Table 1. The distance between the positions of the catheter tip

Patient Number	Location of the accessory pathway	Before elimination of the accessory pathway		After elimination of the accessory pathway	
		RAO	LAO	RAO	LAO
1	Left antero-lateral	15.8 ± 1.4	16.1 ± 1.7	16.3 ± 1.2	16.3 ± 1.3
2	Left antero-lateral	15.8 ± 1.4	16.1 ± 0.8	16.3 ± 1.2	16.3 ± 1.6
3	Left postero-lateral	12.4 ± 1.2	10.1 ± 0.9	12.3 ± 1.2	11.3 ± 0.9
4	Right lateral	12.8 ± 0.8	7.7 ± 0.8	12.0 ± 1.0	7.6 ± 1.0
5	Right antero-lateral	9.0 ± 1.2	11.1 ± 1.3	9.3 ± 1.6	11.3 ± 1.4
6	Left septal	13.5 ± 1.4	15.3 ± 1.2	12.8 ± 1.2	14.8 ± 1.0
Mean		13.2 ± 2.5	12.7 ± 3.6	13.1 ± 2.7	12.9 ± 3.5

Data are expressed as mean ± SD in mm.
LAO, 45˚ left anterior oblique view; RAO, 30˚ right anterior oblique view.
There is no significant difference between values obtained before and after elimination of the accessory pathway in either projection.

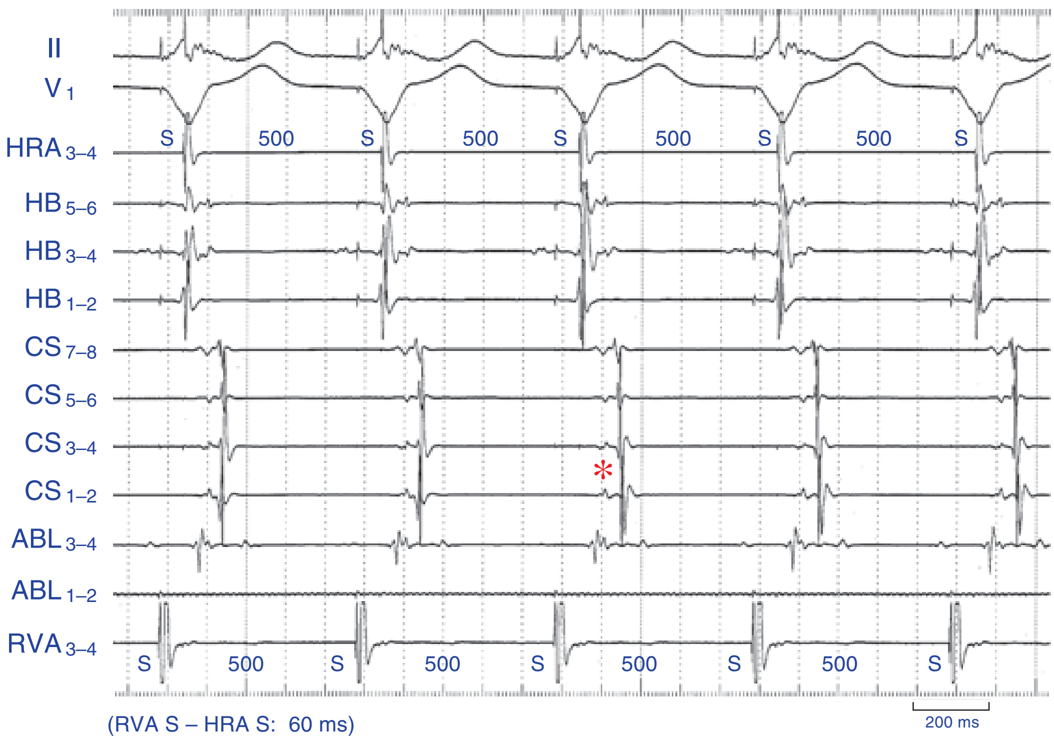

Fig. 6. Surface electrocardiographic (ECG) tracings and intracardiac electrograms recorded during radiofrequency (RF) catheter ablation of a concealed left lateral accessory pathway during sequential ventriculo-high right atrium (HRA) pacing (VRA pacing). This figure demonstrates, from top to bottom, ECG leads II and V_1; intracardiac electrograms recorded from the HRA, proximal ($HB_{5–6}$) and distal ($HB_{1–2}$) His-bundle region, proximal ($CS_{7–8}$) and distal ($CS_{1–2}$) coronary sinus (CS), proximal ($ABL_{3–4}$) and distal ($ABL_{1–2}$) bipoles of the ablation catheter, and right ventricular apex (RVA). The earliest retrograde atrial activation prior to ablation is observed at the distal CS ($CS_{1–2}$). The HRA is paced constantly at an interval of 60 ms following the constant right ventricular (RV) pacing with a drive cycle length of 500 ms before the application of RF current. In this situation, the 2 activation waves in the left atrium, one through the accessory pathway during the RV pacing and the other from the right atrium resulting from the sequential VRA pacing, collided between $CS_{3–4}$ and $CS_{5–6}$. Note the change in the activation sequence of the atrium at $CS_{1–2}$ within 5 s of initiation of the RF energy application as indicated by the asterisk. This change exhibited by lengthening of the ventriculo-atrial interval at $CS_{1–2}$ during sequential VRA pacing, shows that the accessory pathway conduction is eliminated by the RF current. The paper speed is 100 mm/s. S, stimulus artifact.

retrograde atrial activation pattern. After observing that the local atrial activation sequence at CS_{1-2} indicated that there was a loss of VA conduction over the accessory pathway 5 s after RF current delivery had begun, and the RF current was continued for 60 s. During the RF application, the ablation catheter had a stable position and no fusion beats occurred.

Other examples from a patient with a right-sided accessory pathway are shown in Fig. 7. In this case, sequential VCS pacing was performed at a cycle length of 500 ms and with a VA interval of 90 ms. The distal (TVA_{1-2}) and proximal (TVA_{3-4}) bipoles of the quadripolar catheter placed near the accessory pathway reflected the activation of the atria through the accessory pathway during the right ventriculo-basal pacing. When a change in the local atrial activation sequence in the TVA was observed at 7 s after initiation of RF current delivery, indicating loss of VA conduction over the accessory pathway, the RF application was continued for 60 s. During the RF application, the position of the ablation catheter was stable and no fusion beats occurred.

Complications

There were no complications, such as hemodynamic disturbance or serious arrhythmias

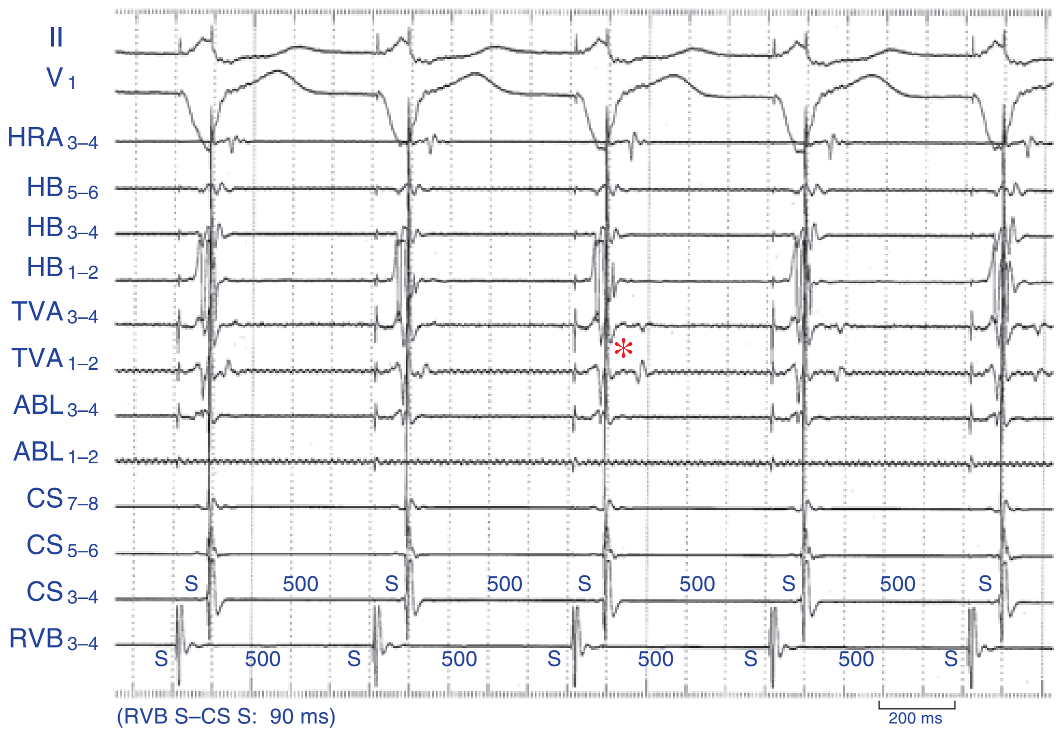

Fig. 7. Surface electrocardiographic (ECG) tracings and intracardiac electrograms recorded during radiofrequency (RF) catheter ablation of a concealed right lateral accessory pathway during ventriculo-coronary sinus (VCS) pacing. This figure demonstrates, from top to bottom, ECG leads II and V_1; intracardiac electrograms recorded from the high right atrium (HRA), proximal (HB_{5-6}) and distal (HB_{1-2}) His-bundle region, proximal (TVA_{3-4}) and distal (TVA_{1-2}) bipoles of the quadripolar catheter placed at the tricuspid valve annulus (TVA), proximal (ABL_{3-4}) and distal (ABL_{1-2}) bipoles of the ablation catheter, proximal (CS_{7-8}) and distal (CS_{3-4}) coronary sinus (CS), and right ventriculo-basal (RVB) region. The TVA catheter was placed near the accessory pathway. The CS is constantly paced before the application of the RF current at an interval of 90 ms after the constant RVB pacing stimulus with a drive cycle length of 500 ms. Note the change in the activation sequence of the atrium at TVA_{1-2} within 7 s after initiating the RF application, as indicated by the asterisk. This change shows that the accessory pathway conduction is eliminated by the RF current. The paper speed is 100 mm/s. S, stimulus artifact.

during the procedure. No accidents involving impedance rises while delivering energy through the ablation catheter occurred during the sequential VRA or VCS pacing.

Discussion

The main findings of this study

In the present study, we found that: i) the AV dissociation after elimination of accessory pathway conduction during the delivery of the RF energy when using RV pacing made the stability of ablation catheter worse; and ii) sequential VRA or VCS pacing during the RF application provided a useful method for maintaining a stable catheter position for catheter ablation of accessory pathways.

The relationship between AV dissociation and the stability of the ablation catheter

In this study, the manner of AV annulus motion was probably related to ventricular contraction rather than the atrial contraction. In visually comparing the TVA motion during sequential VA pacing with that during RV pacing on fluoroscopy, we could not find any significant difference in the degree of movement of the catheter on the TVA between these 2 pacing methods. However, when a fusion beat during RV pacing occurred, the distances observed with the fusion beats were substantially longer than those during sequential VA pacing. In other words, the AV annulus motion during AV dissociation occurring during the RV pacing exhibited little change when no fusion beats occurred. On the other hand, when fusion beats during RV pacing occurred, there was a strong and abrupt movement of the catheter on the TVA. Occetta et al. (1990) reported that adequate ventricular diastolic filling was important for the efficiency of the subsequent ventricular ejection. Dritsas et al. (1993) reported that the magnitude of the beat-to-beat variability in the stroke volume during VVI pacing reflects the relative contribution of the atrium to LV filling. Kuo et al. (1987) reported that left ventricular compliance increased the dependence of cardiac output on atrial filling during late diastole. In our case, ventricular filling was increased by atrial filling in order to maintain AV synchrony with fusion beats. Furthermore, the fusion beats in which the QRS complex on the electrocardiogram was narrower than that with RV pacing, had a reduced ventricular activation time. The ejection timing for each ventricle with fusion beats was shorter than with RV pacing. Therefore RV pacing altered the ventricular contraction during fusion beats. We considered the cause of the ablation catheter dislodgment might be due to the change in the manner of AV annulus motion produced by the alteration in the ventricular contraction pattern during fusion beats.

The novel technique for maintaining catheter position during RF application

Li et al. (1994) reported that entrainment of orthodromic tachycardia during RF application was useful for maintaining catheter position for accessory pathway ablation during atrioventricular reentrant tachycardia. Entrainment of orthodromic tachycardia with RV pacing prevents this abrupt slowing when the orthodromic tachycardia is terminated. However, if the rate of the tachycardia is relatively fast, the patients may experience discomfort due to worsening of the hemodynamic status from the rapid RV pacing at a rate faster than the tachycardia, making it impossible to continue to ablate the pathway. By using sequential VA pacing, none of the patients complained of any symptoms (data not shown). In this study, the rate of sequential VA pacing was not so fast, and we felt that the sequential VA pacing did not affect the hemodynamic status.

RV pacing before the elimination of the accessory pathway conduction by the RF energy delivery also prevents catheter dislodgment empirically. We believed this was due to the stability of the catheter from VA conduction occurring through the accessory pathway during the RV pacing. However, after elimination of accessory pathway conduction, we usually observed catheter dislodgment. This is because the ventricular contraction pattern changes from VA conduction due to RV pacing to AV conduction in fusion beat when the sinus node function recovers after the accessory pathway is eliminated. If retrograde AV nodal conduction occurs during parahisian pacing, there should be little chance of dislodgment since fusion beats also should not occur (Buitleir and Morady, 1997). Clinically, in the case of retrograde conduction propagating through both the AV node and accessory pathway, RV pacing during ablation of accessory pathways was effective in preventing dislodgment of the ablation catheter when no fusion beats occurred. On the other hand, in the case of retrograde conduction propagating through the accessory pathway alone, when fusion beats during RV pacing occurred, there was a strong and abrupt movement of the ablation catheter. As a result, elimination of the accessory pathway may cause dislodgment of the catheter.

Sequential VRA or VCS pacing during RF application

sequential VRA or VCS pacing which inhibits the sinus node function during RF energy delivery is necessary in order to prevent catheter dislodgment. We felt that sequential VRA and VCS pacings were good optional techniques. During the sequential VRA or VCS pacing, dislodgment of the ablation catheter did not occur when elimination of the accessory pathway conduction occurred during the RF application in any of the patients. Fusion beats did not occur since the atrium was activated by the constant atrial pacing instead of propagation through the accessory pathway from the RV pacing following elimination of the accessory pathway conduction. However, strictly speaking, the local activation pattern changed from that of conduction over the accessory pathway to that of atrial pacing, and in a patient with a septal accessory pathway this change was remarkable. We believed that using sequential pacing was better than RV pacing alone, when the accessory pathway was eliminated, because it prevented fusion beats.

One of the problems with this technique was that the optimal RV-HRA or RV-CS pacing interval was necessary to program for various accessory pathway locations. The most optimal pacing interval was programmed to the maximum interval at which the atrial wave front propagating from the HRA or CS pacing site did not hide the earliest activation of the left or right atrium through the accessory pathway. Further, this pacing interval, which was programmed in order to minimize the local atrial activation through the accessory pathway, minimized the change in the manner of AV annulus motion when the atrium was activated by constant atrial pacing instead of through the accessory pathway from the RV pacing following the elimination of the accessory pathway conduction.

Conclusion

The AV dissociation after the elimination of the accessory pathway conduction during RF energy delivery while using RV pacing worsened the stability of the ablation catheter. During the RF application, sequential VA pacing was better than RV pacing, because no fusion beats occurred. Furthermore, sequential VRA or VCS pacing during the RF application provides a useful method for maintaining stable catheter position for catheter ablation of accessory pathways. This technique may be especially useful in patients with concealed accessory pathways and no retrograde conduction over the AV node.

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