Atrial Components Contributing to Pseudo r' Deflection in Lead V₁ in Slow/Fast Atrioventricular Nodal Reentrant Tachycardia
— Analysis of the Atrial Activation Sequence by Basket Catheter Isochronal Mapping —

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Electrocardiographic recognition of the P' wave during tachycardia is very useful in the diagnosis of supraventricular tachycardias. In slow/fast (S/F) atrioventricular nodal reentrant tachycardia (AVNRT), no discrete P' waves are observed on ECG and pseudo r' deflection in lead V₁ (pseudo r') is commonly recognized. However, the atrial components that contribute to the genesis of pseudo r' in lead V₁ have not been described and this study aimed to clarify them by analysis of the whole activation sequence of the right atrium using Basket catheter isochronal mapping. The study group comprised 48 patients with AVNRT. Pseudo r' was defined as an upward deflection in the terminal portion of the QRS complex during tachycardia that was not recognized during sinus rhythm and it occurred in 45 patients (94%). During S/F AVNRT, the retrograde atrial activation was earliest on His bundle electrogram, followed by the coronary sinus ostium, distal coronary sinus and high right atrium. Only the high lateral aspect of the right atrium was activated after the end of the QRS complex. The interval between the onset of QRS in multiple surface ECG leads and the atrial activities on high right atrium was similar to the V-r' interval in lead V₁ (111±20 ms, 117±11 ms) and correlated with the V-r' interval (r=0.56). Pseudo r' deflection in lead V₁ is a highly sensitive indicator of S/F AVNRT, and appears to result from the activation of the superolateral aspect of the right atrium. (Circ J 2002; 66: 236–240)

Key Words: Atrial activation sequence; AV nodal reentrant tachycardia; Pseudo r' deflection

Methods

Patient Population
The subjects were 48 patients (10 males, 38 females; mean age, 58±22 years [mean±SD]) undergoing an electrophysiologic study (EPS).

The diagnosis of S/F AVNRT was made during the EPS, as described previously.6–8 The 12-lead ECGs and the intracardiac electrograms were analyzed and patients with other types of supraventricular tachycardias, including fast/slow AVNRT or slow/slow AVNRT, were excluded.

Electrophysiologic Study
The EPS was performed after discontinuing cardioactive drugs for at least 5 half-lives. Written informed consent was obtained from all patients prior to the study, and the procedure was carried out in accordance with local ethical standards. Two 6-Fr quadripolar electrode catheters with 5 mm interelectrode spacing (USCI (Division of CR Bard), Billerica, MA, USA) were positioned under fluoroscopic guidance at the high right atrium and right ventricular apex for pacing and recording. A 5-Fr decapolar electrode catheter with 2- and 8-mm interelectrode spacing (Cordis-
Webster Inc, Baldwin Park, CA, USA) was inserted into the coronary sinus and positioned at the coronary sinus so that the most proximal pair straddled the ostium. A 6-Fr octapolar steerable electrode catheter with 2 mm interelectrode spacing was placed across the tricuspid valve to record the His bundle electrogram (Cordis-Webster Inc).

Electrocardiographic leads (I, II, aVF, V1) and the intracardiac electrograms were simultaneously displayed, recorded on a multichannel recorder at a speed of 100 or 200 mm/s (RECOR, Siemens-Elema AB, Sweden) or stored on an optical disk using a computer-based signal acquisition system (EP Labo, Quinton Medical, Toronto, Canada). Filters were set at 0.05–100 Hz for the surface ECG recordings and 30–500 Hz for the intracardiac electrograms. Atrioventricular nodal reentrant tachycardia was induced and terminated by programmed atrial and/or ventricular pacing. Electrical stimulation was performed with a programmable stimulator (SEC-3102, Nihon Kohden Inc, Tokyo, Japan).

In 5 patients, time windows covering the entire right atrial activation were mapped using the Basket catheter system (Constellation, EP Technologies, San Jose, CA, USA) as reported previously. An isochronal map was displayed using the QMS mapping system (CathDatas Inc, Toronto, Canada). Time windows that covered the entire activation of the right atrium were arbitrarily selected. Early activation was represented by red, and later activation was expressed by yellow, green, blue and purple.

Definitions

Pseudo r' deflection in lead V1 was defined as an upward deflection recognized in the terminal portion of the QRS complex during tachycardia that was not observed during sinus rhythm. A tiny upward deflection was also accepted in the definition. The V-r' interval was measured as the interval from the onset of ventricular activity and to the end of the r' wave in lead V1. The V-A HRA interval, V-A HBE interval, V-A CS os interval, and V-A CS distal interval were measured as intervals from the onset of ventricular activity to the end of atrial activity in the high right atrium, to the onset of atrial activity of the His bundle electrogram, to the onset of atrial activity on the proximal coronary sinus (Fig 1).

Fig 1. Definitions of measurements. V-r' V1: interval from the onset of QRS to the end of r' deflection on lead V1 (arrow). V-A HRA: interval from the onset of QRS to the end of atrial activity on HRA (arrow). V-A HBE: interval from the onset of QRS to the onset of atrial activity on HBE (arrow). V-A CS dis: interval from the onset of QRS to the end of atrial activity on distal CS (arrow). V-A CS os: interval from the onset of QRS to the onset of atrial activity on CS ostium (arrow).

Fig 2. Electrocardiogram during sinus rhythm and S/F AVNRT. (A) A tiny pseudo r' deflection is observed in lead V1 during AVNRT (right panel), but not during sinus rhythm (left panel). Insets show the magnified view of the V1 lead during sinus rhythm (right) and S/F AVNRT (left). (B) In a patient with chronic obstructive lung disease, right atrial overload is recognized in the inferior leads during sinus rhythm (left panel), and an extremely prominent r' deflection (0.5 mV) is seen in lead V1 during S/F AVNRT (right panel).

Circulation Journal Vol.66, March 2002
sinus, and to the end of atrial activity on the distal coronary sinus (Fig 1).

Statistics

Values are expressed as mean±SD. Statistical comparisons were performed using Student’s t-test for paired data. Linear correlation and linear regression analysis were used to test the correlation between 2 variables. A p<0.05 was considered significant.

Results

Recognition of Pseudo r' Deflection

Pseudo r' deflection in lead V1 was recognized in 45 of 48 patients (94%) (Fig 2A). Pseudo r' deflection exceeded the baseline level in 36 patients (75%), but not in 9 patients (19%). In one patient with chronic obstructive lung disease, an extremely prominent pseudo r' deflection (0.5 mV) was recognized in lead V1 during S/F AVNRT while right atrial overload was recognized in the inferior leads during sinus rhythm (amplitude of the P wave was 0.3 mV in lead II) (Fig 2B).

There was no significant correlation between the amplitude of the pseudo r' deflection during S/F AVNRT and the amplitude of the P wave in lead V1 during sinus rhythm (r=0.003). Pseudo r' deflection was not observed in any patients during right atrial or coronary sinus pacing at the same cycle length as S/F AVNRT.

Atrial Activation Sequences

During S/F AVNRT, the earliest retrograde atrial activation was recorded in the His bundle region in 45 patients (94%) and in the proximal coronary sinus in 3 patients (6%). The following atrial activations were recorded in the proximal coronary sinus, and then in the distal coronary sinus. The latest activation was recorded in the high-right atrium in 45 patients (94%), and in the distal coronary sinus in 3 patients (6%) (Fig 3). The average QRS interval during sinus rhythm was 90±9 ms, whereas V-A HBE, V-A CS os, V-A CS distal and V-A HRA were found to be –12±7, 36±21, 86±20, and 110±20 ms, respectively. The error bar represents 1 SD.

Fig 3. Comparison of the QRS intervals and atrial activation times. The average QRS interval was 90±9 ms, whereas V-A HBE, V-A CS os, V-A CS distal and V-A HRA were found to be –12±7, 36±21, 86±20, and 110±20 ms, respectively. The error bar represents 1 SD.

Fig 4. Isochronal map of the right atrial activation sequence during sinus rhythm (upper panel) and AVNRT (lower panel). The center and the margin of the ring coincide with the superior and inferior right atrium, respectively. During sinus rhythm, the first right atrial excitation occurred in the upper posterolateral right atrium (sinus node area, colored red), and the activation wave thenspread eccentrically through the other parts of the right atrium. During AVNRT, the earliest right atrial excitation occurred in the lower septal right atrium (first AV nodal pathway), and was conducted eccentrically. The latest excitation occurred in the middle to high lateral right atrium.

Fig 5. Comparison and correlation between the V-A HRA interval and V-r' interval. There was no significant difference between them (110±20ms vs 118±11 ms), but a significant correlation was detected (r=0.56, p<0.01).
mapped using the Basket catheter and displayed as an isochronal map (Fig 4). During sinus rhythm, the first excitation appeared in the superior posterolateral aspect of the right atrium (sinus node area), and the activation wave then eccentrically spread through the other parts of the right atrium. However, during S/F AVNRT, the earliest excitation appeared in the inferior septal aspect of the right atrium (fast pathway area), and was conducted eccentrically. The latest excitation occurred in the middle to high lateral right atrium (sinus node area). The major right atrial activation was oriented in the posteroseptal to anterolateral direction.

**V-A HRA Interval and V-r’ Interval**

There was no significant difference between the V-A HRA and V-r’ interval in lead V1 (110±20 ms vs 115±11 ms) (Fig 5). Moreover, a significant correlation between the V-A HRA and V-r’ interval was observed (slope=0.89, r=0.56, p=0.01). The slope of the linear regression line was nearly one.

**Discussion**

**Main Findings**

In most patients with S/F AVNRT, either no discrete P waves are observed on surface electrocardiography, or the terminal part of the QRS complex is slightly distorted, showing a possible ‘pseudo-S wave’ in the inferior leads, a ‘pseudo-r’ wave’ in lead V1, or non-specific terminal notchings.3 In patients in whom the P wave distorts the terminal QRS, the tachycardia must be distinguished from circus movement tachycardia using a bypass tract.1,4 In the present study, because a slight positive deflection was also included, the sensitivity of the pseudo r’ deflection in lead V1 was as high as 94% (45 of 48 patients).

The final atrial excitation was observed at the high-right atrium (Fig 4), and was excited after completion of the QRS complex. The pseudo r’ deflection appeared almost simultaneously with the excitation of the high-right atrium. Accordingly, a pseudo r’ deflection may arise from excitation of the superolateral aspect of the right atrium.

**Sensitivity and Clinical Usefulness of Pseudo r’ Wave in Lead V1**

Few studies have examined the sensitivity or clinical usefulness of the pseudo r’ in lead V1.5 Kalbfleish et al reported that the sensitivity, specificity, and the predictive value of the pseudo r’ in S/F AVNRT were 58%, 91%, and 82%, respectively.1 In the present study, because even a slight r’ deflection that did not exceed the baseline level of the QRS-ST junction was included, the sensitivity was as high as 94%.

**Atrial Activation Sequences and the Mechanisms of Appearance of Pseudo r’ Deflection in Lead V1**

During typical AVNRT in the present cases, the earliest site of retrograde atrial activation was in the His bundle electrogram, followed by the electrograms recorded in the coronary sinus ostium, distal coronary sinus, and finally the high-right atrium. These findings were similar to those of previous studies.10,11 In most of the present patients (94%), the latest atrial activation (HRA) occurred after the end of the QRS complex (V-A HRA interval >QRS duration). Excitation of the other parts of the atrium was buried in the QRS complex. Only the superolateral aspect of the right atrium was excited following completion of ventricular activity.

These results suggest that the pseudo r’ deflection may be caused by activation of the superolateral aspect of the right atrium (ie, HRA), which occurs after the end of the QRS complex. Moreover, in one patient with chronic obstructive lung disease, a prominent r’ deflection was observed in lead V1 during S/F AVNRT and a prominent P wave was recognized in the inferior leads during sinus rhythm (Fig 2B). This finding further supports the contention that pseudo r’ deflection originates from the right atrium. According to the Basket catheter isochronal map, right atrial activation proceeds from the posteroseptal to the anterolateral direction.

Kalbfleish et al proposed another possible explanation for r’ deflection as a rate-related right ventricular conduction delay! In the present study, no pseudo r’ was observed in any patients during right atrial or coronary sinus pacing at the same cycle length as S/F AVNRT. Accordingly, the rate-related right ventricular conduction delay may have been excluded.

**Usefulness of Basket Catheter Isochronal Mapping**

The Basket catheter has been used successfully in human studies to define atrial arrhythmias and its reliability, feasibility, and safety in the right atrium have been demonstrated.4,12,13 However, clinical experience with Basket catheter isochronal mapping in patients with AVNRT has not been published. The main advantage of this mapping system is the simultaneous and multiple recordings for almost the entire right atrial endocardial surface, and the construction of 2-dimensional patterns of activation.13 The color coded images assist in navigating the catheter during ablation.

**Implications and Limitations**

Electrocardiographic diagnosis of supraventricular tachycardia is very important and the pseudo r’ wave in lead V1 is a useful diagnostic marker for S/F AVNRT. In the present study, the positive rate (sensitivity) of pseudo r’ deflection in lead V1 in patients with S/F AVNRT was as high as 94% because even a slight positive deflection of the QRS-ST junction in lead V1 was also considered as a ‘pseudo r’ deflection’. However, the specificity and predictive value of pseudo r’ deflection in V1 were not clarified because the other categories of supraventricular tachycardias were not included in the present study.

In cases of aberrant conduction, pseudo r’ deflection was not noted because completion of the ventricular excitation may have occurred later than the excitation of the high right atrium. In a small number of patients with S/F AVNRT (6%), pseudo r’ deflection in lead V1 was not recognized. In such cases, alternative electrocardiographic criteria are required.

**References**


