single ablation with 12 of the remaining tumours successfully retreated. Decision not to treat 8 of the remaining tumours was made on clinical or technical grounds with two further patients awaiting retreatment. 5/97 patients experienced
complications. On multivariate analysis, tumoral size <3cm was the only significant variable to influence procedural outcome.

- In a recent meta-analysis comparing the efficacy of cryoablation and radio-frequency ablation in treatment of 1375 renal tumours in 45 institutions (10). The mean patient age for all ablated lesions was 67.2 years. Mean tumour size for all renal lesions undergoing ablation was 2.64cm, with a mean duration of reported follow-up after ablation of 18.7 months.

- Local tumour progression was reported in 5.2% of lesions following cryoablation and 12.9% after RFA, a difference found to be statistically significant. Furthermore, 8.5% of RFA treated lesions required repeat ablation compared to 1.3% of cryoablated tumors, also of statistical significance. No significant difference regarding progression to metastatic disease was seen between the two modalities with 1% of cryoablated lesions and 1.8% of RF ablated lesions demonstrating metastatic progression (10).

- However, the majority of lesions treated by cryoablation were performed laproscopically (63%) while 93% of RFA was performed percutaneously and therefore the differences in achieving complete tumoral destruction may relate to approaches used versus inherent differences in the ablative techniques. In addition, local disease recurrence may be successfully managed by repeat ablation and given the short term follow up of included studies, the ultimate rate of treatment failure remains to be defined.

Images for this section:
**Fig. 1:** A: RITA multi-tine electrode system (Rita Medical Systems, Mountain View, California) B and C: Cool-tip radiofrequency ablation system (Radionics, Burlington, Mass.)
Fig. 2: LeVeen Electrode (Radiotherapeutics, Mountain View, California) is a multi-tine electrode design
Patient Selection

Indications for RFA are influenced by lesion size, location, comorbidities and patient preferences.

- RFA may be considered in patients unsuitable for surgical resection and its inherent mortality and morbidities because of comorbidities, limited renal reserve or unresectable tumors and in patients with a predisposition to multiple bilateral renal malignancies, such as in Von Hippel Lindau disease, where renal preservation is paramount.

- More recently, RFA has been used to manage local recurrence post-operatively or in patients with bilateral RCCs or for palliative symptom control.

- Tumour size is a consideration for patient selection. While there is no absolute size limit, smaller tumours provide a greater chance for local ablation success, with the greatest success in tumours less than 3-4cm (11) and treatment of larger tumours should be considered for cytoreduction rather than cure.

- Exophytic or parenchymal tumours not involving the renal sinus are generally considered technically more amenable to percutaneous RFA. Exophytic tumours surrounded by perinephric fat or easier to target and monitor. In addition, the fat may provide an insulation "oven effect" during ablation. In tumours with a central component, the renal sinus vessels may act as a "heat sink" where vessels greater than one mm reduce tumoral heating by energy dissipation.

- Contraindications to the procedure include uncorrected coagulopathy and acute illness such as sepsis (6).

Technique

- Prior to the procedure, all patients undergo contrast-enhanced CT or MRI abdomen to ensure no tumour spread beyond Gerota's fascia, into the renal vein or to lymph nodes of distant organs as such spread is a contraindication to the procedure unless it is being performed for reasons other than cure.

- Decision to treat was based on imaging characteristics of the tumour as RCC is accurately diagnosed by CT or MR imaging. In some institutions, percutaneous biopsy is performed at time of ablative procedure.
• All patients have a platelet count, coagulation profile and baseline creatinine measured prior to procedure. Serum creatinine was also monitored post procedurally.

• The procedure is performed under conscious sedation with the patient in the prone or decubitus position. Following local anaesthetic infiltration with 1% lidocaine to the renal capsule, the needle electrode is advanced under US or CT guidance, initially to the deep margin of the tumour.

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<table>
<thead>
<tr>
<th>Ultrasound</th>
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| **Advantages** | 1. Real-time imaging  
| | 2. Absence of Ionizing Radiation  
| | 3. Portability | 1. Visualisation of small renal tumours  
| | 2. Lack of obscuring artefacts post-ablation  
| | 3. With contrast enhancement, allows immediate post-procedure assessment of adequacy of ablation |

| Disadvantages | 1. Poor visualisation of small tumours and adjacent air-filled bowel  
| | 2. Hyperechogenicity of ablative zone |

**Fig.**: Comparison of ultrasound and CT guidance for RFA

**References:** R. Dunne; Radiology, St James Hospital, Dublin, IRELAND

• RF electrode selection depends on tumour size with the aim to choose an electrode size that will ablate the tumour and a surrounding rim of normal renal tissue. With respect to size, ablation systems can produce burn diameters ranging from 1 to 5 cm in a single ablation (12). For eccentrically shaped or tumours >3cm, overlapping ablations may be performed by electrode repositioning.
Fig.: Case 1: An elderly male patient with a history of chronic renal impairment. Figure 1: Axial contrast-enhanced CT demonstrating a complex cystic lesion with enhancing components in the upper pole of the right kidney consistent with RCC.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Case 1 Figure 2: Axial non-contrast CT image with patient in the prone position obtained during RFA procedure. After infiltration of local anaesthetic, the needle electrode is advanced under imagin-guidance to the deep margin of the tumour.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 1 Figure 3: Axial non-contrast CT image obtained during the RFA procedure with the patient in the prone position. Once position in tumour confirmed, the tines are deployed in the case of multi-tine RFA devices.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 1 Figure 4: Axial non-contrast CT image obtained immediately after removal of the needle electrode at end of ablative procedure. Note the low attenuation of the ablative zone which includes the tumour and a rim of surrounding normal renal parenchyma. The ablative zone also contains flecks of air in keeping with successful ablation.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 1 Figure 5: Axial contrast-enhanced CT image obtained three months post ablation. The ablative zone does not demonstrate enhancement and has decreased in size in the interval.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND

- The procedure is performed via a posterior or lateral approach to allow displacement of bowel loops and minimizing the risk of bowel injury. In cases where intra-abdominal structures approximate the ablative tract, 5% dextrose +/- air dissection may be performed to protect the adjacent structures and in the case of blood vessels minimize their “heat sink” effect. Saline is not used as it conducts electricity.
**Fig.** Case 2. Technique for displacing adjacent organs before radiofrequency ablation of a renal tumour. Figure 1: Axial non-contrast enhanced CT image with patient in prone position showing advancement of needle electrode in exophytic tumour of the left kidney. The large intestine is immediately adjacent to the tumour.

*References:* R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
**Fig.** Case 2. Figure 2: Axial non-contrast enhanced CT image showing deployment of multiple electrode tines after confirmation of satisfactory electrode position as per previous image.

**References:** R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 2. Figure 3: Under CT guidance, a 22 gauge needle was advanced into the mesenteric fat and air injected. Pneumodissection or hydrodissection using 5% dextrose is used to displace adjacent bowel and minimize risk of thermal injury during ablation.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 2. Figure 4: Axial non-contrast image obtained following removal of electrode during ablative procedure. Note the air filled space created by pneumodissection between the ablated tumour and adjacent bowel.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND

Follow up

• Adequacy of tumour treatment is difficult to determine at ablation. In patients with adequate renal function, performance of a contrast-enhanced CT at the end of presumed-adequate ablation may be performed. Viable enhancing tumour may then be treated with additional ablations at this time.

• Follow-up of RF-ablated tumours should follow a standard follow-up algorithm. Follow-up may be performed with unenhanced and contrast-enhanced CT or MRI. In patients with renal insufficiency, unable to tolerate contrast-enhanced studies, US may be used.

• In our institution, initial post-treatment imaging is performed 6-8 weeks post procedure with further follow-up imaging every three months for the first year and every six months for the second year and yearly thereafter. However, future follow-up is disease dependant and earlier interval follow-up may be required in cases of suspected ablation failure or in patients with a high risk of recurrence.
**Fig.** Case 3: Elderly female with history of left open nephrectomy twenty years previously for RCC. Figure 1: US image demonstrating 3.4cm mixed echogenicity mass arising from the right kidney consistent with contralateral recurrence.

**References:** R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 3 Figure 2: Axial contrast-enhanced CT image pre-ablation demonstrating 3.7cm enhancing exophytic tumour of the right kidney. Note the previous left nephrectomy.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 3 Figure 3: Axial contrast enhanced CT image one year post ablation demonstrating decrease in size of lesion with lack of enhancement with site of previous tumour extending to include a rim of renal parenchyma.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 3 Figure 4: Follow US examination post ablation in the same patient. The mixed echogenicity mass has decreased in size and now appears cystic in nature.

**References:** R. Dunne; Radiology, St James Hospital, Dublin, IRELAND

- In 2005, a report was published regarding the standardising of terminology and reporting of follow-up studies (13). In addition to reporting of changing tumour size, it identified two types of imaging post ablation: those related to zones of decreased perfusion and those in which the attenuation (CT), signal intensity (MR) of echogenicity (US) are altered.

- The ablation zone is used to describe the area of gross tumour destruction visualised at imaging. Ideally ablation of 0.5-1cm of tissue beyond the tumor margin should be ablated to ensure complete tumour destruction. This is termed the ablative margin. On contrast-enhanced studies, the creation of an ablation margin results in zones of low attenuation (CT) and absent perfusion that extends into the renal parenchyma. Increased attenuation (CT) may be seen in low attenuation areas such as the perinephric fat for exophytic tumours.

- Areas of contrast enhancement (>10HU or >15% with CT and MR imaging respectively) are used to identify areas of residual viable tumour.

- Benign periabalational enhancement is a transient finding up to 6 months post ablation and is best appreciated on arterial phase imaging. It is seen as a smooth concentric rim of enhancement at the periphery of the ablation zone, measuring < 5mm.
In contrast, irregular peripheral enhancement represents residual tumour at the ablation margin and may be scattered, nodular or eccentric. It is best appreciated on portal venous and delayed contrast-enhanced images.

**Fig.**: Case 4: Elderly female unsuitable for surgical resection due to multiple co-morbidities. Figure 1: Axial contrast-enhanced lesion pre-ablation demonstrating a 2.5 cm exophytic RCC arising from the right kidney. Note the proximity of the tumour to the IVC anteriorly and the renal sinus posteriorly.

**References**: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 4 Figure 2: Coronal image from the same study.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 4 Figure 3: Axial contrast-enhanced CT image obtained immediately post RFA of right RCC. The ablative zone contains flecks of air and does not demonstrate enhancement indicative of successful ablation. The ablative margin is seen to extend beyond the tumour margins into normal renal parenchyma. Note the low attenuation fluid within the perinephric space post hydro-dissection during the procedure to prevent heat sink effect of adjacent IVC and renal artery.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND

Fig.: Case 4 Figure 4: Axial contrast-enhanced CT image obtained 6 months post RFA. The ablative zone has decreased in size from 2.5cm to 1.5cm and appears more cystic compared to pre-ablative studies. Note the regular peripheral rim enhancement consistent with benign periablational enhancement.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 4 Figure 5: Coronal contrast enhanced image from the same study.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Fig.: Case 5: 73 year old lady with chronic renal failure who underwent MRI kidneys for evaluation of 5cm RCC of left kidney. Figure: 1 Axial T1W fat saturated non-contrast image demonstrating an exophytic complex cystic mass arising from the left kidney. A contralateral 1.5cm parenchymal lesion was seen in the right kidney.

References: R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
**Fig.**: Case 5 Figure 2: Axial T1W fat saturated image post gadolinium administration in the same patient demonstrating enhancement in both lesions, consistent with bilateral RCC.

**References:** R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
**Fig.**: Case 5 Figure 3: Axial contrast-enhanced CT image obtained 9 months post RFA of right renal tumour. There is eccentric peripheral enhancement of the lateral aspect of the ablative margin indicating residual viable tumour. The patient was referred for repeat ablation.

**References:** R. Dunne; Radiology, St James Hospital, Dublin, IRELAND
Complications

- Overall the rate of serious complications is estimated to be 1% for RFA of RCC and most patients may be treated on an outpatient basis (14).
- Haematuria frequently occurs, usually resolving without complication <24 hours. Perirenal haemorrhage is also commonly encountered, however, is rarely of clinical significance. Breen et al reported one case of perirenal haematoma requiring transfusion in 105 RFA procedures.
• Infection and abscess formation may be prevented by antibiotic prophylaxis.
• In general, renal function is preserved post procedure as a only a narrow rim of renal tissue is ablated. Central tumour ablation can usually be performed without clinically important pelvicalyseal damage, however, cases of urinoma and ureteral stricture have been reported (14).
• Tumor track seeding is minimised by tract ablation post procedure.
• Damage to adjacent structures including bowel, ureter, psoas muscle and adjacent nerves may be minimized by used of hydro-dissection techniques as previously described. In cases where ablation is performed close to the adrenal gland, the operator should be prepared to administer α-adrenergic blockers as sudden release of vasoactive catecholeamines may occur.

Images for this section:

![Image](image_url)

**Fig. 1:** Case 2. Technique for displacing adjacent organs before radiofrequency ablation of a renal tumour. Figure 1: Axial non-contrast enhanced CT image with patient in prone position showing advancement of needle electrode in exophytic tumour of the left kidney. The large intestine is immediately adjacent to the tumour.
Fig. 2: Case 2. Figure 2: Axial non-contrast enhanced CT image showing deployment of multiple electrode tines after confirmation of satisfactory electrode position as per previous image.
Fig. 3: Case 2. Figure 3: Under CT guidance, a 22 gauge needle was advanced into the mesenteric fat and air injected. Pneumodissection or hydrodissection using 5% dextrose is used to displace adjacent bowel and minimize risk of thermal injury during ablation.
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![Axial non-contrast image](image)

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![Axial contrast-enhanced lesion](image)
Fig. 6: Case 4 Figure 2: Coronal image from the same study.
**Fig. 7:** Case 4 Figure 3: Axial contrast-enhanced CT image obtained immediately post RFA of right RCC. The ablative zone contains flecks of air and does not demonstrate enhancement indicative of successful ablation. The ablative margin is seen to extend beyond the tumour margins into normal renal parenchyma. Note the low attenuation fluid within the perinephric space post hydro-dissection during the procedure to prevent heat sink effect of adjacent IVC and renal artery.

![Axial contrast-enhanced CT image obtained immediately post RFA of right RCC.](image)

**Fig. 8:** Case 4 Figure 4: Axial contrast-enhanced CT image obtained 6 months post RFA. The ablative zone has decreased in size from 2.5cm to 1.5cm and appears more cystic compared to pre-ablative studies. Note the regular peripheral rim enhancement consistent with benign periablational enhancement.

![Axial contrast-enhanced CT image obtained 6 months post RFA.](image)
Fig. 9: Case 4 Figure 5: Coronal contrast enhanced image from the same study.
**Fig. 10:** Case 5: 73 year old lady with chronic renal failure who underwent MRI kidneys for evaluation of 5cm RCC of left kidney. Figure:1 Axial T1W fat saturated non-contrast image demonstrating an exophytic complex cystic mass arising from the left kidney. A contralateral 1.5cm parenchymal lesion was seen in the right kidney.
**Fig. 11:** Case 5 Figure 2: Axial T1W fat saturated image post gadolinium administration in the same patient demonstrating enhancement in both lesions, consistent with bilateral RCC.
**Fig. 12:** Case 5 Figure 3: Axial contrast-enhanced CT image obtained 9 months post RFA of right renal tumour. There is eccentric peripheral enhancement of the lateral aspect of the ablative margin indicating residual viable tumour. The patient was referred for repeat ablation.
**Fig. 13:** Case 5 Figure 4: Coronal contrast-enhanced CT image in the same patient demonstrating peripheral nodular enhancement as previously described.
Conclusion

- Percutaneous RFA is a safe and effective curative treatment modality in patients unsuitable for surgical intervention with promising short to medium term results, particularly in treating small (<3cm) exophytic tumours, although tumours up to 5cm may be successfully ablated.

- Longer-term studies of RFA of RCC left in situ will provide additional guidance for the most appropriate selection of patients for this treatment.

- In addition, RFA shows promise for the successful care of other patients including local recurrence, isolated metastases and refractory haematuria.

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References