Percutaneous Ablation of Hepatocellular Carcinoma: A Pictorial Review

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Disclosure

- Ellen Cheang, MD: Nothing to disclose
- Jonah Hirschbein, MD: Nothing to disclose
- Bijan Bijan, MD, MBA, CIIP: Nothing to disclose
Background

- Hepatocellular carcinoma (HCC) is a common cancer with high mortality and morbidity.

- Surgical resection and orthotopic liver transplantation have curative potential but fewer than 20% of patients are suitable candidates.

- Percutaneous thermal ablation is considered the optimal treatment of choice for focal unresectable HCC of early stage, reduction of tumor burden in more advanced disease and as a bridge to transplantation.

- Imaging follow up after ablation is crucial to ensure that disease recurrence is detected early.

- MRI in particular has proven to be a powerful tool in post-ablation imaging follow up.
Learning Objectives

- Compare and contrast radiofrequency ablation (RFA) and microwave ablation (MWA) as treatment options for hepatocellular carcinoma (HCC).

- Review the appropriate post-ablation imaging follow up and expected findings with an emphasis on MRI.

- Illustrate the appearance of post-ablation disease recurrence.

- Discuss the potential pitfalls of post-ablation imaging follow up.
## Comparison of RFA and MWA

<table>
<thead>
<tr>
<th></th>
<th>RFA</th>
<th>MWA</th>
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<tbody>
<tr>
<td><strong>Principle</strong></td>
<td>Electric current in the radiofrequency range producing heat-based coagulation necrosis (^1)</td>
<td>Electromagnetic energy creates a rapid and homogeneous heating → coagulation necrosis (^2)</td>
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<tr>
<td><strong>Heat sink effect</strong></td>
<td>More heat sink effect → size of ablation less predictable (^3)</td>
<td>Less heat sink effect → more predictable ablation zone (^4)</td>
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<tr>
<td><strong>Size of tumor</strong></td>
<td>- Effective for tumors &lt;3 cm</td>
<td>- Can use alone to treat tumors 5-8 cm (^5)</td>
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<tr>
<td></td>
<td>- RFA combined with TACE is recommended for tumors &gt; 3 cm (^6)</td>
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<tr>
<td><strong>Procedural time</strong></td>
<td>Longer</td>
<td>Shorter</td>
</tr>
<tr>
<td><strong>Indications</strong></td>
<td>Patients with early HCC who are ineligible for surgical treatment due to comorbidities, and in patients who refuse resection or when there is a need to preserve liver function.</td>
<td>Same</td>
</tr>
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</table>
## Comparison of RFA and MWA

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<tr>
<td><strong>Contraindications</strong></td>
<td>Presence of metallic device, decompensated ascites, severe bleeding diathesis (platelet &lt;50,000), hemostatic compromise(^7)</td>
<td>same</td>
</tr>
<tr>
<td><strong>Relative contraindications</strong></td>
<td>Lesions near GI, biliary system and heart</td>
<td>same</td>
</tr>
<tr>
<td><strong>Rate of major complications</strong></td>
<td>2.2% (^8)</td>
<td>2.9% (^9)</td>
</tr>
<tr>
<td><strong>Complete ablation rate</strong></td>
<td>93% (^10)</td>
<td>95% (^10)</td>
</tr>
<tr>
<td><strong>Local recurrence rate</strong></td>
<td>5.2-20.9% (^11-15)</td>
<td>3.9-19% (^11-15)</td>
</tr>
<tr>
<td><strong>Survival rate</strong></td>
<td>68-100% at 1st year, 24-78% at 4th year (^11-15)</td>
<td>68-100% at 1st year, 24-78% at 4th year (^11-15)</td>
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\(^7\) Cheang, Hirschbein & Bijan

\(^8\) Society of Abdominal Radiology - 2016
At most institutions, a 3 or 4-phase contrast enhanced CT is performed immediately or within 1 month after ablation to assess the technical success of treatment.

If ablation was technically successful, multiphase CT or MR may be repeated at a 3-month intervals for evaluation of recurrence.

MRI is more sensitive to detect smaller residual and recurrence tumors with sensitivity up to 84% with MRI and 47% with CT respectively. 

16-17.
Post-treatment Imaging

Normal Findings

- Ablation zone
- Periablation zone
- Biliary changes
- Vascular changes
- Perihepatic changes

Abnormal findings

- Residual disease
- Recurrent disease
- Tumor seeding
- Biliary complications
- Vascular complications
- Infection

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Normal post-treatment changes
## Ablation zone

<table>
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<tr>
<th>General characteristics</th>
<th>CT findings</th>
<th>MR findings</th>
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<tr>
<td>- Refers to the area of coagulative necrosis induced by RFA</td>
<td>- Immediate post-op: The ablation zone appears hypoattenuating or heterogeneously hyperattenuating because of coagulative necrosis</td>
<td>- Initial follow-up: the ablation appears hyperintense on T1, hypointense on T2 due to coagulative necrosis and blood products.</td>
</tr>
<tr>
<td>- Should encompass the treated tumor with a circumferential margin of 5-10 mm around the tumor ***</td>
<td>- Initial follow-up: the ablation zone becomes homogeneously hypoattenuating over time on NECT.</td>
<td>- Marked hyperintensity on T2 suggestive liquefactive necrosis or biloma</td>
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<td>- The shape can be irregular due to heat sink effect.</td>
<td>- No enhancement</td>
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### Teaching points

- Comparison of pre- and post ablation images is crucial to determine successful ablation. **Ablation zone should have circumferential margin of 5-10 mm around the tumor.**

- Tiny air bubbles caused by tissue necrosis may be seen within ablation zone immediately after RFA. This finding should not mistaken for infection or abscess.
Case 1: Ablation zone

Figure 1: 58 yo male who underwent RFA for hepatocellular carcinoma (HCC)
A: Sonographic image of a patient being treated with radiofrequency ablation for hepatocellular carcinoma.
B: Axial CECT demonstrates a non-enhancing ablation zone indicating treatment success.
Case 1: Ablation zone

Figure 1: 58 yo male who underwent RFA for hepatocellular carcinoma (HCC)
Axial non-contrast T1 (C), early contrast enhanced arterial phase (D), delayed phase (E) and T2 images obtained 1 month after RFA reveal non-enhancing oval ablation zone. The findings suggests adequate treatment without residual disease.
### Peri-ablation changes

**General characteristics**
- Periablation hyperemia due to inflammatory reaction and granulation tissue formation induced from thermal injury.
- Peri-ablation changes should **progressively decrease** 4-9 months after ablation.

**CT findings**
- NECT: a sharply marginated, hypoattenuating rim
- CECT: an ill-defined, thin rim of enhancement on arterial phase and sometimes persists on portal venous phase.

**MR findings**
- T2: a subtle hyperintense rim suggestive of periablation edema
- Post contrast MR: an ill-defined, thin rim of enhancement on arterial phase and sometimes persists on portal venous phase.

### Teaching points
- The pattern of periablation enhancement is different from that of tumor, which is thick and nodular. However, residual/recurrent tumor may be subtle and difficult. **Careful comparison of pre- and post-ablation images is crucial** and close follow up is necessary in equivocal cases.
- Equivocal cases on CT or MR can be evaluated with PET/CT.
Case 2: Periablation changes

Figure 2: 68 yo M who underwent RFA for HCC.
A: Axial CECT image obtained 1 month after RFA demonstrates hypoattenuating ablation zone with an ill-defined circumferential enhancement representing periablation hyperemia.
B: T2 weighted image obtained 3 months after RFA reveal a rim of hyperintensity represents periablation edema.
C & D: Early arterial image demonstrate a very subtle rim enhancement which persists on delayed phase.
Case 2: Periablation changes

Figure 2: 68 yo M who underwent RFA for HCC.
E: Follow up CECT image obtained 9 months after RFA no longer reveals rim enhancement.
F, G & H: Follow up T2 weighted, early arterial and portal venous contrast enhanced MR images obtained 12 months after RFA no longer demonstrate rim of T2 hyperintensity and rim enhancement.
## Biliary changes

### General characteristics
- Biliary changes after RFA include biliary dilatation, gallbladder edema and hemobilia.
- Transient bile duct dilatation peripheral to the ablation zone is a common finding, which resolves as the ablation decreases in size.

### CT findings
- NECT/CECT: focal biliary dilatation adjacent to the ablation zone.
- No enhancement

### MR findings
- T2: hyperintense focal biliary dilatation adjacent to the ablation zone
- No enhancement

### Teaching points
- Persistent or increasing biliary dilation suggests irreversible damage to the bile ducts during RFA
Case 3: biliary dilatation

Figure 3: 60 yo female who underwent RFA of HCC in the left hepatic lobe.
A: Axial contrast enhanced CT obtained 3 months after RFA reveal mild biliary dilatation adjacent to the ablation zone.
B: T2 weighted image obtained 6 months after RFA demonstrates persistent biliary dilatation adjacent to the ablation zone.
# Hematoma

## General characteristics
- Small peripheatic hematoma caused by mechanical injury to hepatic or perihepatic vessels by electrodes.
- Mild or moderate bleeding with stability in size is reassuring in hemodynamically stable patient.

## CT findings
- NECT: hyperattenuating collection within the ablation zone.
- No enhancement

## MR findings
- Variable appearance on MRI depending on the age of hemorrhage during and after ablation

## Teaching points
- When hemorrhage is seen immediately after RFA, short term follow up within 24 hours may be indicated to ensure stability in size.
Case 4: hematoma

Figure 4: 54 yo M who underwent RFA for HCC.
A: NECT obtained immediately after RFA demonstrates hyperattenuating hemorrhage within the ablation zone.
B: Arterial phase CT immediately after RFA demonstrates hemorrhage without enhancement.
Abnormal post-treatment changes
Residual disease

General characteristics
- Caused by incomplete coverage of tumor because of large tumor size, inaccurate targeting, satellite nodules or heat sink effect.
- MR (89%) offers a higher sensitivity than CT (49%) in detecting residual disease.\(^{16-17}\)

CT findings
- CECT: residual disease appears as an eccentric, irregular, peripheral enhancing nodule with early arterial enhancement and washout on delayed phase.

MR findings
- Focal, nodular T2 hyperintense focus adjacent to the ablation zone with corresponding early arterial enhancement and washout on delayed phase is suggestive of residual disease.

Teaching points
- Careful comparison of pre- and post-ablation imaging are essential to evaluate for residual disease.
- MR is more sensitive than CT in detecting residual disease.
Case 5: Residual disease

Figure 5: 59 yo female who underwent RFA for HCC.
A & B: CECT obtained immediately after RFA demonstrates an early arterially enhancing nodule adjacent to the ablation zone suspicious for residual disease. However, this nodule does not demonstrate wash out on delayed phase.
C & D: Dynamic contrast MR images obtained 3 months RFA confirms residual disease with early arterially enhancement and washout on delayed phase.
# Recurrent disease

## General characteristics
- Development of tumor on follow up imaging after tumor was successfully ablated.
- Recurrence manifest as a new peripheral enhancing nodule.
- Recurrence can also appear as an irregular or asymmetric thickening along the margin of the ablation zone or as new/progressively enlargement of the ablation zone.

## CT findings
- CECT: recurrence appears as a **new** eccentric, irregular, peripheral enhancing nodule with early arterial enhancement and washout on delayed phase.

## MR findings
- New focal, nodular **T2 hyperintense focus** adjacent to the ablation zone with corresponding early arterial enhancement and washout on delayed phase is suggestive of recurrence.

## Teaching points
- The time period of development of recurrence can be variable and therefore regular follow up CT or MRI is essential to assess for recurrence.
- PET/CT can be an important diagnostic tool for equivocal cases.
Case 6: recurrent disease

Figure 6: 49 yo female who underwent RFA for HCC.
A: Contrast T1 image prior to RFA reveals an arterially enhancing mass in the right hepatic lobe consistent with HCC.
B: CECT obtained 3 months after RFA demonstrates successful ablation without evidence of residual disease.
C & D: Dynamic contrast MR images obtained 12 months after RFA demonstrate a new nodule adjacent to the ablation site with early arterially enhancement and washout on delayed phase, consistent with recurrence.
CT and MR pitfall

MR offers higher sensitivity than CT in detecting residual/recurrence disease because MR has better tumor tissue contrast.

The time period of development of recurrent disease can be variable and subtle. Therefore, regular follow-up CT and MR is essential for surveillance.

When CT and MR findings are equivocal, PET/CT can be an important diagnostic method for early detection of recurrent disease.
Case 7: CT and MR pitfall

Figure 7: 63 yo male who underwent RFA for HCC.
A: CECT obtained 10 months after RFA did not show recurrence.
B & C: Dynamic contrast enhanced MR obtained 9 months after RFA demonstrates a new arterially enhancing nodule superior to the ablation suspicious for recurrence. However, this nodule does not definitively reveal wash out on delayed phase.
D: PET/CT confirmed recurrence at the ablation site.
Percutaneous ablation has emerged as a powerful and versatile treatment option for HCC. Appropriate interpretation of post-ablation imaging is crucial in the optimization of patient outcomes, ensuring that recurrence is caught as early as possible.

MRI in particular has proven to be a powerful tool in post-ablation imaging follow up.

Detection of subtle recurrence can be extremely challenging. PET/CT serves as an important diagnostic tool for equivocal cases.
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