Radiofrequency Ablation for WPW Syndrome with Monitoring the Local Electrogram at the Ablation Site

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SUMMARY

Catheter ablation for septal accessory pathways is occasionally associated with complications, such as atrioventricular block, since the septal region is a complex anatomical structure containing the atrioventricular conduction system. Therefore, we designed a signal separator composed of an inductance-capacitance network with which the local electrogram at the ablation site could be continuously monitored during the delivery of radiofrequency (RF) energy. We tested the safety and efficacy of RF catheter ablation using a signal separator in 17 patients with septal accessory pathways (10 anteroseptal and 7 midseptal cases). RF energy (520 KHz) was applied at an output of 20–40 W for 30–120 sec. to the atrioventricular annulus where the shortest atrioventricular interval or accessory pathway potential was recorded on the electrogram using a large tip ablation electrode. In ablation for the anteroseptal or midseptal accessory pathways, the atrial to ventricular amplitude ratio on the local electrogram was maintained at 1 or less during the delivery of RF energy. In all 17 cases, the interruption of accessory pathways was successful without atrioventricular block. In one patient, accessory pathway conduction recurred which could be treated by the second session. There were no late complications during the 4 to 46 month follow-up period.

In conclusion, RF catheter ablation using a signal separator is a safe and reliable method for treating patients with septal accessory pathways. (Jpn Heart J 1996; 37: 741–750)

Key words: Anteroseptal Midseptal Accessory pathway Signal separator Atrioventricular block

GREAT advances have been made in the treatment of Wolff-Parkinson-White (WPW) syndrome.1–6) The introduction of catheter ablation5–6) in
particular has ushered in a new era of treatment and a number of catheter ablation procedures have been done worldwide. However, several problem areas with respect to ablation for septal accessory pathway (AP) remain. Since the anteroseptal or midseptal region is a complex anatomical structure containing the atrioventricular (AV) conduction system, catheter ablation in this region is occasionally associated with AV block.\textsuperscript{7-12)

Therefore, we developed a new filtering system: a signal separator composed of an L-C network, and attempted to record the local electrogram directly using the ablation electrode during the delivery of radiofrequency (RF) energy. We tested the safety and efficacy of RF catheter ablation for these septal AP using this signal separator.

**Methods**

Seventeen patients with septal APs were referred to Yokohama Red Cross Hospital for the treatment of RF catheter ablation from January 9, 1991 to August 10, 1995. There were 10 males and 7 females, and their mean (\(\pm SD\)) age was 41 \(\pm\) 15 years (ranging from 16 to 81).

These patients had recurrent drug-resistant attacks of paroxysmal tachycardia. Ten had anteroseptal AP and 7 midseptal AP. Two patients had experienced syncope, 3 vertigo, and 17 palpitations. Written informed consent was obtained from all patients. Electrophysiological studies and catheter ablation were performed under mild sedation after cardioactive drugs had been withdrawn for more than 5 half-lives. Four multipolar electrode catheters were positioned in the high right atrium, His bundle region, right ventricular apex and the coronary sinus. A 7 F deflectable catheter with a large tip 4 mm electrode (Webster-Cordis, MA, EP Technology, CA, USA) was inserted for ablation. Biplanar fluoroscopy (right anterior oblique 30° and left anterior oblique 60° view) was used to verify the position of the electrode catheters. The RF generator used for ablation was a Nova-Flame (Japan Crescent, Chiba) which constantly produced an unmodulated sine wave output with a frequency of 520 KHz. RF energy was delivered between the large tip electrode of the catheter and the electric plate on the back of the patient at an output of 20–50 W with an exposure duration of 30–120 seconds. The impedance, current and voltage, and the local electrogram were monitored.

**Monitoring the local electrogram with the ablation electrode:** We designed a new signal separator with which the local electrogram at the ablation site could be recorded via the distal pairs of the ablation catheter with 2 mm interelectrode spacing. It rejected the noise of the RF current during the delivery of RF energy. Figure 1 shows the signal separator, composed of the circuitry with high cut filters...
Figure 1. Schematic illustration of a specially designed filtering system (Signal Separator) composed of low and high cut filters. RF = radiofrequency; 8 ch = 8 channel.

and a low cut filter. The electric wire connected to the ablation electrode was divided into two parts. Wire A was connected to the polygraph (50–300 KHz, NEC-Sanei, Tokyo) through a common mode filter and 3 high cut filters (>100 KHz, >10 KHz, >1 KHz) which could conduct signals less than 1 KHz without attenuation, while wire B was connected to the RF generator through the low cut filter, which rejected currents less than 300 KHz. All data, including the intracardiac electrogram and standard ECG leads, were stored by a digital data recorder (Sony, Tokyo) and played back on the thermal recorder (NEC-Sanei, Tokyo) at a paper speed of 10–200 mm/sec.

**Definition:** Septal accessory pathways are classified into anteroseptal, midseptal and posteroseptal pathways according to the location of AP. If an AP potential or earliest ventricular activation was recorded anteriorly to the His bundle region, the pathway was classified as anteroseptal. If an AP potential or earlier activation was recorded from an area bounded posteriorly by the recording site of the His bundle potential and anteriorly by the CS ostium, the pathway was defined as midseptal.

**The ablation site:** The site of AP was determined by endocardial mapping along the annulus. The ventricular insertion site of the AP was determined by the earliest activation of the ventricle or the AP potential in manifest WPW syndrome, and the atrial insertion site was determined by the earliest activation of the atrium or the AP potential during AV reentrant tachycardia or ventricular pacing.

After inserting the His bundle and CS catheters, the anteroseptal area anterior to the His bundle catheter and the midseptal area between these two cath-
eters were mapped by the large tip electrode introduced from the femoral vein in a RAO 30° and LAO 60° projection. The optimal ablation site was determined by the electrogram stability. Since the ablation site was very close to the compact AV node, we attempted to position the catheter more to the ventricular aspect of the tricuspid annulus. Such a position is indicated by the A/V ratio of the local electrogram less than 1.8,5,11)

After successful ablation of the AP conduction, programmed electrical stimulation was attempted to investigate the function of the AV conduction and under isoproterenol infusion to examine whether tachycardia could be induced. **Patient follow-up:** All patients were examined using chest X-ray, echocardiography and blood chemistry (including CPK-MB enzyme) at 1 day, 1 week, 1 month and 3 months after ablation. Aspirin (80 mg per day) was prescribed for two months after the ablation and the patients were followed up at the outpatient clinic.

**Results**

It was possible to monitor in all 17 cases the local electrogram at the ablation site through the distal pair of electrodes of a steerable catheter during delivery of RF current. The noise caused by RF current could be eliminated by the high cut filter of the signal separator when using an output of RF current less than 40 W. When the output was greater than 40 W, there was slight noise interference with the local electrogram.

At the successful ablation site of anteroseptal APs, the atrial-ventricular (AV) interval ranged from 14 to 36 msec (22 ± 9 msec), the ventricular-delta wave interval from 14 to 32 (25 ± 5), and the atrial-ventricular amplitude ratio from 0.4 to 1.0 (0.7 ± 0.3) in antegrade AP conduction. During retrograde conduction, the ventricular-atrial interval was 55.3 ± 6.3 msec (ranging from 38 to 63 msec).

In all 10 cases with anteroseptal AP, it was possible to interrupt AP conduction immediately after the application of RF energy. It was always found to coincide with the disappearance or diminution of the AP potentials and normalization of the AV interval, monitoring the local electrogram at the ablation site (Figures 2 and 3). In 2 times of ablation procedure, we stopped the delivery of RF energy as soon as the His bundle potential was recorded clearly at the ablation site and it resulted in no complication of AV block. As a side effect, right bundle branch block occurred in one patient during catheter ablation of anteroseptal AP. It disappeared immediately upon withdrawal of the catheter and termination of RF delivery.

All 7 cases with midseptal AP were right-sided since midseptal AP is located
inside the triangle of Koch (Figure 4). At successful ablation sites, the AV interval was 40 ± 11 msec (ranging from 27 to 59 msec) and the ventricular-delta wave interval 17 ± 5 msec (range of 11–24) during sinus rhythm. During retrograde conduction, the ventricular-atrial interval was 69 ± 9 msec (range of 58–80). The AP potential could be recorded in 4 of 7 cases. The A/V ratio was 0.4 ± 0.3 (0.1–0.8).

During the application of RF energy, the A/V ratio of the local electrogram at the ablation site was continuously monitored and was maintained at less than 1 in all cases (Figure 5). Accelerated AV junctional rhythm was observed in 5 subjects immediately after starting the delivery of RF energy when the earliest activation of the atrium was recorded at the ablation site. In 2 cases it was followed by VA block in whom a normal AV interval was resumed by stopping the delivery of RF energy as soon as possible. In all cases, delta waves and AP potentials disappeared simultaneously. After ablation, AH interval was 63 ± 22
Figure 3. Surface ECG lead II, V1, His bundle electrogram (HBE), coronary sinus electrogram (CS), and the local electrogram at the ablation site (ABL). Before ablation, the atrial and ventricular potentials were recorded in conjunction with an accessory pathway potential (K). Immediately after RF application (output of 20 W), accessory pathway conduction was interrupted simultaneously with disappearance of the delta wave and normalization of the atrioventricular (AV) interval. Arrow = Artifact due to the collision of two electrodes.

msec (range 55–90) and HV interval 45±8 msec (range 35–55). The blocking cycle length was 270±42 msec (range 220–320) for antegrade AV conduction and 310±94 msec (range 210–420) for retrograde conduction.

In all 17 cases, the interruption of AP was accomplished without any complications related to the ablation procedure such as pericardial effusion, pulmonary embolism or life threatening arrhythmia, by monitoring the local electrograms as well as the impedance at the ablation site during RF delivery.

One subject experienced a recurrence of AP conduction, however this was successfully treated by the second session. There were no late complications during follow-up periods of 4 to 46 months.

**DISCUSSION**

It is feasible to monitor the local electrogram at the tip of the ablation catheter using a signal separator during RF ablation of AP. Monitoring the A/V ratio of the local electrogram at the ablation site during RF application allowed
Figure 4. In the RAO 30° (top) and LAO 60° (bottom) projections, the optimal ablation site is determined by mapping the area between the His bundle and coronary sinus catheter using the large tip electrode. Since the ablation site is very close to the compact AV node, we attempted to position the catheter more to the ventricular aspect of the tricuspid annulus. This position is indicated by an A:V ratio of the local electrogram of less than 0.5.

us to undertake the selective ablation of AP. In all 17 cases in the present study, septal APs near the AV node could be successfully interrupted without complications such as AV block. The successful ablation of AP depends on the stability of the local electrograms, AP potential, AV interval and the A/V ratio. Conventionally, local electrograms at ablation sites are recorded before RF application. During RF application, the location of the tip of the catheter electrode is confirmed by fluoroscopy. It is difficult however to precisely assess whether the catheter is in close contact with the target site, such as the AV junction, where movement of the catheter electrode is likely as the heart beats. Local electrogram-guided ablation is more accurate than fluoroscopic-guided ablation for positioning the electrode catheter. It has been difficult to record local electrograms at ablation sites by attenuating RF noise using a conventional filtering system since the power of the RF energy was 20–40 W (corresponding to 30–50 V), which is 10,000 times greater than the input signals (0.1 to 5 mV). Due to the
Figure 5. Surface ECG leads II and V1 and His bundle electrogram (HBE), coronary sinus electrogram (CS) and the local electrogram at the ablation site (ABL). Before ablation, the A:V ratio of the local electrogram at the ablation site was less than 0.5. The AV and AK intervals were 50 msec and 30 msec, respectively. Immediately after applying the RF energy, accelerated AV junctional rhythm occurred with 1:1 AV conduction, but was soon followed by VA block. However, normal sinus rhythm resumed before stopping delivery of the RF energy. The A/V ratio of the local electrogram was continuously monitored so as to maintain the ratio less than 0.5 during application of the energy. The delta wave and K potential disappeared at the same time.

fundamental differences in signal frequencies between the local electrogram (10 to 230 Hz) and RF current (520 KHz), the signal separator has permitted us to attenuate high-frequency noises and obtain low frequency electrograms at the ablation sites in all cases.

The anteroseptal AP is located close to the His bundle and right bundle branch.8,9,12) If the electrodes for ablation are inserted too deeply towards the ventricle, right bundle-branch block (RBBB) can develop. If the electrodes are inserted too proximally to the tricuspid annulus, AV block may occur due to ablation of the AV node-His bundle junction or the non-perforating part of the His bundle. The perforating part of the His bundle is surrounded by the central fibrous body and is relatively resistant to heating. Therefore, AV block can be avoided by ablation of this AP at this level. The optimal location of the electrode catheter relative to the annulus is determined by the A/V ratio and the presence or absence of His bundle electrograms. Successful ablation using the signal separator could be performed without causing AV block if the A/V ratio of the local
electrogram at the ablation site was maintained below 1 (during AP conduction) or below 0.5 (after interruption of the AP) while simultaneously confirming the absence of His bundle potential.

Midseptal AP are subclassified into right and left midseptals. All of our 7 cases were right midseptal, with the distance between the AP and His bundle ranging between 11 and 34 mm. AV block can be caused by compact AV nodal ablation if the midseptal AP is within 1 cm of the His bundle. If the ablation electrode is located higher than the tricuspid annulus, the input of the fast pathway from the anterior septum to the AV node can be damaged, causing AV block. It is important to keep the A/V ratio of the local electrogram below 0.5 to avoid damage to the AV node during RF application since the muscular interventricular septum separates the right atrium from the left ventricle and the tricuspid annulus is displaced apically with respect to the mitral annulus.

Accurate ablation of the midseptal AP without any serious complications was achieved by monitoring local electrograms during RF. The slow pathway conduction disappeared after ablation in one case with dual AV nodal pathway, although no serious damage to the normal AV conduction system was noted because the fast pathway conduction remained intact.

Four of 7 cases exhibited AV junctional rhythm because the midseptal accessory pathway is located close to the atrioventricular node. Analysis of the local electrograms of these 4 cases upon the appearance of AV junctional rhythm revealed that the atrial electrograms of the area to which RF was applied proceeded to atrial excitation of the His bundle electrogram. This indicates that the AV junctional rhythm is attributable to enhanced automaticity of the RF ablation site, but does not originate from the compact AV nodal cells, and seems to reflect the enhancement of automaticity due to the heating of transitional cells by ablation.

The appearance of AV junctional rhythm during ablation of anteroseptal AP indicates that the non-perforating area of the His bundle or the NH lesion has been ablated, although we have never experienced such a case. This site is a major component of the fast pathway, and damage may lead to complete AV block. Ablation should be immediately discontinued if AV junctional rhythm appears during ablation of the anteroseptal pathways.

**CONCLUSION**

The ablation of anteroseptal or midseptal APs very close to the normal AV conduction system can be performed accurately and safely without complication by AV block using fluoroscopic-guidance combined with the monitoring of local
electrograms at the ablation site.

REFERENCES