Freezing and Frying Renal Cancers:
An Imaging Menu for Radiologists to Understand Intra- and Post-Procedural Imaging Findings after Renal Tumor Ablation

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DISCLOSURES

- Heidi Coy-None
- Michael Douek-None
- Steven Raman-None
OBJECTIVES

1. Review intraprocedural image findings of cryoablation, radiofrequency ablation, microwave ablation and irreversible electroporation of renal cell carcinoma in various imaging modalities

2. Describe surveillance image findings and define imaging characteristics of successful ablation

3. Define signs of tumor recurrence seen at longitudinal follow-up

Target Audience: Trainees, Interventional Radiologists, Multidisciplinary Clinicians
BACKGROUND
Renal Tumor Ablation: Patient Selection

- Patients with contraindications to surgery
- Patients with solitary kidneys
- Patients with prior surgical resections
- vHL patients with multiple tumors

Or patients who just want Ablation!
BACKGROUND
Renal Tumor Ablation: Importance of Multiphasic Imaging for Lesion Detection and Follow-up

• A dedicated four-phase renal mass protocol is best to differentiate small vascular lesions which may blend into the cortex in an early arterial phase (corticomedullary) and hypovascular lesions which may have delayed enhancement and will not be as apparent until a delayed phase (nephrographic and excretory)

• On 16-64 Detector CT
  • Unenhanced Scan
  • Enhanced Scan Phases:
    • Inject 100-150 cc Omnipaque 350 @ 3-4 cc/sec
    • Bolus tracking (image @ 25 sec after aorta HU > 150 )
    • Corticomedullary phase scan (45 sec)
    • Nephrographic phase scan (80-90 sec)
    • Excretory phase scan (3 min)
BACKGROUND
Renal Tumor Ablation: Discrimination of Histological Subtypes on MDCT

- Prior work from our group has shown that renal cell carcinoma (RCC) subtypes and common benign RCC mimics have distinct absolute enhancement profiles across the four-phases on MDCT and in comparison to normal renal parenchyma, enabling clinicians to better stratify patients to the correct therapeutic pathway.
## BACKGROUND

Renal Tumor Ablation: Lesion Selection

<table>
<thead>
<tr>
<th>IDEAL:</th>
<th>MORE DIFFICULT LESIONS:</th>
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<tbody>
<tr>
<td>• LESIONS &lt;5CM</td>
<td>CENTRAL LESIONS</td>
</tr>
<tr>
<td>• POSTERIOR</td>
<td>ANTERIOR AND MEDIAL LESIONS</td>
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<tr>
<td>• EXOPHYTIC</td>
<td>ADJACENT TO URETER OR UPJ</td>
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- More difficult lesions:
  - Central lesions
  - Anterior and medial lesions
  - Adjacent to ureter or UPJ
BACKGROUND
Renal Tumor Ablation: Avoid Potential Complications
BACKGROUND
Imaging Guidance

Ultrasound (US)
- Unparalleled precision

US Guidance/CT Monitoring

MR Guidance

CRYOABLATION
Ablative Technique and Imaging Guidance

- Relies on the Jewel Thomson effect to create an ice ball
- Placing one or more needle-like cryoprobes (14-G-18G) directly into renal neoplasm under image guidance
- Cell death via freezing to <-40°C followed by thawing
- Intracellular ice formation and osmotic imbalance resulting from extracellular ice formation
- Indirect cell death from induced microvascular damage and apoptosis

Endocare
CRYOABLATION

Intraprocedural Image Findings

- US is suboptimal compared to CT or MR because the developing ice ball obscures sound wave penetration resulting in small echogenic leading edge with a hypoechoic shadow deep to the leading edge at the lesion.
- The ice ball is a uniformly hypodense (CT) or T1 hypointense (MR) ovoid sphere which ideally encompasses the entire lesions with a ≥ 5mm margin.

[Courtesy Matt Callstrom, Mayo Clinic]
CRYOABLATION
Intraprocedural Image Findings

Pre | Freezing | Thaw

Courtesy: Fred Lee, UW Madison
CRYOABLATION

Image Findings Immediately After Ablation

CT IMAGING:
- During the acute period immediately following ablation, the treatment zone appears larger than the original tumor and infiltration in the fat surrounding the ablation zone may enhance.
- The ablation zone has low attenuation, and emergence of the peripheral halo in perinephric fat surrounding the smaller high density ablated lesion can be seen the first few months following cryoablation.

MR IMAGING:
- Cryo-treated lesions appear variably T1 hyperintense or and T2 hypointense relative to the renal parenchyma.
- The peripheral halo of the ablation zone border after can be seen after contrast administration and surrounding fat retains signal on all sequences.

RCC in a 63 year old man treated with cryoablation. Diagnostic CT (a) shows an endophytic lesion. Immediately following cryoablation (b) there is a hypodense ablated lesion with stranding and enhancement within the perinephric fat.
CRYOABLATION
Successful Ablation and Surveillance Imaging Findings

- Lesion size progressively decreases over time to a greater degree than RF treated lesions
  - Up to 32% of cryo-treated lesions may become undetectable over time
- Decreased stranding, hematomas & perinephric fluid
- Emergence of the peripheral halo in perinephric fat surrounding the smaller high density ablated lesion

In a 63 year old man, diagnostic CT shows an exophytic papillary RCC.

1 month post cyroablation, CT imaging shows stranding and a hypodense ablation zone.

1 year post cyroablation, significant decrease in ablation zone and lesion size, with residual curvilinear enhancement and stranding in the perinephric fat.

2 years post cyroablation, significant decrease in ablation zone and lesion size, with reduced curvilinear enhancement and persistent stranding.
CRYOABLATION

Signs of Recurrence

- Usually occurs within or adjacent to ablation zone
  - Enlarging ablation zone
  - Increased linear or nodular enhancement

- May also occur in:
  - Renal vein
  - Contralateral kidney
  - Adrenal glands
  - Lymph nodes
  - Liver, lung, pleura or bones

A 67 year old man with an endophytic lesion treated with cryoablation. 1 month post-cryoablation surveillance MR imaging shows curvilinear enhancement within the ablated lesion.

3 months post-cryoablation surveillance MR imaging shows persistent curvilinear enhancement and a subtle increase in lesion size.

6 months post-cryoablation surveillance MR imaging shows increased nodular enhancement and an increase in lesion size confirmed tumor recurrence.
Radiofrequency (RF)

- Ionic Agitation AC current
- Slow sustained heating >60° C
- Coagulative Necrosis with Protein denaturation and cell death

For heat-based thermal ablation techniques such as RFA or MW, intraprocedural ablation findings are similar but vary slightly with the type of device and the relative speed of ablative change. RF and MW ablation is performed by placing one or more probes or within the renal tumor under US or CT guidance.

Central Coagulative necrosis with hyperemic margin

15G single needle systems with expandable umbrella-like internal tines

17G internally cooled needles electrodes

Raman et al. AJR 2000
MICROWAVE ABLATION
Ablative Technique and Imaging Guidance

**Microwave (MW)**
- Wavelike electromagnetic properties
- Rapid heating $>100^\circ$ C
- Coagulative necrosis

**Available Microwave Devices: 2015**

- NeuWave: 2.45 GHz
- Covidien: 2.54 GHz
- BSD Medical: 915 MHz
- Amica: 2.45 GHz
- Medwaves: 902-928 MHz
- Microsulis: 2.45 GHz
RF and MICROWAVE ABLATION

Intraprocedural Image Findings

ULTRASOUND:
Ultrasound shows antennae placement within the lesion targeted for microwave ablation (a). Temperatures inside the lesion raise above 50 degrees Celsius, water vapor and nitrogen are released as gas, resulting in echogenic reflectors (b) and eventually an echogenic cloud which fully encompasses the lesion (c,d).
RF and MICROWAVE ABLATION
Intraprocedural Image Findings

**CT MONITORING:**
Unenhanced:
- Stranding
- Gas from vaporization
- Ablated lesion becomes smaller and of higher density
- Small subcapsular or perinephric hematomas
- Latrogenic perinephric or peritoneal low density fluid from percutaneous hydrodissection

**Enhanced CT:**
- Complete lack of enhancement in the ablated lesion and a surrounding rim
- Lesion may appear larger
- Variable enhancement in surrounding unablated renal parenchyma
- May see a perilesional halo from ablation of perinephric fat

**MR MONITORING:**
On MR Imaging, the lesion becomes more T2 hypointense and more T1 hyperintense as heating above 60 degrees Celsius occurs. Towards the end of ablation, the original lesions shrink
In a 68 year old man, diagnostic MR shows a T1 contrast enhanced posterior lesion (a) and US image used for lesion targeting for RF ablation (b). On unenhanced CT (c) intraprocedural gas (CO2) at the end of RF ablation. Also noted is crescent shaped D5W hydrodissection in the posterior pararenal space. Immediate post procedural contrast enhanced CT (d) shows lack of enhancement in the ablated lesion and a wedge shaped margin consistent with coagulation necrosis and infarct.
RF and MICROWAVE ABLATION

Image Findings Immediately After Ablation

- Some of the immediate peri-lesional changes seen following thermal ablation include:
  - Blood products (b) (compare pre- with post-contrast to differentiate degraded blood products from residual tumor enhancement)
  - A post-ablation halo (c)
  - A cortical wedge shaped infarct associated with or adjacent to the treated lesion and as a result of segmental arterial thrombosis in the treatment zone (c)
  - The presence of perinephric stranding (c)
  - Immediately following treatment (24 hours to one week), a circumferential high attenuating region corresponding to a marginal hyperemic inflammatory reaction to the damaged cells can be seen in the surrounding renal parenchyma causing the lesion to appear larger than the pre-treatment lesion (a compared to c)
RF and MICROWAVE ABLATION
Image Findings Immediately After Ablation

Contrast Enhanced Ultrasound (CEUS):
Intravascular microbubble US contrast agents have been approved for diagnostic US imaging outside the United States, however many centers in the US use these agents off label. This enables much higher renal mass contrast relative to renal parenchymal background in real time over multiple contrast phases. CEUS is can be used in patients with renal insufficiency or with a contraindication to contrast.

In a 77 year old woman, diagnostic sagittal MR shows a T2 hyperintense lesion (a). Diagnostic CEUS shows lesion enhancement (b) Immediately following microwave ablation, no residual enhancement can be seen on contrast enhanced ultrasound (c) indicating ablative success.
RF and MICROWAVE ABLATION
Successful Ablation and Surveillance Imaging Findings

- MRI is preferred for most patients due to its superior tissue contrast, lack of ionizing radiation, and minimal contrast requirement relative to CT.
- However, either modality is preferable to performing an unenhanced US, which is limited for detection of early recurrences.
- Over time, the central area of coagulative necrosis is replaced by fibrosis and scar tissue rather than resorbed, likely accounting for the presence of a persistent mass at follow-up imaging.

In a 73 year old woman with clear cell RCC treated with RFA, diagnostic MR shows a T2 hyperintense lesion (a). Longitudinal follow-up MR imaging shows a persistent post-ablation defect with peri-ablation halo without a change in size at 3, 6, and 12 months (b-d).
RF and MICROWAVE ABLATION

Successful Ablation and Surveillance Imaging Findings

- With heat based thermal ablative techniques, the hallmark of successful renal tumor ablation is lack of tumor enhancement and without an increase in lesion size

A 70 year old man with an exophytic posterior papillary RCC lesion treated with RF ablation. Longitudinal surveillance CT imaging acquired at 3 month post RF ablation shows stranding within the perinephric fat (a). A 6 month post RF ablation CT image (b) shows no significant decrease in size, no residual enhancement, and emergence of the perinephric halo. A 12 month post RF ablation CT image (c) shows no significant decrease in size and no residual enhancement, indicating ablative success.
RF and MICROWAVE ABLATION

Signs of Recurrence

- Any nodular or linear enhancing tissue within the original lesion

A 57 year old man with a large posterior endophytic clear cell RCC treated with RF ablation (a).

At 2 year longitudinal follow-up imaging, the echogenic ablated lesion became partially hypoechoic on US (b) and the hypoechoic region appeared T2 hyperintense (c).

MR subtraction imaging (f) confirmed tumor recurrence.

At 2 year longitudinal follow-up imaging, the hypoechoic region appeared hypointense relative to the ablation zone on pre-contrast T1 (d).

The ablated lesion enhanced on T1-post contrast corticomedullary imaging (e).
IRREVERSIBLE ELECTROPORATION (IRE)
Ablative Technique and Imaging

- Role in tissue ablation is largely investigational
  - Multiple needle electrodes deliver high voltage charges
  - Malignant cell wall disruption and apoptosis

- On ultrasound, there is a subtle decrease in US echotexture during electroporation
- On CT, aside from changes related to the needle, there are no reliable CT findings during the procedure
  - Sometimes gas may be seen in the lesion due to mild associated thermal effects
- There are no MR compatible probes and thus intraprocedural MR findings have not been described
- Immediately following, there will be a relatively avascular hypodense poorly enhancing area corresponding to the electroporated region with sharp margin parallel to the long axis of the needle


A typical sonographic image obtained during monitoring of the positioning of the needle electrode for IRE. The “hockey-stick” curve shows the envelope of the kidney; the dark central mass is the tumor; and the slightly off-horizontal line passing through it is the electrode.
SUMMARY OF IMAGE FINDINGS AFTER ABLATION

CRYOABLATION:
- Immediately after treatment: ablation zone appears larger than the original tumor
- In the first few days to months after treatment: emergence of the peripheral halo in perinephric fat surrounding the smaller high density ablated lesion
- Definition of successful ablation: no residual tumor enhancement and decrease in size, decreased stranding, hematomas & perinephric fluid
- Signs of recurrence: Enlarging ablation zone and increased linear or nodular enhancement >10HU

RADIOFREQUENCY AND MICROWAVE ABLATION:
- Immediately after treatment: ablation zone appears larger than the original tumor
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IRREVERSIBLE ELECTROPORATION:
- Insufficient evidence as to length of time to renal tumor involution to occur after successful IRE ablation
LONGITUDINAL FOLLOW-UP IMAGING

• Unenhanced and multiphasic scans at three and six months following ablation to assess treatment success, followed by annual abdominal scans thereafter for five years.

• Beyond five years, there is no defined indication for imaging, but patients may undergo further scanning based on individual patient risk factors.

• Patients undergoing ablative procedures who have either biopsy proven low risk renal cell carcinoma, benign lesions such as oncocytoma, non-diagnostic biopsies or no prior biopsy, should undergo annual chest x-ray to assess for pulmonary metastases for five years.
SUMMARY

• Proper imaging techniques are critical during ablation and in the assessment and management of RCC at longitudinal post-ablation follow-up.

• Surveillance imaging should be evaluated not only for tumor recurrence in the ablation zone, but also for evidence of metastatic disease and delayed complications.
Thank you for taking the time to view our exhibit. If you have any questions or comments, please feel free to email Heidi Coy at hcoy@mednet.ucla.edu.