Treatment of Tachycardia by Atrial Pacing

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Electrical stimulation of the heart has previously been used only for heart block. Its clinical use, however, has recently been widely extended. It is applied now not only for heart block but also for various arrhythmias without heart block, especially for tachydias.

This paper presents our experiences with atrial pacing of hearts with tachycardias and of our newly developed inductive radio-frequency atrial pacemaker.

METHODS

Electrical stimulation was given to the intraventricular endocardium near the SVC orifice through intravenously introduced bipolar electrodes. The stimulation was of 2 msec duration with a 1–15 mA current, and a frequency of 70-500/min.

The patients treated were seven cases of supraventricular tachycardia including two WPW syndrome (Table 1). The tachycardias of these cases were difficult to control with ordinary drug therapy and lasted a considerable time. The tachycardias of all these cases were terminated immediately by atrial pacing for several seconds. Some of the cases were treated repeatedly because of the recurrence. Besides these seven cases, more than fifty postoperative patients with various arrhythmias, including sinus or ventricular tachycardias, have been successfully treated by atrial pacing. In these postoperative patients,

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<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age</th>
<th>Type of Tachycardia</th>
<th>Ventricular Rate</th>
<th>Period of Symptoms</th>
<th>D.C. Shock</th>
<th>Heart Failure Remarks</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>45</td>
<td>Paroxysmal Supravent. Tachy.</td>
<td>180 (min)</td>
<td>20 (years)</td>
<td>65 (times)</td>
<td></td>
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<tr>
<td>2</td>
<td>F</td>
<td>20</td>
<td>W-P-W Syndrome</td>
<td>150</td>
<td>15</td>
<td>5</td>
<td>Corrected Transposition</td>
</tr>
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<td>3</td>
<td>F</td>
<td>27</td>
<td>Paroxysmal Supravent. Tachy.</td>
<td>210</td>
<td>5</td>
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<td>T. Fallot</td>
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<td>60</td>
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<td>170</td>
<td>3</td>
<td>2</td>
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<tr>
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<td>F</td>
<td>22</td>
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<td>160</td>
<td>3</td>
<td>2</td>
<td>Mitral Stenosis</td>
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<td>F</td>
<td>42</td>
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<td>33</td>
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<td>Heart Failure</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>61</td>
<td>Junctional Atrial Fib.</td>
<td>240</td>
<td>2</td>
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Key Words:
Atrial stimulation
Atrial pacemaker
Tachycardia

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atrial pacing was performed either with two insulated electrode wires attached to the atrium when the cardiac surgery was over, or transvenous semi-floating wires inserted into the atrium through appropriate veins.

In each of these seven cases an intra-atrial electrode catheter was inserted through the appropriate vein. The electrode catheter was left in the atrium for several days or, in some cases, weeks. During this period, various tachycardias appeared repeatedly several times. Electrical stimulation of various frequencies between 70 and 500/min were tested upon these tachycardias. It was found that atrial stimulation of between 250 and 300 times per minute was most effective to terminate tachycardias such as paroxysmal supraventricular, sinus and ventricular. Occasionally other frequencies of stimulation such as 110 (1st case) or 400/min (7th case) converted the tachycardias, but in most cases, any frequencies of stimulation other than between 250 and 300/min were not effective.

**RESULTS**

The evidence and patterns of termination of tachycardias are shown in the following figures.

Fig. 1 shows an attack of paroxysmal supraventricular tachycardia of a patient which was terminated by atrial stimulation. The tachycardia of 160/min is converted to normal sinus rhythm by atrial stimulation of 250/min for 7 seconds between the mark of ON and OFF. During the atrial pacing, only one ventricular contraction against two atrial contractions synchronized with each atrial stimulation is observed. In other words, 2 to 1 heart block occurred during the pacing.

The above findings are much more clearly demonstrated in a His bundle electrogram. Fig. 2 was taken from the same patient as Fig. 1. The tachycardia rate is 150/min. Atrial and ventricular contraction are seen to be regular. In the
lower line A, H and V are also seen to be regular. The atrial stimulation of 250/min is started between the third and fourth ventricular contraction. The first two stimulation did not affect the cardiac cycle at all. The third stimulation captured the atrium (A), which was followed by His potential (H) and ventricular contraction (V). The fourth stimulation was given just before this H and respective atrial contraction occurred but no ventricular contraction followed. The fifth stimulation caused a reaction to the cardiac cycle similar to the third one. The sixth stimulation caused the same reaction as the fourth. That is, the third, fifth, seventh, ninth, and so on stimuli captured atrial contraction and transmitted it to the distal conduction system and finally ventricular contraction ensued. On the other hand, the fourth, sixth, eighth, tenth and so on stimul

were followed by atrial contracion only and no further conduction of the stimuli is seen in the ECG. Thus 2 to 1 A-V block occurred and the cardiac rhythm was regulated by electrical stimulation of the atrium. At this moment tachycardia was converted. When the electrical stimulation was discontinued, normal sinus rhythm was resumed.

The same principle of atrial pacing can be used to control various arrhythmias, including some types of tachycardias after cardiac surgery. These arrhythmias are sinus tachycardia, ventricular extrasystole, bigeminy and nodal rhythm.

Fig. 3 shows a sinus tachycardia of 150/min after radical correction of tetralogy of Fallot. Atrial pacing of 288/min was used. Three to one heart block appeared and the heart rate decreased to 96/min immediately.

Fig. 4 shows an application of the atrial pacing for ventricular extrasystole combined with bigeminy. Immediately after giving 225/min atrial pacing 2 to 1 A-V block appeared and the heart rate decreased to 112/min. The contraction became very even, which is seen in ECG, and the blood pressure rose.

Occasionally tachycardia can be converted by a different mechanism. Fig. 5 shows a junctional tachycardia with atrial fibrillation. This tachycardia could not be controlled by 250-300/min stimulation of the atrium. When 400/min atrial stimulation was given for several seconds, a slow nodal rhythm with sinus arrest appeared which was soon followed by normal sinus rhythm.

Radiofrequency inductive atrial pacemaker

We developed a new radio-frequency inductive atrial pacemaker in 1970. This apparatus consists of two parts: a high radio-frequency receiver which is implanted on the right atrial wall (Fig. 6, button type) or in the subcutaneous tissue of the anterior thoracic wall with a transvenous electrode catheter in the right atrium (catheter type), and an oscillator.

The receiver has been implanted into seven cases as of this writing. When tachycardia occurs, patients apply their own oscillator for several seconds. By turning the ON switch, an electrical impulse is transmitted to the internally placed receiver. The frequency of the impulse can be changed to anywhere from 70 to 500/min. However, 250 to 300/min was used in six cases and 400/min was used in one case. All occurrences of tachycardia were able to be terminated by the patients themselves. The first patient to be equipped with a pacemaker has been using it for two and a half years. During this time he has treated himself for more than 300 recurrences of tachycardia without a single failure.

Discussion
Several reported methods of atrial pacing are grouped by (1) single or pair of stimulation, (2) frequency of repetitive stimulation is less than those of tachycardia, (3) frequency of repetitive stimulation is greater than those of tachycardia. Our experiences of clinical application indicates that the frequency of between 250 and 300/min electrical stimulation is most effective for converting various tachyarrhythmias.

Mechanism of the artificial A-V block produced by the atrial pacing is most likely due to differences of refractory periods of various portions of the heart. The refractory periods of the conduction system distal to the A-V node is much longer than the one of the atrium. When atrial stimulation with the interval little longer than the refractory period of the atrium is given to the atrium, the atrium can becontracted with each electrical stimulus. However, the refractory period of the conduction system distal to the A-V node cannot be activated by the transmitted impulse because of their longer refractory period. Thus A-V block occurs. We found that the most suitable electrical impulse is between 250-300/min, which interval is between 200 and 240 msec. It is widely believed now that the cause of paroxysmal supraventricular tachycardia is due to the re-entry mechanism of the stimulation. The electrical stimulation with suitable frequency can interrupt the circus circuit of the stimulation. The interruption of the stimulus can be achieved by even one or two electrical stimulus if they are given to the appropriate portion of the cardiac cycle.

The mechanism of artificial heart block or atrial capture by the atrial pacing against the sinus tachycardia is just the same as the one of paroxysmal supraventricular tachycardia. However, the cause of the sinus tachycardia after cardiac surgery is hyperaction of sinus node and not due to re-entry mechanism of the stimulation. The heart rate decreases only while the optimal atrial pacing is given. Therefore, the atrial pacing is applied for a longer period than is in use for paroxysmal supraventricular tachycardia, or several times intermittently until the activated sinus node calms down to normal.

It is possible, however, that another mechanism of conversion of supraventricular tachycardia took place (Fig. 5). The tachycardia could have been converted only by greater frequency stimulation, the rate of which was 400/min. The findings in the ECG suggests an overdrive suppression of the sinus node.

Many of the tachycardias can be treated by drugs, vagus stimulation maneuver or may even heal spontaneously. However, some are resistant to ordinary treatment. The application of atrial stimulation gives us not only interesting electrophysiological findings on arrhythmias but also a significant achievement for treatment of various tachycardias.

The sinus tachycardia often appears after major cardiac surgery such as radical correction of tetralogy of Fallot, closure of large VSD, closure of cushion defect, and intracardiac valve replacement. The sinus tachycardia can be hardly controlled with medication or DC countershock. These postoperative tachyarrhythmias often cause decreasing of cardiac output, lowering of blood pressure and deteriorates the condition of the patients. Therefore, the control of these arrhythmias has a great significance for the postoperative course of the patients.

The supraventricular tachycardia tends to appear repeatedly throughout their lives and sometimes they appear several times a day. The patients equipped with inductive radiofrequency atrial pacemakers can treat the tachycardias by themselves. Elimination of the necessity for a hospital visit on each occasion will give the patients many benefits.

**Summary**

Various tachycardias were treated by atrial pacing. Those treated were supraventricular with and without WPW syndrome, ventricular and sinus tachycardias. The evidence and patterns of termination of the tachycardias have been shown and the mechanism of the termination by the atrial stimulation has been discussed.

Our newly developed inductive radiofrequency atrial pacemaker has been also presented.

**REFERENCES**