Can Segmental Pulmonary Vein Ablation Reduce the Recurrence of Atrial Fibrillation When Using a Higher RF Power, Larger Tip Electrode Catheter, and Additional RF Deliveries?

The limitations of point-by-point RF ablation

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SUMMARY

The aim of this study was to investigate whether segmental ostial catheter ablation (SOCA) designed to prevent the electrical connections (ECs) between the left atrium and pulmonary veins (PVs) might help increase the efficacy of SOCA in paroxysmal atrial fibrillation (PAF).

PV mapping and successful SOCA were performed with a basket catheter in 108 consecutive patients with PAF. Radiofrequency energy was delivered using a maximum output of 30 W with a 4 mm tip catheter (group I; 47) or 40 W with an 8 mm tip catheter (group II; 61). Only in the group II patients were additional radiofrequency deliveries to the specific sites where the ECs tended to recover performed after successful SOCA. After the first procedure, PAF recurred in 47% of the group I patients and 32% of the group II patients. In all 27 patients who underwent repeat procedures, EC recoveries were observed more frequently in group I than in group II (69% versus 49%; \( P < 0.05 \)). After multiple procedures, there was more freedom from PAF in group II (84%) than in group I (66%) \( (P < 0.05) \).

SOCA with a higher RF power, larger tip catheter, and additional RF deliveries could achieve a more effective SOCA. (Int Heart J 2006; 47: 219-228)

Key words: Atrial fibrillation, Pulmonary veins, Radiofrequency catheter ablation

THE pulmonary veins (PVs) have been demonstrated to be the major source of atrial premature beats triggering paroxysmal atrial fibrillation (PAF).1,2)

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Ablation techniques for PAF have been used most commonly in clinical practice. One is segmental ostial catheter ablation (SOCA) to electrically isolate the PVs from the left atrium and the other is left atrial catheter ablation (LACA) to encircle the PVs. Oral, et al designed a randomized, prospective study to directly compare the 2 approaches and demonstrated that LACA eliminates PAF more reliably than SOCA. However, even after their report, whether or not complete electrical disconnection of PVs is necessary for procedural success has been a matter of controversy.

We agree that complete electrical disconnection of the PVs is necessary to eliminate PAF. In SOCA, frequent recovery of the electrical connections (ECs) between the left atrium and PVs has become the main cause of AF recurrence. We thought that SOCA might be as effective in eliminating PAF as LACA if the EC recoveries could be prevented. Our study on EC recoveries after SOCA suggested that the EC tended to recover at specific sites and a lower RF power might create inadequate RF burns. Therefore, we hypothesized that a higher RF power, larger tip electrode catheter, and further RF lesions at those specific sites might help increase the efficacy of SOCA in PAF. The aim of this study was to verify our hypothesis and determine the limitations of SOCA.

**METHODS**

**Patient characteristics:** The study population consisted of 108 consecutive patients (91 men, 57 ± 12 years) with symptomatic paroxysmal AF refractory to 4 ± 1 class I or class III antiarrhythmic drugs. The mean AF history was 4 ± 4 years (1 to 13). The mean left atrial dimension was 35 ± 5 mm (25 to 42) and mean left ventricular ejection fraction 66 ± 9% (56 to 89). No patient had any structural heart disease and 7 had emboli. Each patient gave informed consent, and all antiarrhythmic drugs were discontinued for at least 5 half-lives prior to the study.

**Electrophysiological study:** A 7-French decapolar catheter with 1-5-1-mm interelectrode spacing between each electrode pair (St. Jude Medical, Daig Division, Minnetonka, MN, USA) was introduced into the coronary sinus via the subclavian vein. The transseptal procedure was performed with intracardiac echocardiography guidance recorded with a 9-French transducer catheter (Boston Scientific, Natick MA, USA) operating at 9 MHz. Catheterization into the left atrium was performed with a one puncture and two-sheath technique (one sheath (8-French, St. Jude Medical, Daig Division) for ablation catheter and another (8.5-French, Soft Tip EP Sheath™, EP Technologies) for mapping catheter). Intravenous heparin was administered to maintain an activated clotting time > 250 seconds after the atrial transseptal procedure.
PV mapping and SOCA: In all cases, PV mapping and SOCA with a 31-mm multielectrode basket catheter (MBC) (Constellation<sup>TM</sup>, EP Technologies) were performed using the same technique as previously reported. The left superior PV (LSPV), left inferior PV (LIPV), right superior PV (RSPV), and right inferior PV (RIPV) were all targeted for this PV isolation technique according to the evidence reported in previous studies. However, when the RIPV was difficult to cannulate with a multielectrode basket catheter (MBC), it was isolated with a ring catheter as previously reported.

QMS2<sup>TM</sup> is a computerized three-dimensional mapping system, which can construct a three-dimensional color map from a total of 56 bipolar electrograms recorded by an MBC. QMS recordings were obtained during sinus rhythm (right PVs) or distal coronary sinus pacing (left PVs). An animation of a three-dimensional potential map, which could reflect a series of electrical activations, was used to reveal the style of the EC, distribution of the PV musculature, and activation pattern within the PV. The short stay of the activation wavefront near the outer frame of the three-dimensional PV potential map before the longitudinal propagation, which reflected a conduction delay, was defined as indicating the left atrial-PV junction where continuous fractionated potentials connecting the left atrial potentials and PV potentials were observed. The serial activation patterns moving around the outer frame of the three-dimensional PV potential map before the longitudinal propagation were defined as indicating the left atrial-PV junction. The onset of a centrifugal activation at the left atrial-PV junction was identified as a prior EC.

Study design: This was a retrospective study. The first 47 patients were assigned to group I and the second 61 patients to group II. The clinical characteristics of the patients in the 2 groups did not differ significantly (Table I).

SOCA procedures in the 2 groups: In the SOCA procedure, an RF application was delivered to the preferential EC identified by the three-dimensional PV

### Table I. Clinical Characteristics of the 2 Groups

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<th>Group I</th>
<th>Group II</th>
<th>P value</th>
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<tbody>
<tr>
<td>Age, years</td>
<td>56 ± 14</td>
<td>59 ± 10</td>
<td>NS</td>
</tr>
<tr>
<td>Sex, M/F</td>
<td>40/7</td>
<td>51/10</td>
<td>NS</td>
</tr>
<tr>
<td>Duration of PAF, y</td>
<td>5 ± 4</td>
<td>5 ± 5</td>
<td>NS</td>
</tr>
<tr>
<td>Ineffective AADs, n</td>
<td>3 ± 1</td>
<td>3 ± 1</td>
<td>NS</td>
</tr>
<tr>
<td>Previous embolic episode, n</td>
<td>3</td>
<td>4</td>
<td>NS</td>
</tr>
<tr>
<td>LAD, mm</td>
<td>35 ± 4</td>
<td>35 ± 6</td>
<td>NS</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>67 ± 10</td>
<td>65 ± 9</td>
<td>NS</td>
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y indicates years; M/F, male/female; PAF, paroxysmal atrial fibrillation; AAD, antiarrhythmic drug; LAD, left atrial diameter; and LVEF, left ventricular ejection fraction.
potential map with the guidance of a navigation system (Astronomer™) associated with the MBC. RF energy was delivered with a target temperature of 55°C and maximum power output of 30 W (group I) or 40 W (group II) for 60 seconds (EPT-1000TC generator, EP Technologies), using a 4-mm (group I) or 8-mm (group II) tip catheter (Blazer II 5031T or 5770T, EP Technologies).

The QMS recording was performed after every radiofrequency application, and if the elimination of a target EC was confirmed, another EC was identified and ablated. Successful SOCA was defined as either the abolition or dissociation of the distal PV potentials (Figure 1).

Additional RF deliveries to the edge of the original ECs and between the RF

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**Figure 1.** Change in the pulmonary vein (PV) potentials recorded from a multielectrode basket catheter (MBC) after segmental ostial catheter ablation (SOCA) (left panels) and a schema showing the electrical connections (ECs) between the PV and left atrium and the distribution of the PV musculature (right panel).

**Left panels:**
(1): Before the ablation during distal coronary sinus pacing.
(2): After elimination of the segmental breakthrough at the inferior wall (spline B) by the RF application near electrode pair B7-8.
(3): After elimination of the segmental breakthrough at the posterior wall (spline H) by the RF application near electrode pair H7-8.
(4): After elimination of a part of the segmental breakthrough at the superior wall (spline F) by the RF application near electrode pair F7-8.
(5): After completion of the PV isolation by the final RF application near electrode pair E7-8 at the superior wall. The distal to proximal electrodes of the MBC were numbered from 1 to 8. The arrowheads indicate the earliest PV potentials suggesting the preferential ECs.

**Right panel:**
The round outer frame corresponds to the PV ostium and the center of the image to the distal PV (bull’s eye image). The alphabetical letters from A to H in the figure indicate the splines of the multielectrode basket catheter. The gray area indicates the distribution of the PV musculature which was identified by the 3-D potential map, dotted areas the RF lesions corresponding to the change in the PV potentials in the left panels, and stars the additional RF delivery sites attempted to prevent an EC recovery.
lesions on the continuous broad ECs identified by the PV potential maps constructed by QMS2™ were performed only in group II patients after successful SOCA (Figure 1).

**Follow-up and re-ablation:** During the follow-up period, no antiarrhythmic drugs were administered in any of the patients. Clinical follow-up was performed at 2 weeks, 1 month, and every month thereafter, using 24-hour Holter and cardiac recordings, and enhanced electron beam tomography for the detection of PV stenosis in all patients.

In the patients who underwent a second session because of AF recurrence after the first SOCA procedure, the same PV mapping and SOCA as in the first session were performed. We attempted to deploy all splines of the MBC to the same sites within the target PVs as in the first session using biplane fluoroscopic guidance and contrast medium.

**Identification of the EC between the left atrium and PVs, distribution of the PV musculature, and EC recovery:** The style of the EC and PV musculature was finally determined after the effect of the RF applications was evaluated by QMS mapping. In the PVs with EC recoveries after SOCA, both of the three-dimensional PV potential maps obtained in 2 separate sessions were compared as previously reported to identify the location of the EC. 11) **Statistical analysis:** Continuous variables are expressed as the group mean ± 1 SD. Comparisons of continuous variables were analyzed using Student’s t-test. The chi-square test was used to compare nonparametric data in different groups. Kaplan-Meier analysis with the log-rank test was used to determine the probability of freedom from recurrent PAF. Statistical significance was considered to be P < 0.05.

**RESULTS**

**QMS mapping and SOCA:** The results of the QMS mapping and SOCA are shown in Table II. QMS mapping with an MBC was performed in 47 LSPVs, 47 RSPVs, 44 LIPVs, and 36 RIPVs in group I and in 61 LSPVs, 61 RSPVs, 55 LIPVs, and 43 RIPVs in group II. Three left PVs in group I and 6 in group II with a common trunk in which an MBC could be positioned appropriately, were included in the group of LSPVs. The deployment of the MBC was impossible in 11 RIPVs in group I and 18 in group II because of their small ostia or complex branching patterns.

In all the PVs that the QMS mapping was available in, successful SOCA could be achieved. There were no significant differences in the extent of the ECs between the 2 groups (superior PVs: 74 ± 20% versus 72 ± 17% and inferior PVs: 49 ± 25% versus 47 ± 21%, respectively). In all the RIPVs in which an MBC was
not available, successful SOCA with a ring catheter could be achieved.

The averages of the total procedure and fluoroscopy times were significantly reduced in group II compared to group I (223 ± 86 minutes versus 152 ± 52 minutes; \( P = 0.001 \) and 104 ± 38 minutes versus 71 ± 26 minutes; \( P < 0.001 \), respectively). Though the RF energy needed to complete the SOCA in the superior PVs was significantly greater in group II than in group I (12020 ± 11860 J

Table II. Results of the QMS Mapping and SOCA

<table>
<thead>
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<th>Group I</th>
<th>Group II</th>
<th>( P ) value</th>
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<tr>
<td>Procedure time, min</td>
<td>223 ± 86</td>
<td>152 ± 52</td>
<td>0.001</td>
</tr>
<tr>
<td>Fluoroscopy time, min</td>
<td>104 ± 38</td>
<td>71 ± 26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>RF energy, J</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior PV</td>
<td>12020 ± 11860</td>
<td>16400 ± 10210</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Inferior PV</td>
<td>9200 ± 6570</td>
<td>10920 ± 6300</td>
<td>0.09</td>
</tr>
<tr>
<td>Extent of EC, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior PV</td>
<td>74 ± 20</td>
<td>72 ± 17</td>
<td>NS</td>
</tr>
<tr>
<td>Inferior PV</td>
<td>49 ± 25</td>
<td>47 ± 21</td>
<td>NS</td>
</tr>
<tr>
<td>CVA</td>
<td>none</td>
<td>none</td>
<td>NS</td>
</tr>
<tr>
<td>Tamponade</td>
<td>none</td>
<td>none</td>
<td>NS</td>
</tr>
<tr>
<td>PV stenosis, %</td>
<td>none</td>
<td>none</td>
<td>NS</td>
</tr>
</tbody>
</table>

RF indicates radiofrequency; and CVA, cerebrovascular accident. The other abbreviations are as in Figure 1.

Figure 2. PV results after SOCA in the 2 groups.
LSPV indicates left superior PV; RSPV, right superior PV; LIPV, left inferior PV; RIPV, right inferior PV; E, EC recovery at the edge of the original ECs; and M, EC recovery at the mid-portion of continuous broad original ECs. The other abbreviations are the same as in Figure 1.
versus 16400 ± 10210 J; \( P < 0.05 \)), there were no significant differences in RF energy in the inferior PVs between the 2 groups (9200 ± 6570 J versus 10920 ± 6300 J; \( P = 0.09 \)).

**Follow-up and repeat procedures:** At 6 months of follow-up after the first ablation procedure, PAF recurred in 22 of the 47 group I patients (47%) and in 20 of the 61 group II patients (32%).

Fifteen group I patients and 12 group II patients with recurrent PAF provided informed consent and underwent a repeat electrophysiologic study and catheter ablation.

**QMS mapping and SOCA in the repeat procedures:** Repeat procedures were performed at a mean of 155 ± 98 days after the first session. The results of the repeat procedures are shown in Figure 2. In the repeat procedure, QMS mapping with an MBC was performed in all 52 PVs (15 LSPVs, 15 RSPVs, 12 LIPVs, and 10 RIPVs) in group I and 42 PVs (12 LSPVs, 12 RSPVs, 10 LIPVs, and 8 RIPVs) in group II, in which successful SOCA under the guidance of QMS mapping was achieved in the first session. In all 27 patients who underwent repeat procedures, an EC recovery was observed in at least one PV. EC recoveries were observed more frequently in group I than in group II (36 (69%) of 52 PVs versus 20 (49%) of 41 PVs; \( P < 0.05 \)). There were no significant differences in the occurrence of EC recoveries among the PVs in each group (10 (67%) LSPVs, 12 (80%) RSPVs, 8 (67%) LIPVs, and 6 (60%) RIPVs) in group I and 7 (58%) LSPVs, 5 (42%) RSPVs, 4 (40%) LIPVs, and 4 (40%) RIPVs) in group II. The occurrence of an EC recovery per PV was significantly reduced in group II as compared to group I (1.7 versus 1.2; \( P < 0.005 \)).

A comparison of the original three-dimensional PV potential map obtained from the first session with the re-map of the repeat session revealed that the occurrence of an EC recovery at the edges of the original ECs was significantly reduced in group II as compared to group I (65% versus 39%; \( P < 0.05 \)).

**Re-ablation and follow-up:** In all 56 PVs with EC recoveries in both groups, the SOCA method was repeated again using the same technique as in the first session. All of these EC recoveries could be eliminated by a local radiofrequency application without any catheter instability, and resulted in successful SOCA of all PVs.

The 8 group I patients and 10 group II patients who underwent the re-ablation were free of symptomatic PAF without any antiarrhythmic drugs during the follow-up period (235 ± 49 days) after the repeat session. After multiple procedures in 108 patients, there was freedom from symptomatic PAF in 66% of the group I patients and 84% of the group II patients (\( P < 0.05 \)).

**Complications:** Follow-up enhanced electron beam tomography revealed PV narrowing of ≤40% in 9 (5%) PVs in 7 group I patients and 36 (15%) PVs in 30
group II patients ($P < 0.001$). The incidence of narrowing of the superior PVs showed no significant difference between the 2 groups, while that of the inferior PVs was significantly higher in group II (22%) than in group I (7%) ($P < 0.005$). No PV stenosis of $\geq 50\%$ was found in either group. The patients with PV narrowing were asymptomatic. No critical complications occurred in any cases.

**DISCUSSION**

In the SOCA procedure, the fairly high occurrence of EC recoveries between the left atrium and PVs has been recognized as the main cause of AF recurrence.\textsuperscript{3,7-10} It has been reported that the completion of a PV electrical disconnection by repeated SOCA can eliminate PAF in spite of a high occurrence of EC recoveries after the SOCA.\textsuperscript{7-9} Therefore, if a technique to prevent the EC recovery can be designed, the efficacy of the SOCA in PAF can be expected to increase. The findings of the present study have demonstrated the efficacy of SOCA using a technique designed to prevent EC recoveries as well as its limitations.

In the present study, a higher power for the RF ablation with an 8 mm tip catheter could significantly reduce the procedure and fluoroscopic times to complete the SOCA as compared with a lower power for the RF ablation with a 4 mm tip catheter. This is probably because the higher power using the 8 mm tip catheter could reduce the number of RF applications not only by making larger RF lesions,\textsuperscript{12} but also by preventing an EC recovery during the procedure. In SOCA, higher power using an 8 mm tip catheter has a procedural advantage over lower power using a 4 mm tip catheter.

The present study demonstrated that a higher RF power, larger tip electrode catheter, and further RF lesions at the specific sites where the EC tended to recover could reduce the EC recoveries and PAF recurrence after SOCA. The proportion of freedom from PAF after multiple procedures using the SOCA technique was as high as that after LACA.\textsuperscript{5,6} However, only one SOCA procedure did not eliminate the PAF more reliably than did LACA.\textsuperscript{5,6} These findings suggested that point by point RF ablation targeting preferential ECs in only one initial procedure could not eliminate the EC recoveries and PAF recurrence completely. Therefore, the strategy of the PV ablation may need to be shifted from the SOCA technique to circumferential ablation targeting the PV antrum. However, we believe that SOCA may be appropriate in young AF patients without any structural heart disease in whom extensive PV ablation should be avoided because extensive PV ablation can cause critical complications\textsuperscript{13} and left atrial flutter.\textsuperscript{6} Therefore, the SOCA procedure designed to prevent EC recovery in this study may be the most effective strategy in that particular patient group.
The present study demonstrated that EC recovery, especially at the edge of original ECs, could be reduced by adding the further RF lesions in this study. This finding suggested that additional radiofrequency deliveries to the edge of the original ECs might be effective in reducing the EC recovery. On the other hand, the EC recovery at the mid-portion of continuous broad original ECs could not be reduced. Consequently, one limitation of SOCA may be that SOCA will not always allow the completion of continuous RF lesions, which is unlike linear ablation.

A more aggressive SOCA procedure might increase the risk of PV stenosis. In the present study, the incidence of narrowing of the inferior PVs which had a thinner myocardial wall than the superior PVs was increased by the SOCA designed to prevent EC recovery in this study. Though no occurrence of PV stenosis may guarantee the safety of this SOCA, a more aggressive SOCA than this, such as with much higher RF power, should be avoided, especially in the inferior PVs.

Previous study: Marrouche, et al have already reported the efficacy of an 8 mm tip catheter in SOCA compared to a 4 mm tip catheter. However, in their technique, the RF delivery was adjusted not under the power control but according to monitoring microbubbles. We believe that the present study is significant because the efficacy of an 8 mm tip catheter was compared with that of a 4 mm tip catheter when different RF power settings were combined using a standard RF system.

Study limitation: The learning curve of the ablator might have affected the results of this study. However, we think that the technique of this SOCA could lessen the effect of the learning curve because the QMS mapping enabled one to recognize the EC easily by visualization and the navigation system could achieve an accurate and mechanical ablation.

Conclusions: A higher power RF ablation with an 8 mm tip catheter utilizing QMS2™ guidance with an MBC could achieve a more effective SOCA than a lower power RF ablation with a 4 mm tip catheter without any reduction in the safety, probably because the higher RF power ablation with an 8 mm tip catheter could make a continuous and transmural RF lesion more easily. However, one limitation of SOCA may be that SOCA cannot always eliminate the EC recoveries completely in the first initial ablation procedure even with a higher RF power, larger tip catheter, and additional RF deliveries.

Acknowledgements

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