Sequential Evaluation of Left Ventricular Systolic and Diastolic Function After Radiofrequency Catheter Ablation

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SUMMARY

Radiofrequency (RF) catheter ablation has become standard therapy for many types of arrhythmias. RF energy may cause deterioration in left ventricular function by damaging the myocardium. The aim of the present study was to assess the changes in left ventricular function after catheter ablation using various echocardiographic parameters.

Forty patients (22 women), aged 37 ± 14 years (range, 15-76 years), underwent catheter ablation for various tachycardias. Routine echocardiographic examination was done in all patients. Left ventricular systolic function was evaluated by the modified Simpson method and tissue Doppler. With regard to left ventricular diastolic function parameters, diastolic early (E) and late (A) transmitral filling velocities, deceleration time (DT), isovolumetric relaxation time (IVRT), and tissue Doppler parameters were assessed. All ventricular function parameters were assessed before, and 1 hour, 1 day, and 1 month after the catheter ablation procedure. To avoid any influence of heart rate on diastolic function parameters, the E/A ratio, DT, and IVRT were adjusted to heart rate (cE/A, cDT, cIVRT).

No changes in left ventricular systolic function after the ablation were observed. After the ablation procedure (1 hour, 1 day, and 1 month) the cE/A ratio decreased from 1.42 ± 0.43 to 1.19 ± 0.40, 1.18 ± 0.40, and 1.30 ± 0.33 (P = 0.009), respectively. cDT increased from 210 ± 54 to 272 ± 64, 255 ± 60, 240 ± 64 (P = 0.001), respectively. Likewise cIVRT increased from 113 ± 22 to 133 ± 54, 123 ± 27, 117 ± 19 (P = 0.007), respectively. Significant changes were also observed concerning tissue Doppler parameters in assessing diastolic function.

Although no significant changes were observed in systolic function after RF ablation, this procedure may have some detrimental effects on ventricular diastolic function parameters. (Jpn Heart J 2004; 45: 429-440)

Key words: Radiofrequency ablation, Systolic function, Diastolic function
**Methods**

**Patients:** Forty patients (22 women), aged 37 ± 14 years (range 15-76 years), who underwent catheter ablation for various tachycardias were enrolled in this study. The patients had undergone RF catheter ablation for either drug refractoriness or intolerable clinical manifestations. Eight patients with atrioventricular reentry tachycardia (AVRT) and 18 patients with Wolff-Parkinson-White syndrome (WPW) underwent ablation of the accessory pathway. All AVRT patients had a left-sided atrial ablation on the mitral valve annulus. Eight patients with atrioventricular nodal reentry tachycardia (AVNRT) were treated by ablation of the slow pathway. Ablation of the isthmus was performed in three patients with paroxysmal atrial flatter. Three patients with right ventricular outflow tract tachy-
cardia underwent ablation below the pulmonary valve. Other than these 3 patients, all right-sided ablations were performed at the atrial side of the tricuspid valve annulus, while left-sided ablations were carried out at the atrial side of the mitral valve annulus. The exclusion criteria were: (1) More than trace associated valvular regurgitation, (2) associated aortic stenosis or mitral stenosis, (3) an ejection fraction less than 55%, and (4) poor echocardiographic visualization. All patients had normal sinus rhythm during the study.

**Study protocol:** Informed consent was obtained from each patient. The recommendations given in the Declaration of Helsinki for guiding physicians in biomedical research involving human subjects were followed.

**Electrophysiological study and ablation procedure:** All patients were in a postsorptive, nonsedated state. All medications were discontinued at least 2 days before the electrophysiological study and were not resumed until the last echocardiographic examination was completed. Each patient underwent baseline electrophysiologic study and catheter ablation in the same session. The details of the electrophysiologic study and the ablation technique were as previously described.\(^\text{11}\) A deflectable catheter with a 4 mm tip and 2.5 mm interelectrode spacing (Medtronic RF ablator) was used for mapping and ablation purposes. The RF current was supplied by a 484 kHz generator (Medtronic Atakr II, Medtronic Inc.) at constant preset electrical power usually ranging from 30-100 W. Current impedance or catheter-tip temperature were monitored throughout current discharges lasting 30 seconds. Heparin (100 U/Kg as a bolus) was administered for left heart approaches only. Before the procedure and 8 hours afterwards, the MB fraction of creatine kinase (CKMB) was measured in all patients. In addition, troponin-T concentrations were also measured before and 24 hours after the ablation procedure in 11 patients.

**Echocardiographic examination:** Transthoracic echocardiography was performed by one of the authors, who did not have any information on the patients' clinical data, using a Hewlett-Packard Sonos 1500 echocardiograph (Hewlett-Packard, Andover, Mass.) with a 2.5 MHz phased array transducer.

Recordings were taken with the patients in the left lateral decubitus position. The M-mode traces were recorded at a speed of 50 mm/sec and the Doppler signals were recorded at a speed of 100 mm/sec. The average of 3 consecutive cycles was calculated for every parameter. Measurements of left ventricular and left atrial systolic diameter were made on M-mode traces recorded from the parasternal long axis view according to established standards.\(^\text{12}\) Left ventricular ejection fraction was calculated by the modified Simpson method.\(^\text{13}\)

The peak E velocity (peak early transmitral filling velocity during early diastole), peak A velocity (peak transmitral atrial filling velocity during late diastole), deceleration time [$\text{DT}(\text{time elapsed between peak E velocity and the point}$$]
where the extrapolation deceleration slope of the E velocity crosses the zero baseline], and isovolumetric relaxation time [IVRT (time period between the end of mitral diastolic flow Doppler tracing and the beginning of aortic flow Doppler tracing)] were used as left ventricular diastolic function parameters. The transmirtal diastolic flow Doppler tracing was imaged in the apical 4 chamber view, using pulsed Doppler echocardiography with the sample volume sited at the tip of the mitral leaflets. The IVRT was measured on a Doppler tracing obtained from the apical five-chamber view with the sample volume placed at the left ventricular outflow tract. Each of the Doppler derived time intervals (E, A, E/A, DT, IVRT) was corrected for heart rate (cE, cA, cE/A, cDT, cIVRT) according to Bazett's formula (ie, by the square root of the R-R interval).

The echocardiograph was arranged so that the filter settings and gains were adjusted at the minimal optimal level while the compress and reject settings were arranged at the maximal optimal level in order to obtain tissue Doppler parameters. The sample volume of the pulsed wave Doppler was placed on the lateral side of the mitral annulus in order to obtain early (Em) and late (Am) diastolic and systolic mitral annulus tissue Doppler velocities (Sm). Tissue Doppler velocities were also obtained from the septum of the left ventricular side (Es, As, Ss) and from the lateral side of the tricuspid annulus (Et, At, St).

In assessing left ventricular systolic function, the left ventricular ejection fraction and Sm were taken into account. As far as diastolic function is concerned, cE velocity, cA velocity, cE/A ratio, cDT, cIVRT, Em/Am, E/Em, and Et/At were assessed. Statistical analysis: Data are expressed as the mean ± SD. The changes in ventricular function parameters were assessed by repeated measurement analysis. The paired Student's t test was used for comparisons of CKMB levels and troponin-T concentrations before and after the ablation procedure. All statistical analyses were performed using a computer software package with SSPS modality. A P value less than 0.05 was considered statistically significant.

RESULTS

Isolated right-sided ablation was performed in 30 patients and isolated left-sided ablation in 10 patients. The mean procedure time was 3.2 ± 1.5 hours. The mean pulse numbers of RF ablation were 13.25 ± 13.28. The RF current was given at a mean power of 48.13 ± 8.24 W delivered at a mean duration of 323 ± 295 seconds. The CKMB levels before and 8 hours after the ablation procedure were 10.05 ± 3.55 ng/mL versus 19.87 ± 4.85 ng/mL (P < 0.001). Twenty-four hours after the ablation procedure, troponin-T concentrations were found to be
significantly increased (troponin-T increased from 0.023 ± 0.015 to 0.124 ± 0.102, \( P = 0.003 \)).

Heart rate was higher within 1 hour after the ablation procedure than that before the ablation procedure, and 1 day and 1 month after the ablation procedure (87 ± 11 versus 76 ± 9, 77 ± 6 and 78 ± 5 \( P < 0.01 \), respectively). The echocardiograms revealed mild tricuspid regurgitation in 5 patients, mild mitral regurgitation in 3 patients, and mild aortic regurgitation in 1 patient. On the postablation echocardiogram 1 patient developed new mild mitral regurgitation and 1 patient developed new mild aortic regurgitation. There were no significant changes in the left ventricular diastolic and systolic diameters, ejection fraction, or left atrial diameter before and after the ablation procedure (Table I).

The cE/A ratio decreased to its lowest degree 1 hour and 1 day after the ablation and began to improve after 1 month (the cE/A ratios before and 1 hour, 1 day, and 1 month after the ablation were 1.42 ± 0.43, 1.19 ± 0.40, 1.18 ± 0.40, and 1.30 ± 0.33, respectively, \( P = 0.009 \)) (Figure 1). The cDT increased in the early period after the ablation (1 hour and 1 day) and decreased 1 month after the ablation (the cDT measurements before, and 1 hour, 1 day and 1 month after the ablation procedure were 210 ± 54, 272 ± 64, 255 ± 60, and 240 ± 64, respectively, \( P < 0.001 \)) (Figure 2). Left ventricular cIVRT increased in the early period after the ablation and improved in the late period (the cIVRT measurements before and 1 hour, 1 day, and 1 month after the ablation procedure are 113 ± 22, 133 ± 54, 123 ± 27, and 117 ± 19, respectively, \( P = 0.007 \)) (Figure 3). No statistically significant change was observed in the E/Em ratio.

### Table I. Data Obtained Before and 1 Hour, 24 Hours and 1 Month After Ablation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Basal</th>
<th>Postablation 1</th>
<th>Postablation 2</th>
<th>Postablation 3</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>76.75 ± 9.72</td>
<td>87.05 ± 11.99</td>
<td>77.22 ± 6.24</td>
<td>78.17 ± 5.82</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LVDD</td>
<td>4.73 ± 0.65</td>
<td>4.65 ± 0.62</td>
<td>4.71 ± 0.61</td>
<td>4.68 ± 0.54</td>
<td>NS</td>
</tr>
<tr>
<td>LVSD</td>
<td>3.12 ± 0.85</td>
<td>3.15 ± 0.77</td>
<td>3.08 ± 0.75</td>
<td>3.00 ± 0.71</td>
<td>NS</td>
</tr>
<tr>
<td>EF</td>
<td>59 ± 12</td>
<td>61 ± 11</td>
<td>60 ± 14</td>
<td>64 ± 10</td>
<td>NS</td>
</tr>
<tr>
<td>LAD</td>
<td>3.42 ± 0.50</td>
<td>3.47 ± 0.52</td>
<td>3.53 ± 0.55</td>
<td>3.52 ± 0.57</td>
<td>NS</td>
</tr>
<tr>
<td>cE/A</td>
<td>1.42 ± 0.43</td>
<td>1.19 ± 0.40</td>
<td>1.18 ± 0.40</td>
<td>1.30 ± 0.33</td>
<td>0.009</td>
</tr>
<tr>
<td>cDT</td>
<td>210 ± 54</td>
<td>272 ± 64</td>
<td>255 ± 60</td>
<td>240 ± 64</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>cIVRT</td>
<td>113 ± 22</td>
<td>133 ± 54</td>
<td>123 ± 27</td>
<td>117 ± 19</td>
<td>0.007</td>
</tr>
<tr>
<td>E/Em</td>
<td>5.31 ± 1.54</td>
<td>5.91 ± 2.35</td>
<td>5.69 ± 1.67</td>
<td>6.01 ± 1.95</td>
<td>NS</td>
</tr>
</tbody>
</table>

Abbreviations: NS = not significant; HR = heart rate; LVDD = left ventricular diastolic diameter; LVSD = left ventricular systolic diameter; EF = ejection fraction; LAD = left atrial systolic diameter; cE/A = mitral diastolic early and late flow velocity ratio adjusted to heart rate; cDT = Deceleration time adjusted to heart rate; cIVRT = isovolumetric relaxation time adjusted to heart rate; E/Em = mitral diastolic early flow and tissue Doppler velocity ratio.
Figure 1. The change in mitral diastolic early and late flow velocity ratio (cE/A).

Figure 2. The change in deceleration time (cDT).
The Em/Am ratio obtained from the lateral side of the mitral annulus using tissue Doppler was statistically different before and after the ablation procedure (the Em/Am ratios before and 1 hour, 1 day, and 1 month after the ablation procedure were 1.63 ± 0.56, 1.58 ± 0.83, 1.38 ± 0.53, and 1.47 ± 0.53, respectively, \( P = 0.02 \)) (Figure 4, upper line). Measurements obtained from the lateral side of the tricuspid annulus demonstrated significant changes after the ablation procedure (the Et/At ratios before and 1 hour, 1 day, and 1 month after the ablation procedure were 1.28 ± 0.45, 1.01 ± 0.44, 1.06 ± 0.41, and 1.10 ± 0.36, respectively, \( P = 0.002 \)) (Figure 4, bottom line). There were also significant changes in the tissue Doppler parameters obtained from the left ventricular side of the septum (the Es/As ratios before and 1 hour, 1 day, and 1 month after the ablation procedure were 1.48 ± 0.46, 1.25 ± 0.47, 1.20 ± 0.50, and 1.30 ± 0.40, respectively, \( P = 0.003 \)) (Table II).

There were no changes in the systolic tissue Doppler S velocities obtained from three different sites (Table II).

Figure 3. The change in isovolumetric relaxation time (cIVRT).
Figure 4. The changes in mitral annular early and late diastolic tissue Doppler velocity ratio (Em/Am), septal early and late diastolic tissue Doppler velocity ratio (Es/As), tricuspid annular early and late diastolic tissue Doppler velocity ratio (Et/At).

Table II. Tissue Doppler Values Obtained Before and 1 Hour, 24 Hours and 1 Month After the Ablation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Basal</th>
<th>Postablation 1</th>
<th>Postablation 2</th>
<th>Postablation 3</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Em/Am</td>
<td>1.63 ± 0.56</td>
<td>1.58 ± 0.83</td>
<td>1.38 ± 0.53</td>
<td>1.47 ± 0.53</td>
<td>0.02</td>
</tr>
<tr>
<td>Es/As</td>
<td>1.48 ± 0.46</td>
<td>1.25 ± 0.47</td>
<td>1.20 ± 0.50</td>
<td>1.30 ± 0.40</td>
<td>0.003</td>
</tr>
<tr>
<td>Et/At</td>
<td>1.28 ± 0.45</td>
<td>1.01 ± 0.44</td>
<td>1.06 ± 0.41</td>
<td>1.10 ± 0.36</td>
<td>0.002</td>
</tr>
<tr>
<td>Sm (cm/sec)</td>
<td>11.44 ± 3.13</td>
<td>11.48 ± 2.59</td>
<td>11.73 ± 2.81</td>
<td>11.65 ± 2.75</td>
<td>NS</td>
</tr>
<tr>
<td>Ss (cm/sec)</td>
<td>10.53 ± 3.00</td>
<td>10.38 ± 2.54</td>
<td>10.75 ± 2.44</td>
<td>10.40 ± 2.58</td>
<td>NS</td>
</tr>
<tr>
<td>St (cm/sec)</td>
<td>16.18 ± 3.58</td>
<td>15.59 ± 3.56</td>
<td>16.03 ± 3.81</td>
<td>16.56 ± 3.78</td>
<td>NS</td>
</tr>
</tbody>
</table>

(*): The P values of repeated measurement analysis.

NS = not significant; Em/Am = Mitral annular early and late diastolic tissue Doppler velocity ratio; Es/As = septal early and late diastolic tissue Doppler velocity ratio; Et/At = tricuspid annular early and late diastolic tissue Doppler velocity ratio; Sm = mitral annular systolic tissue Doppler velocity; Ss = septal systolic tissue Doppler velocity; St = tricuspid annular systolic tissue Doppler velocity.
DISCUSSION

This study has demonstrated that no discernible negative effect was seen on left ventricular systolic function, while an impairment in diastolic function parameters was observed without any change in the diastolic filling pressure index after RF ablation.

Several studies have reported improvements in systolic and diastolic left ventricular function after RF ablation of the AV conduction system in patients with left ventricular dysfunction induced by atrial tachycardia. These studies were not able to show an effect of the RF ablation procedure itself on left ventricular function. In other words, the induction of complete heart block and the subsequent pacemaker treatment cause several hemodynamic changes that might influence the outcome in these patients. These include down-regulation of the heart rate, a change from irregular to regular rhythm, and discontinuation of drugs exerting a negative inotropic influence on the left ventricle. All these factors may act positively on left ventricular function. As it is known that incessant tachycardia leads to left ventricular dysfunction, the cessation of tachycardia itself may result in improvement in left ventricular function.

Chen, et al described the reversibility of left ventricular systolic dysfunction after successful RF catheter ablation of supraventricular reentrant tachycardia in which AV nodal conduction block was not created. However, their study was conducted in patients with left ventricular systolic dysfunction in which improvement is expected with the treatment of tachycardia. In another study, they found no evidence that RF ablation may impair left ventricular systolic function in patients with preserved left ventricular function, but they did not evaluate left ventricular diastolic function. Our study results showed no negative effect of RF ablation on left ventricular systolic function in patients with normal left ventricular systolic function, in accordance with the results of Chen, et al.

The present results were also in agreement with those of Shyu, et al who found that RF ablation has no harmful effect on left ventricular systolic function. However, they also reported no change in left ventricular diastolic function, which was in contrast with our results. Shyu, et al used E velocity, A velocity, and the E/A ratio in assessing diastolic function. Although they found significant alterations in left ventricular filling patterns (E, A, E/A), these changes were attributed to the change in heart rate after RF ablation. They divided their study patients into three groups based on the magnitude of heart rate change instead of adjusting the E/A ratio to heart rate. Although statistically insignificant, there was a change in the E/A ratio in patients whose heart rates changed by < 10%, or by between 10% and 20%. In the present study, during echocardiographic examination within the first hours after RF ablation the heart
rates were significantly higher than before the ablation procedure. In order to
overcome certain limitations caused by heart rate, E, A, E/A, DT, and IVRT data
were adjusted to heart rate in our study. There were significant changes in these
parameters, indicating impairment in left ventricular diastolic function even after
adjustment to heart rate, after RF ablation.

Tissue Doppler parameters are independent of preload and heart rate. They can be used both in assessing left ventricular diastolic function and in
assessing right ventricular diastolic function. We also used tissue Doppler
parameters in our study. The Em/Am, Es/As, and Et/At ratios changed significantly
after RF ablation, while there was no alteration in the E/Em ratio. The E/
Em ratio is a reliable index which may be able to demonstrate left ventricular fill-
ing pressure. In this regard, we suggest that whatever the damage caused by RF
ablation, it may have a detrimental effect on left ventricular and right ventricular
diastolic function without changing the left ventricular filling pressure index.

It might be possible to explain the deterioration of diastolic function para-
meters by the RF ablation procedure itself. During RF catheter ablation, RF cur-
cent passes through the tissue in close contact with the electrode and thermal
injury to the myocardium occurs. Histologic examination of these lesions
reveals coagulation necrosis with destruction of the myofibril architecture and
contraction band necrosis. Several biochemical parameters have been validated
in the diagnosis of this myocardial damage induced by RF ablation. In this
regard, we measured CKMB concentrations in all patients before and 8 hours
after the procedure. Compared with before the procedure, the CKMB levels sig-
ificantly increased after the RF ablation (P < 0.001). We also measured tropon-
in-T concentrations in 11 patients. Twenty-four hours after the ablation
procedure, troponin-T concentrations were found to be significantly increased
(from 0.023 ± 0.015 to 0.124 ± 0.102, P = 0.003). This increase in biochemical
parameters indicates myocardial damage which may be the cause of diastolic dys-
function after RF catheter ablation. Even though ventricular ablation was per-
formed only in 3 patients, it is surprising that right and left ventricular diastolic
dysfunction occurred after atrial RF ablation. There are three possible explana-
tions for this ventricular diastolic dysfunction. First, coagulation necrosis and
fibrosis in the atrium may lead to stiff atria, and a stiff atria may be the indirect
mechanism of ventricular diastolic dysfunction. Second, the ablation on the
atrial side may also have an impact on the ventricular side. Ablation was per-
formed on the areas where a small atrial great ventricular intracardiac electro-
gram was recorded. In other words, our ablation area was very close to the
ventricular side. We know that RF lesions can also reach a size of 17 x 17 x 5 mm
and are surrounded by edematous tissue which makes the lesion even greater. Taking this into account, it seems likely that these lesions may exceed the atrium
and infiltrate into the ventricular tissue. It is also possible that the ventricles are mainly affected by the edematous changes which may resolve afterwards and result in an improvement in diastolic function. This may also explain the improvement in diastolic function we observed 1 month after the ablation procedure.

Besides the stiff atria and RF lesion itself, tissue subjected to temperatures higher than 45°C may also be the third reason for this resting tension of the myocardium.\textsuperscript{29) The temperature used in our study was 60 ± 8°C. As we pointed out earlier, our ablation side was very close to the ventricle side and such high temperatures may easily affect the ventricular myocardium. Hyperthermally-mediated injury damages plasma membranes, permitting the influx of extracellular sodium and calcium that results in depolarization and increased myocardial resting tension, respectively.\textsuperscript{29) Study limitation: Conduction patterns changed after RF ablation in 18 patients with manifest WPW syndrome. This conduction change may have influenced our study results. However, even after the removal of patients with WPW, there were still significant changes regarding cE/A (P = 0.49), cDT (P < 0.001), and cIVRT (P = 0.008) after the RF ablation procedure. Therefore, this conduction change may not have had a major impact on our study results.

Conclusion: Although no significant changes were observed in systolic function after RF ablation, this procedure may have some detrimental effects on ventricular diastolic function without changing the left ventricular diastolic filling pressure index.

REFERENCES