Basic concepts, techniques and safety issues of arrhythmia ablation

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How RF ablation works

- RFC is passed through the patient circuit. The tissue around the probe tip is heated by the electric current.

- The rise in tissue temperature causes a lesion and interrupts transmission of myocardial signals.

- The tip does not get hot itself.

- The temperature rise takes place directly in the tissue and is measured in the tip by a

  **Thermocouple:** exactly in the center of a full metal tip for best thermal conductivity

  or

  **Thermistor:** compatible with older generator technologies
Tissue Heating

Electrode tip heated from the tissue

Heat lost to circulating blood

Zone of resistive heating

Zone of conductive heating

Huang and Wilber: Radiofrequency Catheter Ablation of Cardiac Arrhythmias Futura Publishing 2000
The current follows two pathways: blood and tissue, each with different impedance (R).

- $R_{\text{Blood}}$ is smaller than $R_{\text{Tissue}} \Rightarrow$ most current is lost to blood
- Good wall contact $\Rightarrow$ more contact area $\Rightarrow$ more current enters the tissue
Temperature controlled ablation
Effects of low and high blood flow

Low blood flow:
target temperature reached with 15 W → small lesion

High blood flow:
target temperature reached with 30 W → large lesion
Conventional Electrodes: 4 mm vs 8 mm Tip

4 mm Tip Electrode

Blood Flow: 350 ml/min

8 mm Tip Electrode

* p<0.05 vs 4mm Tip

Experimental Experience

1) High blood flow allows higher power delivery to the tissue and this results in deeper lesions

2) Larger electrodes provide greater electrode cooling allowing higher power delivery and this results in deeper lesions

3) Small electrodes have a higher recording resolution
Different electrodes

<table>
<thead>
<tr>
<th>4mm</th>
<th>8mm</th>
<th>irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording resolution</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Risk of thrombus</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Large lesions possible</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>
Irrigated tip ablation – Lesion size

4mm Electrode
Power Output = 20 watts

Open Loop Irrigation Electrode
Power Output = 40 watts
Irrigated Tip Ablation – Lesion shape

Conventional Ablation

Irrigated Tip Ablation

Maximum Diameter
Ablations using irrigated tip (Oldenburg)

• Irrigation flow
  - mapping: 2 ml/min
  - ablation: 17 ml/min (<30W)
  - ablation: 30 ml/min (≥30W)

• Power control
  - CS/MCV: 10 W (increase in 5 W steps)
  - other parts: 30 W (max. 40 W, caveat 50W)

• Temperature limit: 43°C

• Duration of ablation: 120 sec

• Cave: volume overload due to irrigation fluid
Effect of Irrigation Flow on Ablation (50W, 60s)

<table>
<thead>
<tr>
<th></th>
<th>10ml/min</th>
<th>17ml/min</th>
<th>30ml/min</th>
<th>60ml/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode Temp.</td>
<td>59 ± 6°C*</td>
<td>47 ± 5°C*</td>
<td>39 ± 3°C*</td>
<td>34 ± 2°C*</td>
</tr>
<tr>
<td>Thrombus</td>
<td>85%*</td>
<td>33%*</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Impedance Rise</td>
<td>46%*</td>
<td>13%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

* p<0.05 between flow rates

Matsudaira, Nakagawa et al., NASPE 1999
2 mm versus 5 mm Irrigated Electrode

Irrigated Tip
2 mm

Irrigated Tip
5 mm

Nakagawa et al., Circulation 1998; 98: 458-465
Circuit for RF Ablation

<table>
<thead>
<tr>
<th></th>
<th>perpendicular 2 mm</th>
<th>perpendicular 5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{\text{Remote}}$</td>
<td>30 $\Omega$</td>
<td>30 $\Omega$</td>
</tr>
<tr>
<td>$R_{\text{Tissue}}$</td>
<td>199 $\Omega$</td>
<td>198 $\Omega$</td>
</tr>
<tr>
<td>$R_{\text{Blood}}$</td>
<td>103 $\Omega$</td>
<td>50 $\Omega$</td>
</tr>
</tbody>
</table>

Nakagawa et al., Circulation 1998; 98: 458-465
Summary

• RFC heats the tissue, which then heats the ablation electrode
• Blood flow and electrode-tissue contact have the largest impact on lesion formation during conventional RFC ablation
• During ablation the electrode temperature, power and impedance should be monitored
• Risk of thrombus formation is increased at high electrode temperatures
• High electrode temperatures predominantly occur at high power and can be avoided by using an irrigated tip electrode
3. Huang and Wilber: Radiofrequency Catheter Ablation of Cardiac Arrhythmias Futura Publishing 2000