Radiofrequency ablation using a 15G Octopus® electrode: comparison with a clustered electrode and a 17G Octopus® electrode in ex vivo bovine liver

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Purpose

<Background>

Imaging guided percutaneous thermal tumor ablation procedures are used increasingly for treating HCC and CRLM
-- RFA, cryoablation, PEIT…

RFA is a widely preferred local treatment method, but it has a limitation of high recurrence rate (1.7~14%)
-- insufficient safety margin, especially in large tumors

<Efforts for achieving sufficient safety margin>

Recommended sufficient margin
-- 3~5mm or more ablative margin is needed

1) Current method for sufficient safety margin
overlapping ablation technique with multiple placement of a single electrode
--> technically challenging due to poor sonic window by echogenic bubbles after 1st ablation

2) Multiple trials for sufficient safety margin
-- multi-tined expandable electrodes with saline infusion
-- perfusion electrodes
-- using different RF energy with multiple electrodes

<USE of Larger Electrodes>

Currently used electrode diameter: 17G (m/c)
Minimal coagulation necrosis created by a 17G in CM mode or multiple 17G in SM mode
--> insufficient to treat 3cm tumor with 5mm safety margin

Increasing electrode G with wider inter-electrode distance may create larger ablation zones than conventional methods

<Purpose>
To demonstrate the ex vivo efficacy of RFA using a 15G separable clustered electrode (Octopus ®) to create a large area of ablative zone in bovine livers in comparison with a 17G clustered electrode or a 17G separable clustered electrode (Octopus ®) in CM mode or SM mode.
Methods and Materials

RF Equipment

In this experiment, we used a multichannel RF generator (SSP-2000; STARmed Co., Ltd.), consisting of three generators with a maximum power of 200 W for each at a frequency of 480 kHz. With the multichannel RF generator, we used an internally cooled clustered electrode (Cluster™ electrode, Covidien, Burlington, MA, USA), or a 17G or 15G separable clustered electrodes with 3cm active tips (Octopus® electrode, STARmed Co., Ltd.) in either the CM or SM mode in order to create a larger coagulation. The cluster electrode is composed of three parallel 17G internally cooled electrodes, spaced 0.5 cm apart and grouped equidistantly in a triangle. The 17G separable clustered electrodes is composed of three 17G cooled-tip electrodes similar to a clustered electrode, but has the separability of each individual electrode using a special adaptor which connects the three cables to one piece. As each electrode has a 50-cm-long flexible cable, the each electrode can be placed in the liver with a variable, inter-electrode distance determined by the size of the tumor. The 15G separable clustered electrode has the same design with 17G separable clustered electrode except the gauge of each electrode.

In Vitro Experimental Setting

Eighty six RFA were performed in 50 explanted fresh bovine livers weighing an average of 7 Kg. The liver was cut into one or two, 12x12x7cm³ blocks which were immersed in 50x20x25cm³ saline-filled baths. Based on the previous study results with RFA using multiple electrodes, three electrodes of the 17G or 15G separable clustered electrode were placed in triangular arrays with equidistant IED at 5mm, 10mm, 15mm for CM-RFA, and 40mm for SM-RFA through an acrylic plate containing multiple holes at 5mm intervals.

Ablation Protocol

A total of 86 ablation zones were created in explanted bovine livers using a multichannel RF generator and one of the three kinds of electrodes: a) clustered electrodes(Cluster™ electrode, Covidien), b) 17G separable clustered electrodes (17G Octopus® electrode, STARmed Co., Ltd), or c) 15G separable clustered electrodes (15G Octopus® electrode, STARmed Co., Ltd). Ablation zones was created in the bovine livers using one of five RFA protocols: 1) group A, CM-RFA using a Cluster electrode (Cluster™, Covidien) with a 5-mm IED (n=10); 2) group B, CM-RFA using a 17G separable clustered electrode with a 5, 7 and 10-mm IEDs (n=30); 3) group C, CM-RFA using a 15G separable clustered electrode with a 5, 7 and 10mm IEDs (n=30); 4) group D, SM-RFA using 17G
separable clustered electrodes with a 40mm IED (n=8); and 5) group E, SM-RFA using 15G separable clustered electrodes with a 40mm IED (n=8) (Table 1). RF energy was applied in either CM mode (Groups A, B, and C) or SM mode (Groups D and E). In CM mode, RF energy (~ maximum 200W) was consecutively applied to all electrodes simultaneously for 18 minutes. In SM mode, the RF energy (~ maximum 200W) was applied to one of the three electrodes, depending on tissue impedance changes. RF energy was delivered at maximum wattage (200W) using an impedance-controlled algorithm to optimize energy administration to the tissue. The changes in impedance, and current during RFA as well as the diameters and volumes of the thermal ablation zones were compared among the three groups (groups A, B, and C) using CM-RFA and between the two groups (groups D and E) using SM-RFA.

Lesion Size Measurement and Shape Analysis

The liver blocks containing lesions were dissected along the perpendicular plane to the axis of the probe insertion, and then, the blocks sliced again in the transverse plane perpendicular to the electrode tracks. As the white central area of the RF-induced ablation zone has been shown to correspond to the zone of coagulation necrosis, two observers (technicians who have at least 3 years of experience in RF experiments) measured the long-axis diameter \(D_l\), the vertical diameter \(D_v\) and the short-axis diameter \(D_s\) of the central, white region of the RF-induced ablation zones at the slice showing the maximum area in consensus (Fig.2). In addition, in order to avoid any bias in measurements of ablation zones, the slices were placed on an optical platform and photographed with a ruler using a digital camera (canon EOS 600D; Canon Inc, Tokyo Japan) and the pictures were saved in a computer equipped with Image J software (http://rsb.info.nih.gov). The lesion size measurements were reconfirmed by one blinded reviewer among the authors (J.M.L.) having experience of performing more than 2000 RFA procedures, by measuring the diameters of the white central areas of the ablation zone using Image J program, without an information regarding the used RFA techniques.

The volume of the RFA zone was evaluated by approximating the lesion to a sphere using the following formula: the volume of RFA zone= \(\frac{4}{3}\pi(D_l/D_s)^3\). The shape of the RF-induced ablation zone was characterized by the ratio between the long-axis diameter and the short-axis diameter \(D_l/D_s\).

Statistical Analysis

For all of the experiments, the results were reported as mean ± standard deviation (SD) values. The dimensions and shapes of the thermal ablation area and the technical parameters of the three groups (Groups A, B, and C) using CM mode, and the other two groups (Group D and E) using SM mode were compared using the Kruskal-Wallis test or Mann-Whitney test. All statistical analyses were performed using commercially available software (IBM SPSS, version 19, SPSS Inc., IBM Company, Armonk, NY, USA; Medcalc,
Medcalc Software, Mariakerke, Belgium). A $P$ value less than 0.05 was considered to indicate a significant difference.
**Images for this section:**

![Image](image-url)

**Fig. 1:** Three electrodes are clustered with 5mm of inter-electrode distance (Upper) Three electrodes can be separated with wanted inter-electrode distance (Below)

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Results

15G separable clustered electrodes (Octopus) delivered higher RF energy than 17G separable clustered electrodes and Cluster electrodes in CM and SM-RFA ($P<0.001$). 15G separable clustered electrodes showed larger ablation volume (82.67 ± 29.0 cm$^3$) than 17G separable clustered electrodes (67.75 ± 27.3 cm$^3$) or Cluster electrode (51.92 ± 16.4 cm$^3$) at the same IED ($P<0.01$) in CM-RFA. The mean ablation volume (87.38 ± 9.54 cm$^3$) of 15G separable clustered electrodes was significantly larger than that (75.16 ± 14.5 cm$^3$) of 17G separable clustered electrodes ($P=0.03$) in SM-RFA.
**Fig. 1:** Three electrodes are clustered with 5mm of inter-electrode distance (Upper) Three electrodes can be separated with wanted inter-electrode distance (Below)

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Fig. 2: Five RFA protocols in 86 ablation zones *= Three electrodes of a separable clustered electrode were inserted at a distance of 5mm (n=10), 7mm (n=10) and 10mm (n=10). CM= consecutive monopolar, SM= switching monopolar

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<table>
<thead>
<tr>
<th></th>
<th>Mode</th>
<th>Electrode</th>
<th>Inter-electrode distance</th>
<th>Total ablation time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A (n=10)</strong></td>
<td>CM</td>
<td>17 G Cluster</td>
<td>5mm</td>
<td>18 minutes</td>
</tr>
<tr>
<td><strong>Group B (n=30)</strong></td>
<td>CM</td>
<td>17G separable clustered</td>
<td>5, 7, 10mm*</td>
<td>18 minutes</td>
</tr>
<tr>
<td><strong>Group C (n=30)</strong></td>
<td>CM</td>
<td>15G separable clustered</td>
<td>5, 7, 10mm*</td>
<td>18 minutes</td>
</tr>
<tr>
<td><strong>Group D (n=8)</strong></td>
<td>SM</td>
<td>17G separable clustered</td>
<td>40mm</td>
<td>18 minutes</td>
</tr>
<tr>
<td><strong>Group E (n=8)</strong></td>
<td>SM</td>
<td>15G separable clustered</td>
<td>40mm</td>
<td>18 minutes</td>
</tr>
</tbody>
</table>

Fig. 3: Comparison of Delivered RF energy & Ablated Volume among Groups A-C 15G Octopus delivered the highest RF energy among three electrode groups. 15G Octopus created significantly larger ablation zone The shape of created ablation zones were round in groups A-C (Ds/Dl) **CM= consecutive monopolar; SM= switching monopolar; Dl=Long diameter; Ds= Short diameter; Volume =ablated volume obtained by a following equation: #/6 × Dl × Ds × Dv; *=statistical difference between group B and group C.

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### Table: Comparison of Delivered RF Energy & Ablated Volume among Groups D-E In SM mode

<table>
<thead>
<tr>
<th></th>
<th>Group D (SM 17G Octopus)</th>
<th>Group E (SM 15G Octopus)</th>
<th>P value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF energy (kJ)</td>
<td>98.86 ± 12.8</td>
<td>116.82 ± 8.3</td>
<td>0.01</td>
</tr>
<tr>
<td>Dl (cm)</td>
<td>5.87 ± 0.26</td>
<td>6.22 ± 0.31</td>
<td>0.02</td>
</tr>
<tr>
<td>Ds (cm)</td>
<td>5.62 ± 0.32</td>
<td>5.88 ± 0.21</td>
<td>0.05&lt;</td>
</tr>
<tr>
<td>Dy (cm)</td>
<td>4.33 ± 0.44</td>
<td>4.55 ± 0.28</td>
<td>0.05&lt;</td>
</tr>
<tr>
<td>Ds /Dl</td>
<td>0.96 ± 0.03</td>
<td>0.95 ± 0.03</td>
<td>0.05&lt;</td>
</tr>
<tr>
<td>Volume (cm³)</td>
<td>75.16 ± 14.5</td>
<td>87.38 ± 9.54</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**Fig. 4:** Comparison of Delivered RF energy & Ablated Volume among Groups D-E In SM mode, 15G Octopus delivered significantly higher RF energy and created larger ablation zone than 17G Octopus. **SM: switching monopolar

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### Table: Differences of Ablation Volume Regarding Electrode Gauge and Inter-electrode Distance

<table>
<thead>
<tr>
<th></th>
<th>Group B (n=30) (CM, 17G) (cm³)</th>
<th>Group C (n=30) (CM, 15G) (cm³)</th>
<th>P value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>5mm distance</td>
<td>45.86±11.58</td>
<td>55.68±7.59</td>
<td>0.02</td>
</tr>
<tr>
<td>(n=10, each)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7mm distance</td>
<td>76.86±30.46</td>
<td>85.40±21.57</td>
<td>0.55</td>
</tr>
<tr>
<td>(n=10, each)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10mm distance</td>
<td>80.56±23.18</td>
<td>106.93±26.78</td>
<td>0.02</td>
</tr>
<tr>
<td>(n=10, each)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P value*</td>
<td>0.004</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 5:** Differences of ablation volume depending on the electrode gauge and inter-electrode distances in group B and group C. As IED increased, ablation volume also significantly increased in groups B and C. 15G Octopus showed larger ablation zones than 17G Octopus at the same IED. **CM=consecutive monopolar; *=statistical difference depends on the distance of electrodes within a group; **=statistical difference between group B and group C at the same inter-electrodes distance.
Conclusion

RFA using 15G separable clustered electrodes at greater IED than 10 mm were more effective than Cluster electrodes or 17G separable clustered electrodes for creating large ablation zones in ex vivo bovine livers.


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