THE RESPONSE OF ATRIOVENTRICULAR JUNCTIONAL TISSUE TO TEMPERATURE

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To determine the optimal temperature for catheter heat mapping without damaging cardiac tissue, we studied the electrophysiologic and histologic responses of the atrioventricular (AV) conduction system exposed to a specific range of temperatures. In 18 closed-chest dogs, an electrode catheter with a thermistor, tip was positioned transvenously at the AV junction. Radiofrequency current (RFC) was applied in incremental temperature steps until transient 2nd-degree AV block was induced. Catheter tip temperature (CTT) was measured at each step. RFC was immediately discontinued when AV block occurred. AV conduction was evaluated before and 4 weeks after the procedure. Acute transient 2nd-degree AV block was induced in 45 applications, during which the average CTT was 48.7±2.7°C. In another 40 applications in which 2nd degree AV block was not induced, the average CTT was significantly lower [46.3±2.5°C] (p<0.001). Eleven of 16 dogs showed acute 2nd-degree AV block, but had normal AV conduction at 4 weeks (Group A). In the other 5 dogs, 1st-degree AV block was seen at 4 weeks (Group B). The lowest CTTs in Groups A and B were 45 and 49°C, respectively. Histologic findings in 2 dogs from Group A revealed that 10–15% (by area) of the AV node was fibrotic. These findings suggest that the induction of fully reversible AV block can be achieved by titration of RFC, during the application of RFC to the AV junction. In conclusion, RF energy was used to produce a tip temperature of between 45°C and 49°C, which induced reversible and significant interruption of conduction of in tissue in the AV junction, and presumably also in target sites in clinical RF ablation. (Jpn Circ J 1994; 58: 351–361)

RECENT clinical studies1–5 have shown that percutaneous catheter-mediated ablation using radiofrequency current (RFC) can effectively eliminate drug-refractory tachyarrhythmias. Although RFC ablation is believed to be relatively safe, in terms of acute results2–4,6,7 possible complications, such as radiation injury8 or ablation-related arrhythmias, should not be ignored as late-onset complications. We postulated that “heat mapping”, i.e., application of heat to induce reversible changes in conduction, can be used in the same way that “ice” mapping has been used in the surgical therapy of arrhythmias to determine the optimal site for ablation. We believe that a heat mapping

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**Key words:**
- Temperature monitoring
- Radiofrequency current
- Catheter ablation
- AV junction

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Japanese Circulation Journal Vol.58, May 1994 351
Teflon Coated Thermistor Tip

7F Modified Bipolar Lumen Catheter

Fig. 1. Schema showing an electrode catheter used to apply RF current. The thermistor tip is embedded in a hole on the side of the distal electrode.

The purpose of this study was to evaluate the electrophysiologic and histological response of the atrioventricular (AV) conduction system to various temperatures. An initial basic study such as this may serve as a basis for the eventual clinical use application of the heat mapping technique.

METHODS

All of the experiments were performed according to the Guide for Animal Experimentation at Tokyo Medical and Dental University.

Eighteen mongrel dogs of both sexes weighing 8–13 kg were studied. Dogs were anesthetized with ketamine hydrochloride (15 mg/kg) given intramuscularly, followed by sodium pentobarbital (10–20 mg/kg) given intravenously. The animals were intubated and ventilated with a constant volume respirator. Three electrode catheters were inserted percutaneously through femoral veins and advanced into the heart. Two of the catheters were 6F quadripolar electrode catheters (Josephson-quadripolar electrode, United States Catheter Instruments, MA, USA), which were positioned in the right atrium and the right ventricle for stimulation and/or recording. The third catheter was a 7F modified bipolar lumen catheter (One Lumelec Electrode Catheter, Multipurpose A-2, Cordis Corp., FL, USA) with a thermistor at the catheter tip. The distal electrode used for RFC delivery was 2 mm long. The teflon-coated thermistor tip (thermoelements; Cu & Cu/Ni, Type IT-18, Physitemp, NJ, USA) could accurately record temperature recording over a range of −273 to 150 °C. The thermistor was fixed in the distal electrode so that it protruded through a hole in the side of the tip electrode tip where it was bonded with heat conductive epoxy (Fig. 1). Catheter tip temperature (CTT) was displayed on a digital thermometer (model; TH-5, Bailey Instrument, CA, USA) which read temperatures from 0 to 99 °C with a resolution of ±0.1 °C.

Electrophysiologic Testing

Programmed electrical stimulation was performed with a programmable stimulator (3F-51, San-ei Sokki, Japan) which delivered impulses of 2 ms duration at a strength of approximately twice the diastolic threshold. Conduction time through the AV node and through the His-Purkinje system was measured during normal sinus rhythm as the interval between the onset of rapid low septal right atrial depolarization to the onset of depolarization of the His bundle (A-H interval), and the interval between the onset of depolarization of the His bundle to the onset of ventricular depolarization (H-V interval).

Japanese Circulation Journal Vol.58, May 1994
Both sets of measurements were taken from a His-bundle electrogram (HBE) and standard ECG leads.

The AV nodal Wenckebach point was determined using incremental atrial stimulation until 2nd-degree block occurred in the AV node, and was recorded as the A-A interval at that point. The effective refractory period of the ventriculo-atrial conduction system (VACS-ERP) was determined using a train of consecutive ventricular stimuli with a basic cycle length 20–50 ms shorter than the length of the sinus cycle. During programmed stimulation, surface electrogram leads I, II and V1, and a His bundle electrogram were displayed on a multichannel oscilloscope (Monitor Oscilloscope 2G66, Nihon San-ei, Japan) and recorded on a thermal recorder (RF-80, Fukuda Denshi, Japan).

Protocol of RF Current Delivery

In the present study, the electrophysiological response to temperature was examined at the AV junction because dramatic electrophysiological changes in AV conduction could be seen, and also because this was one of the easiest sites at which the electrode catheter could be placed consistently. We considered 2nd-degree AV block during sinus rhythm, rather than 1st-degree AV block, to be an indicator of the effects of heat on the AV conduction system because the former was more specific.

The catheter for RFC delivery was initially positioned so that the bipolar electrodes recorded the largest His bundle potential. The catheter was then withdrawn until the bipolar electrodes recorded a small, but sharp, His bundle potential and a relatively large atrial potential with an amplitude ratio of 0.5–1.0 (atrium/ventricle). RFC (continuous wave, 520 kHz) was generated by a HAT-200 generator (Dr. Ospyka GmbH, Medizintechnik, Germany). RFC was applied to the distal electrode using a standard adhesive electrosurgical dispersive electrode (12×18 cm) placed on the left posterior chest as a return electrode. In each dog, the first RFC application was performed using low power (5 or 10 W) for a period of 30 sec or until transient 2nd-degree AV block occurred. If 2nd-degree AV block was not induced, a 5 W more power was applied without changing the catheter position. This incremental power-up was repeated until 2nd-degree AV block was induced. If tip temperature did not increase, or if 2nd-degree AV block was not induced despite an appropriate temperature rise, the catheter for RFC delivery was repositioned. RFC was then reapplied at the lowest power setting so that it was the 1st application at the repositioned site, and the incremental power-up described above was repeated until 2nd-degree AV block was induced. At each application, RFC delivery was immediately discontinued when 2nd-degree AV block was recognized on the monitor. The RFC delivery protocol was terminated when transient 2nd-degree AV block was induced in most of the dogs. However, in some dogs, several applications of RFC delivery were performed after 2nd-degree AV block was achieved to determine the reproducibility of the electrophysiological response to the same thermal application.

Electrophysiological Testing after the Procedure

After the final RFC application, the dogs were monitored for 30 min. Electrophysiological testing, including programmed stimulation, was then performed in all of the dogs. All of the dogs were kept alive for 4 weeks and the same electrophysiological testing procedure was repeated under anesthesia.

Histological Examination

The hearts of 2 dogs were excised and the AV conduction system was sectioned into 3 blocks according to the method of Lev et al. These sections were embedded in paraffin. Serial sections (5 μm-thick) were made and every 20th section was retained on a glass slide. Hematoxylin-eosin, elastica-van Gieson and Azan staining were performed in succession.

Statistical Analysis

Results are expressed as the mean ± standard deviation. Differences in PQ, QRS, AH, HV and AV nodal-Wenckebach point among the baseline status, and 30 min and 4 weeks after the procedure, were evaluated using Student’s t-test for paired data in each subdivided group. Differences in these parameters between groups with or without 1st-degree AV block at 4 weeks were assess-
TABLE I RESULTS AND CHARACTERISTICS OF RFE APPLICATIONS

<table>
<thead>
<tr>
<th>Dog No.</th>
<th>Heart Rhythm</th>
<th>No. of AVB Inductions</th>
<th>Max. TT* (°C)</th>
<th>Power* (W)</th>
<th>Energy* (J)</th>
<th>No. of RFE Applications</th>
<th>Total Delivered Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>10</td>
<td>130</td>
<td>4</td>
<td>515</td>
</tr>
<tr>
<td>2</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>10</td>
<td>140</td>
<td>10</td>
<td>4340</td>
</tr>
<tr>
<td>3</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>20</td>
<td>480</td>
<td>13</td>
<td>4530</td>
</tr>
<tr>
<td>4</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>15</td>
<td>255</td>
<td>3</td>
<td>855</td>
</tr>
<tr>
<td>5</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>15</td>
<td>300</td>
<td>4</td>
<td>1110</td>
</tr>
<tr>
<td>6</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>10</td>
<td>210</td>
<td>23</td>
<td>9510</td>
</tr>
<tr>
<td>7</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>10</td>
<td>490</td>
<td>3</td>
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<td>8</td>
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<td>N</td>
<td>N</td>
<td>4</td>
<td>490-52</td>
<td>20-25</td>
<td>1695</td>
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<tr>
<td>9</td>
<td>II</td>
<td>N</td>
<td>N</td>
<td>5</td>
<td>50-54</td>
<td>15-20</td>
<td>1180</td>
</tr>
<tr>
<td>10</td>
<td>II</td>
<td>I</td>
<td>N</td>
<td>6</td>
<td>46-50</td>
<td>15-20</td>
<td>1450</td>
</tr>
<tr>
<td>11</td>
<td>II</td>
<td>I</td>
<td>N</td>
<td>10</td>
<td>45-53</td>
<td>15-20</td>
<td>4950</td>
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<tr>
<td>12</td>
<td>II</td>
<td>I</td>
<td>I</td>
<td>1</td>
<td>49</td>
<td>10</td>
<td>170</td>
</tr>
<tr>
<td>13</td>
<td>II</td>
<td>I</td>
<td>I</td>
<td>1</td>
<td>49</td>
<td>30</td>
<td>900</td>
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<tr>
<td>14</td>
<td>II</td>
<td>I</td>
<td>I</td>
<td>1</td>
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<td>I</td>
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<td>50-53</td>
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<td>840</td>
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<tr>
<td>16</td>
<td>III</td>
<td>I</td>
<td>I</td>
<td>1</td>
<td>52</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>17</td>
<td>III</td>
<td>I</td>
<td>III</td>
<td>1</td>
<td>58</td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

Heart Rhythm In RFE=heart rhythm during RFE application; AVB=AV block; Max. TT*=maximum catheter tip temperature during RFE application inducing AV block; Power*=power during RFE application inducing AV block; Energy*=total energy during RFE application inducing AV block; N=no AV block; I=first-degree AV block; II=second-degree AV block III=third-degree AV block;

TABLE II ELECTROPHYSIOLOGICAL MEASUREMENTS; BASELINE AND 30 MIN AND 4 WEEKS AFTER THE RFE PROCEDURE

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>SCL</th>
<th>PQ</th>
<th>QRS</th>
<th>A-H</th>
<th>H-V</th>
<th>AVN-WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base.</td>
<td>268±25</td>
<td>81±8</td>
<td>48±6</td>
<td>58±8</td>
<td>15±2</td>
<td>152±10</td>
<td></td>
</tr>
<tr>
<td>A 30 min.</td>
<td>270±19</td>
<td>87±7</td>
<td>48±6</td>
<td>60±8</td>
<td>16±2</td>
<td>156±10</td>
<td></td>
</tr>
<tr>
<td>4 Week</td>
<td>275±19</td>
<td>83±6</td>
<td>49±5</td>
<td>56±9</td>
<td>17±3</td>
<td>161±11</td>
<td></td>
</tr>
<tr>
<td>Base.</td>
<td>290±23</td>
<td>88±9</td>
<td>47±5</td>
<td>61±12</td>
<td>$</td>
<td>$</td>
<td>16±2</td>
</tr>
<tr>
<td>B 30 min.</td>
<td>289±25</td>
<td>104±17</td>
<td>47±5</td>
<td>77±18</td>
<td>$</td>
<td>$</td>
<td>17±3</td>
</tr>
<tr>
<td>4 Weeks</td>
<td>319±72</td>
<td>129±12</td>
<td>48±3</td>
<td>99±13</td>
<td>$</td>
<td>$</td>
<td>18±3</td>
</tr>
</tbody>
</table>

Values are Mean±S.D.(ms). SCL=sinus cycle length; PQ=PQ interval; QRS=QRS width; A-H=A-H interval; H-V=H-V interval; AVN-WP=AV nodal Wenckebach point; RFE=radiofrequency energy. *p<0.05 (paired t-test), $p<0.05$ (unpaired t-test)
ed at each time point with Student’s t-test for unpaired data. In addition, temperatures or powers between the groups with and without 2nd-degree AV block were compared using Student’s t-test for unpaired data. A value of p<0.05 was considered significant.

RESULTS

Results of RF Current Delivery

Transient (<4 sec) 2nd-degree AV block was induced in 16 of 18 dogs, and 3rd-degree AV block was induced in the remaining 2 dogs, during RFC delivery. The results and characteristics of the RF energy applications are given in Table I. We classified 18 dogs into three groups according to the degree of AV block at 4 weeks after the procedure; group A (11 dogs) showed no change in the PR interval; group B (5 dogs) showed 1st-de-
Fig. 2. Inductions of transient 2nd-degree AV block (dog #8). Transient 2nd-degree AV block was induced by applications of RFC. RFC was applied at 10 Watts in all three attempts. 2nd-degree AV block occurred consistently in each application. In panel a), 2:1 mode 2nd-degree AV block began 19.5 sec after onset of RFC delivery, which returned to 1:1 AV conduction at 23 sec. RFC delivery was discontinued within 3 sec after onset of AV block in (a). As seen in (b) and (c), 2nd-degree AV block recovered to 1:1 conduction within 4 sec after termination of RFC in successive RFC applications. Abbreviations: I, II, III; surface electrocardiographic leads. RA; electrogram of right atrium. circled number; time (seconds) after onset of RF current delivery. black bar; period of RF current delivery.

degree AV block; group C (2 dogs) showed 3rd-degree AV block. Table I shows that neither the number of inductions of AV block, the total power nor the energy of the RFC application which induced AV block, the total number of RFC applications, nor the total delivered energy was the determining factor in grouping the dogs.

Table II summarizes the results of the electrophysiological parameters in Groups A and B. In Group A, although 2nd-degree AV block induced during RF energy delivery did not seem to return completely to baseline AV conduction at 30 min after the procedure, it had recovered at 4 weeks. The AV nodal Wenckebach block point in Group A did not change significantly at either 30 min or 4 weeks after induction of acute 2nd-degree AV block. In Group B, although 2nd-degree AV block was induced during RF energy delivery, it did not persist after the procedure. In contrast, 1st-degree AV block, which was defined as 50% or greater prolongation of the PR interval than as compared to the control PR interval, was seen at 30 min in 4 of 5 dogs. All of the dogs in group Group B showed marked 1st-degree AV block at 4 weeks, but the AV nodal Wenckebach block point was not significantly different compared to either at baseline or at 30 min after induction. Retrograde conduction before and after the procedure was investigated in 9 of 11 dogs in Group A, and in all of the dogs in Group B. Five of the dogs in Group A demonstrated ventriculo-atrial conduction in the baseline state. One showed ventriculo-atrial conduction block and VACS-ERP in 2 dogs was prolonged 4 weeks after the procedure. Three of 5 dogs in Group B showed ventriculo-atrial conduction before and after the procedure. VACS-ERPs were not measured in any of the dogs.
in Group B because these were shorter than ventricular refractory periods.

AV Block and Temperature

The catheter tip temperature was monitored in every application in all of the dogs. Six of 16 dogs underwent one or more inductions of AV block after the first induction of 2nd-degree AV block. In each of these dogs, when the delivered RF power was held constant and the catheter was not moved to a different site, the temperature monitored at the catheter-tip was almost identical, and the electrophysiological response to the temperature was similar, as demonstrated in Fig. 2 and 3. In dog #8 (Fig. 3), 2nd-degree AV block was induced reproducibly when the temperature rose to 45°C. The maximum temperatures during RFC application which induced 2nd-degree AV block in Group A (46.3±1.7°C, mean±S.D.) were significantly higher than those in Group B (50.0±1.7°C)[p<0.001]. In addition, the temperatures during induction of 3rd-degree AV block in Group C appeared to be much higher than those in Group B. However, a statistical analysis was unjustified since there were so few dogs in Group C (n=2). Therefore, it is clear that the only determining factor for chronic AV block was the tip temperature. We also recognized that the lowest temperature required to induce transient 2nd-degree AV block was 45°C. In addition, there was a risk of producing irreversible damage to AV nodal conduction when the temperature of the applied heat exceeded 49°C.

A total of 85 applications of RFC were attempted in the 16 dogs in Groups A and B. Forty five of the 85 applications successfully induced acute 2nd-degree AV block. The remaining 40 applications of RFC did not induce 2nd-degree AV block. The average temperature during successful RF energy applications (n=45, 48.7±2°C) was significantly higher (p<0.001) than that during unsuccessful RFC applications (n=40, 46.3±2.5°C), as shown in Fig. 4.

AV Block and RF Power

The RF power which induced 2nd-degree AV block ranged from 10 to 30 W. The RF power in applications which successfully induced 2nd-degree AV block (17.6±4.7 W, n=45) was significantly higher (p<0.01) than that of in the unsuccessful applications (13.3±4.7 W, n=40), as shown in Fig. 5. There was a direct correlation between applied power and temperature (r=0.614, p<0.001), despite a remarkable variation in temperature at any given power value (Fig. 6). Although the power of the delivered RFC was low in both of the dogs in group Group C (Table I), RFC resulted in 3rd-degree AV block in these 2 cases. The tip temperature in these dogs was definitely higher than those in Groups A and B.
Cardiac Tissue Response to Temperature

![Graph showing temperature vs power with two groups: \( \Pi' AVB(+) \) and \( \Pi' AVB(-) \).](image)

**Fig. 4.** Comparison of the temperatures at which application of RF current successfully (\( \Pi' AVB (+) \)) and unsuccessfully (\( \Pi' AVB (-) \)) induced 2nd-degree AV block. The temperatures in the 2nd-degree AVB (+) applications \([48.7 \pm 2.7^\circ C]\) were significantly higher \((p < 0.001)\) than those in the 2nd-degree AVB (-) applications \([46.3 \pm 2.5^\circ C]\).

**Pathological Investigation**

Two dogs in Group A were examined pathologically at 4 weeks after the procedure. In dog #5, a total of 4 RFC applications were performed at a tip temperature of 42–46°C. Second-degree AV block was induced at a tip temperature of 46°C upon the fourth application. Microscopically, fibrosis \((2.7 \times 2.5 \times 1.6 \text{ mm}; \text{ length} \times \text{width} \times \text{depth})\) was observed from the right side of the interatrial septum to the AV node in this dog (Fig. 7). A small area \((1.4 \times 0.3 \text{ mm}; \text{ length} \times \text{depth})\) was ablated in the AV node close to the atrial septum. The maximal damaged area of AV nodal tissue was 15%. Dog #9 underwent six RFC applications, including 5 inductions of transient 2nd-degree AV block at a tip temperature of 50–54°C. Endocardial thickening of the septal leaflet of the tricuspid valve and fibrosis of a small area of the interventricular septum were observed. The AV conduction system was mainly affected at the penetrating His bundle, 10–15 % of which was replaced with fibrotic tissue.

**Complications**

*Japanese Circulation Journal  Vol.58, May 1994*

![Graph showing power vs number of applications with two groups: \( \Pi' AVB(+) \) and \( \Pi' AVB(-) \).](image)

**Fig. 5.** Comparison of the powers at which application of RF current successfully \((\Pi' AVB (+))\) and unsuccessfully \((\Pi' AVB (-))\) induced 2nd-degree AV block. The power used in 2nd-degree AVB (+) was higher than that in 2nd-degree AVB (-) \((p < 0.01)\).

No sustained tachyarrhythmias were induced during RFC application, although AV junctional beats, atrial premature beats and ventricular premature beats were observed.

**DISCUSSION**

RF catheter ablation is undoubtedly a useful technique for treating patients with refractory cardiac tachyarrhythmias. While acute complications are well-recognized\(^{4,6,7}\) and the long-term complications, such as arrhythmogenicity related to ablated myocardial tissues or radiation injuries, have not yet been completely investigated. To limit these possible complications, it would be reasonable to consider how to reduce the number of RFC applications, as well as the length of time required for the procedure time. At present, a short-duration delivery of low-power RFC is usually attempted to test whether the catheter is positioned at a proper site for ablation. We postulated a "heat mapping" technique during catheter ablation which is analogous to ice-mapping in arrhythmia surgery. This may be a simple and effective method for determining the target site. In the present study, we investigated the relation between temperature and AV conduction to determine the optimal
temperature required for inducing transient interruption of AV conduction. In this way, we sought to establish a basis for the use clinical application of catheter-mediated thermal mapping.

Temperature Monitoring
The amount of heat generated in the tissue around an electrode by RFC is governed by three factors: 1) distance from the electrode; 2) RFC intensity; and 3) duration.
of the application of RFC. The actual heat is the difference between the heat generated by RFC flow through the tissue surrounding the electrode tip and the heat loss from this region. Therefore, before discussing the tip temperature as a marker of tissue-heating, the device used in the study to examine the tip temperature should be described.

We used a thermistor protruding from a small hole on the side of the efferent electrode. This is believed to be more accurate than an inner-wall thermistor for measuring the temperature at the electrode-tissue interface. As shown in Fig. 6, temperature was correlated with power for each RFC application. Since the first application of RFC was always attempted at low power, most of the first attempts at RFC application did not induce 2nd-degree AV block due to the lower tip temperature. Second-degree AV block occurred within a few seconds after the tip temperature reached a steady state temperature $(48.7 \pm 2.7^\circ C)$. We also demonstrated the reproducibility of the relationship between temperature and AV block induction.

These findings suggest that the tip temperature and the heating effect was monitored properly in this study.

The Electrophysiological Effects of Temperature Changes

As the present results indicate, the threshold temperature at which transient and reversible effects were observed, and the temperature which had an irreversible effect on AV conduction were 45 and 49°C, respectively. Haines and Watson demonstrated a temperature range of 46.6 to 48.9°C in the marginal area between viable and nonviable tissue estimated in an experimental model using isolated perfused and superfused canine right ventricle. In this study, the threshold temperature associated with the reversible effect and that associated with the irreversible effect were very close to the temperatures shown by Haines. A few studies have examined temperature thresholds in clinical catheter ablation. Tracy et al. reported that the mean temperature at the time of interruption of accessory pathway conduction was $47.24 \pm 10.25^\circ C$ (mean \pm SD) in patients with Wolff-Parkinson-White syndrome. Since these values are supposed to indicate the temperature threshold for a loss of conduction, they are very consistent with our present data. Langberg et al. demonstrated that transient conduction block between atrium and ventricle via an accessory pathway occurred at a temperature of $50 \pm 8^\circ C$ (mean \pm SD), which is just slightly higher than our temperature threshold for reversible effects.

We demonstrated that $45^\circ C$ was the lowest temperature at which an obvious interruption of AV conduction could be induced. On the other hand, temperatures as high as $54^\circ C$ was required to induce a similar change in some cases. An explanation for this difference may be discerned from the histological examination of dog #9. The site of RFC applications in this case, was closer to the His bundle than to the AV node. The latter is encased in a fibrous body and is more resistant to damage by heat than the AV node. Therefore, the temperature required to induce electrophysiological effects depends on the proximity of the electrode tip to the AV node (or to atrial pathway inputs to the AV node).

As seen in the electrophysiological data, the AV nodal Wenckebach point did not change in dogs with apparently prolonged AH intervals (Group B). Marcus et al. demonstrated the similar findings in that RFC application of RFC to the AV junction induced a dissociation between the effects on AV nodal conduction and refractoriness.

There was only a small difference $(3.7^\circ C)$ between the temperature which induced transient interruption of AV conduction and that which had no effect on AV conduction. This indicates that the tip temperature during RFC delivery should be strictly controlled if heat mapping is used in clinical RF ablation.

Power as an Indicator of Thermal Effects

A significant positive correlation was observed between the applied power and tip temperatures. However, the generated tip temperatures varied widely at each power setting, which is consistent with the results of Langberg et al. Even low-power delivery was associated with a risk of inducing 3rd-degree AV block because in some dogs the tip temperature increased to a greater degree than expected. Therefore, power-controlled RFC delivery would not be a appropriate for
catheter heat mapping.

**Histological Examination**

Various reports\(^{17-19}\) have studied the correlation between the electrophysiological changes and histological findings in the AV conduction system produced by RF energy. Lopez-Merino et al\(^{17}\) demonstrated that the AV node was partially invaded by collagenous tissue in a dog with transient 1st-degree AV block produced by RFC. Marcus et al\(^ {18}\) showed that some lesions were produced in the approaches to the AV node in dogs with persistent or transient 1st-degree AV block. Tanaka et al\(^ {19}\) investigated the AV junctional tissue in dogs which showed various degrees of chronic AV block after the application of catheter RF ablation. According to their data, the maximally ablated area (%) of the AV conduction system was $>50\%$, even in dogs which had showed acute and transient 1st-degree AV block.

These data, as well as our results in two dogs, suggest that the electrically reversible (or irreversible) interruption of AV conduction does not necessarily correlate with the degree of histologically reversible changes in AV conductive tissue.

**Conclusions and Clinical Implications**

Our results show that the production of electrically reversible transient interruption of AV conduction could be achieved by titration of RF energy. Electrical reversibility of AV conduction did not necessarily correlate with a lack of histological damage in the AV conductive tissue. We conclude that the heat mapping using thermistors at the efferent electrode could be performed efficiently and safely. The use of RF energy to produce a tip temperature of between 45°C and 49°C induced consistent, reversible and significant interruption of conduction in the AV junctional tissue, and presumably of the target sites in clinical RF ablation.

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Cardiac Tissue Response to Temperature

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