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【 ORIGINAL ARTICLE 】

The Utility of a Lewis Lead for Distinguishing Atrioventricular Reentrant Tachycardia from Typical Atrioventricular Nodal Reentrant Tachycardia

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Abstract:

Objective The Lewis lead configuration is an alternative bipolar chest lead and it can help detect atrial activity. The utility of the Lewis lead to distinguish orthodromic atrioventricular reentrant tachycardia (AVRT) from typical atrioventricular nodal reentrant tachycardia (AVNRT) by visualizing the apparent retrogradely conducted P waves was investigated.

Methods Forty-four patients with paroxysmal supraventricular tachycardia (PSVT) were included in this study. All patients had PSVT documented by an electrocardiogram (ECG) and underwent an electrophysiological study (EPS). During tachycardia, an ECG recording was performed using a Lewis lead with the electrode on the right aspect of the sternum at the second intercostal space instead of the right arm and the electrode on the fourth intercostal space instead of the left arm. The ECG parameters during tachycardia were compared between AVRT and AVNRT.

Results Fourteen patients were diagnosed with AVRTs and 30 with typical AVNRTs on EPS. The positive P wave could be seen in the Lewis lead configuration in 9 of 14 patients with AVRTs and 21 of 30 patients with AVNRTs. P waves were more often visible in the Lewis lead configuration than in the standard leads (66% vs. 45%). The RP interval was significantly longer for AVRTs than for AVNRTs (88±17 vs. 154±34 ms, $p<0.001$), which yields 89% sensitivity and 71% specificity for distinguishing these 2 tachyarrhythmias with a cut-off point of 100 ms.

Conclusion A Lewis lead configuration may help to make an accurate diagnosis among the reentrant supraventricular tachycardias prior to procedures, owing to its ability to locate P waves.

Key words: Lewis lead, electrocardiogram, paroxysmal supraventricular tachycardia

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Introduction

Orthodromic atrioventricular reentrant tachycardia (AVRT) mediated by a concealed accessory pathway and typical atrioventricular nodal reentrant tachycardia (AVNRT) are the most frequent types of paroxysmal supraventricular tachycardias (PSVTs). Implementing non-invasive differential diagnosis of PSVTs prior to an electrophysiological study (EPS) may help specialists to select the optimal treatment (i.e. medication or catheter ablation) and eventually help electrophysiologists select their approach to the procedures (i.e. choice of vascular access and diagnostic and ablation catheters). As a result, this could reduce the total procedural time, fluoroscopic exposure time, and the complication rate.

Several algorithms have been used to distinguish between these two tachycardias on 12-lead ECG observation of retrogradely conducted P waves during tachycardia, such as the presence of pseudo-r' deflection in lead V1 or a pseudo-S wave in the inferior leads, suggesting AVNRT (1, 2). However, recognizing the morphology and onset of retrogradely conducted P waves is still challenging due to the fact that they are often being hidden inside QRS or T waves.

The Lewis lead configuration, which is a bipolar chest

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lead, can help detect atrial activity better than the standard 12-lead ECG. This unique method was invented to magnify atrial electrical activity during atrial fibrillation by Lewis (3). Bakker et al. reported that the Lewis lead made it easy to recognize P-waves during wide QRS tachycardias (4). In the present study, the utility of the Lewis lead to distinguish AVRT through accessory pathways from typical AVNRT by visualizing the retrogradely conducted P-waves was investigated.

Materials and Methods

Study patients

A total of 44 patients with paroxysmal narrow QRS complex tachycardia documented on 12-lead ECG who had an EPS between July 1, 2012 and February 1, 2014 were included in this study. The indications for EPS and catheter ablation were determined individually based on the clinical situation and patient preference. Each patient underwent a standardized diagnostic assessment consisting of physical examination, laboratory analysis, chest X-rays, 12-lead ECG, 24-h Holter monitoring, and transthoracic two-dimensional echocardiography. Patients with long-RP tachycardia, manifest WPW syndrome, apparent sinus node dysfunction, and a disturbance of the electrical conduction system during sinus rhythm were excluded from this analysis. All patients included in this registry provided their written, informed consent to participate in the registry. The study was approved by the Institutional Review Board of Tokyo Medical University (approval number, T2020-0204).

Electrophysiological study and radiofrequency catheter ablation

All patients discontinued anti-arrhythmic drugs, beta blockers, and calcium antagonists at least five half-lives before testing to exclude any external influence on the electrical conduction system. EPS was performed with the patient in a non-sedated state.

In all patients, narrow QRS tachycardias were induced by atrial or ventricular programmed stimulation during EPS. Differential diagnosis between AVRT and AVNRT was performed according to previously described criteria (5). In summary, AVRT was defined as: 1. eccentric atrial activation during tachycardia with the retrograde activation pattern during tachycardia identical to that during rapid ventricular pacing; 2. association of prolongation of the His-ventricle (H-V) interval during tachycardia with a prolonged His-atrial (H-A) interval and an increased cycle length; 3. prolongation of ventriculoatrial (VA) conduction >35 ms, with or without a change in the tachycardia cycle length, associated with the development of bundle branch block ipsilateral to the bypass tract or during right ventricular stimulation in the presence of a left free wall bypass tract; 4. the inability to pre-excite the atrium during tachycardia when the His bundle has been depolarized and is therefore refractory to the retrograde impulse, or the depolarization of the atria by a ventricular premature depolarization delivered during ventricular pacing before retrograde activation of the His bundle; and 5. termination or delay of orthodromic tachycardia in the absence of atrial activation by a ventricular premature depolarization delivered when the His bundle is refractory to retrograde activation. Typical AVNRT (slow-fast AVNRT) was defined as: 1. the earliest atrial activation during tachycardia recorded at the His bundle electrogram; 2. dual atrioventricular (AV) node physiology; 3. VA interval during ventricular pacing - VA interval during tachycardia >85 ms; 4. ventricular post-pacing interval >115 ms longer than tachycardia cycle length with a V-A-V response; 5. VA interval (onset of ventricular activation on ECG to the earliest deflection of the atrial activation in the His bundle electrogram) <60 ms; and 6. an atrial-His/His-atrial ratio (AH/HA) >1.

ECG recording

ECGs with standard leads and with the Lewis lead configuration were recorded at a paper speed of 25 mm/s with a gain setting of 10 mm/mV at baseline during SR and tachycardia. The Lewis lead is a bipolar chest lead with the electrode on the right aspect of the sternum at the second intercostal space instead of the right arm and the electrode on the fourth intercostal space instead of the left arm (Fig. 1). The traces of the Lewis lead were recorded in lead I. In all study patients, the ECG record during EPS was reviewed by two EP cardiologists who were blinded to the diagnosis of the tachycardia. The differential diagnosis between AVRT and AVNRT was performed by ECG observation with standard and Lewis leads based on visible retrograde P waves during tachycardia. The RP interval was measured from the onset of the R wave to the onset of the next P wave on ECG during tachycardia and compared between the patients with AVRT and those with AVNRT if the retrograde P waves were visible. If the onset of the P wave was unclear due to fusion with the QRS or the T wave, then the traceable start was substituted for the onset of the P wave.

Statistical analysis

The numerical data are presented as the means ± standard deviation (SD), and categorical data are presented as absolute numbers or percentages. Serial changes in the electrophysiological parameters were analyzed with the *t*-test. Differences between the groups were analyzed by an analysis of variance (ANOVA) for continuous variables and Pearson's chi-squared test for categorical variables. The statistical analyses were performed using the IBM SPSS software program (SPSS 19; IBM, Chicago, USA). A p value less than 0.05 was considered to be significant.

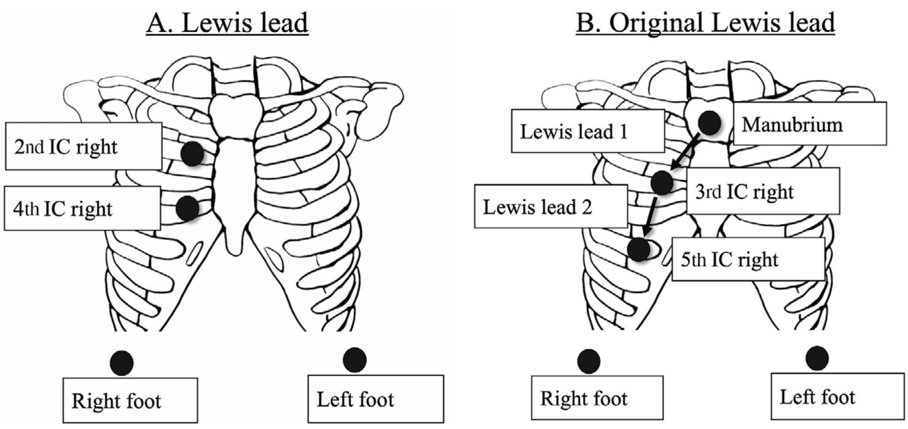

Figure 1. Lewis lead configuration. Black circles indicate the locations of electrodes. A Lewis lead with the electrode on the right aspect of the sternum at the second intercostal space instead of the right arm and the electrode on the fourth intercostal space instead of the left arm (A). The original Lewis lead 1 with the electrode on the manubrium of the right arm and the right aspect of the sternum at the third intercostal space of the left arm. The original Lewis lead 2 with the electrode on the third intercostal space of the right arm and the right aspect of the sternum at the fifth intercostal space of the left arm (B). IC: intercostal space

Table 1. Patients' Characteristics.

	AVRT (n=14)	AVNRT (n=30)	p value
Age (y)	45±15	61±14	0.002
Sex (male, %)	50	53	n.s.
Age at onset of symptoms (y)	29±20	50±20	0.004
Mean duration of episodes (h)	1.8±2	5.0±14	n.s.
Any documented co-arrhythmia (%)	2 (14%)	4 (13%)	n.s.

Data are presented as counts with percentages. Plus-minus values represent standard deviation. AVRT: Orthodromic atrioventricular reentrant tachycardia, AVNRT: atrioventricular nodal reentrant tachycardia

Results

Patients' characteristics

A total of 44 patients (age 56±16, 24 males) were included in this study. In all included subjects, physical examinations, laboratory tests, and chest X-rays did not show any significant changes. ECG documented no abnormality in sinus rhythm such as pre-excitation or PQ shortening. All patients were divided into the AVRT group (n=14) and the AVNRT group (n=30) based on the results of EPS and ablation. The characteristics and clinical history of each group are summarized in Table 1. The age and age at onset of symptoms were significantly younger in AVRT patients than in AVNRT patients (age 45±15 vs. 61±14 years, p=0.002) (age 29±20 vs. 50±20 years, p=0.004). The duration and frequency of arrhythmia were not significantly different between the two groups. Atrial fibrillation as a co-arrhythmia was documented in 14% of the AVRT group and 13% of the AVNRT group.

EPS findings and catheter ablation

In all patients, narrow QRS tachycardia was induced by programmed atrial or ventricular stimulation. The definitive diagnosis was made by the pacing maneuver and confirmed by the efficacy of catheter ablation in all patients. In the AVRT group, catheter ablation successfully eliminated all accessory pathways in all patients. The location of the accessory pathway was defined as the location of the successful ablation site, including 9 in the left, 4 in the right and 1 in the septum. In the AVNRT group, all patients were diagnosed as slow-fast AVNRT. The ablation target was the anatomical slow-pathway area between the tricuspid annulus and the ostium of the coronary sinus in the right posterior septum. Radio frequency energy was applied until junctional tachycardia was initiated. The endpoint of ablation was no inducibility of more than two consecutive AV nodal echo beats of AVNRT under isoproterenol administration. In all patients, AVNRT was not inducible after a mean of 3.9 ablation applications. In addition, no complications were observed in all patients.

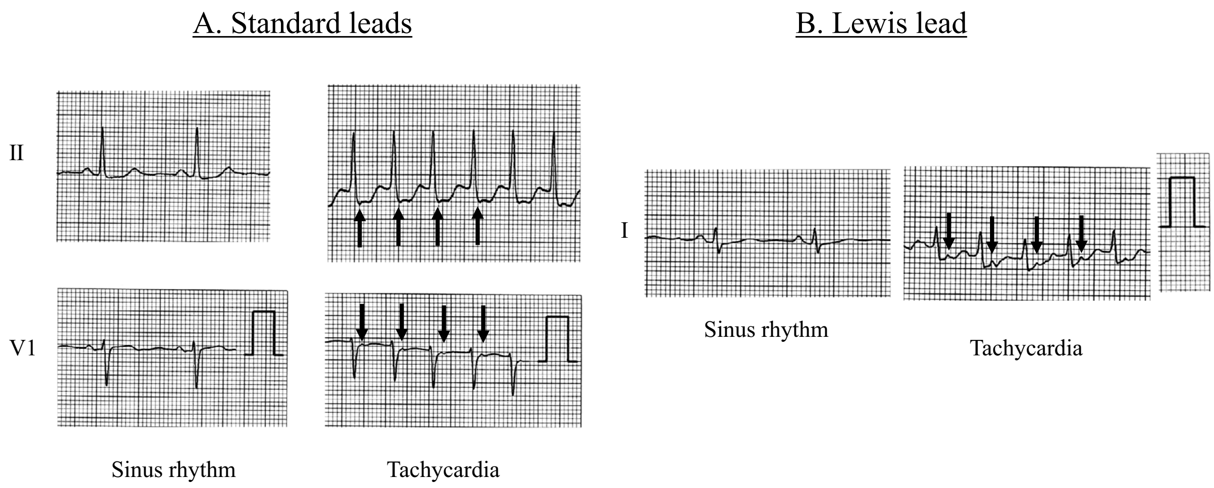

Figure 2. ECG examples of AVNRT. ECG with the standard lead II and lead V1 during sinus rhythm and tachycardia (A). ECG with lead I showing the Lewis lead in a patient with AVNRT during sinus rhythm and tachycardia (B) in the same individual. The arrows indicate a retrograde P wave during tachycardia.

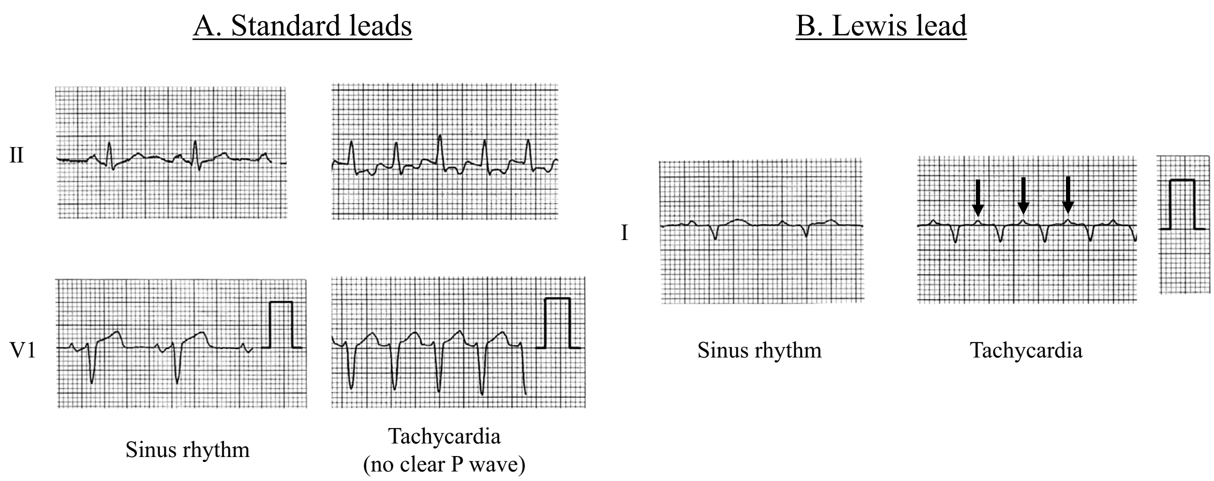

Figure 3. ECG examples of AVRT. ECG example of standard leads (A) and lead I showing the Lewis lead (B) in a patient with AVRT during tachycardia in the same individual. The arrows indicate a retrograde P wave during tachycardia.

ECG findings

In all patients, ECG recordings with standard leads and with Lewis leads during sinus rhythm and tachycardia were completed. During sinus rhythm, the P wave amplitude was significantly higher in the Lewis leads than in the standard leads I (0.08±0.04 vs. 0.04±0.01 mV, $p<0.01$). During tachycardia, P waves were seen in standard lead I in 15 of 30 (50%) patients with AVNRT, and in the Lewis lead in 21 of 30 (70%). Retrograde P waves were more visible in the Lewis lead configuration as an rSr' pattern of the QRS during tachycardia. In the patients with AVNRT, pseudo-r' waves in V1 were seen in only 11 of 30 (37%), and pseudo-S waves were seen in lead II in 6 of 30 (20%).

Fig. 2 shows one of the examples of lead II and V1 recorded as a standard lead and a Lewis lead in a patient with AVNRT. A clearer retrograde P wave can be recognized in the Lewis lead than in the standard lead during tachycardia. Fig. 3 shows a prominent P wave in the Lewis lead during tachycardia in a patient with AVRT. There are no clear P waves in the standard leads. In AVRT, P waves were visible in 4 of 14 (29%) in the standard lead and 9 of 14 (64%) in the Lewis lead.

Differential diagnosis of paroxysmal supraventricular tachycardia

ECG parameters including heart rate and QRS duration during tachycardia with standard leads were not significantly different between the AVRT group and the AVNRT group (Table 2). Cycle length alternans, defined as beat-to-beat oscillations in the cycle length >20 ms, and QRS voltage alternans, defined as beat-to-beat oscillation in QRS amplitude of >1 mm in more than 1 lead, which are specific manifestations of AVRT, were not seen in both groups. The RP interval was significantly longer in AVRT than in AVNRT (88 ±17 vs. 154±34 ms, p<0.001)(Fig. 4). Using an RP interval during tachycardia of more than 100 ms in the Lewis lead, sensitivity, specificity, positive predictive value, and negative predictive value for distinguishing AVRT from typical AVNRT were 89%, 71%, 57%, and 94%, respectively (Table 3).

Table 2. ECG Analysis during Tachycardia with the Standard Leads.

	AVRT (n=14)	AVNRT (n=30)	p value
Heart rate (bpm)	171.5±28.9	169.4±25.5	n.s.
QRS duration (ms)	81.8±10.0	84.3±10.7	n.s.
Cycle length alternans (%)	0	0	
QRS voltage alternans (%)	0	0	

Cycle length alternans is defined as beat-to-beat oscillations in the cycle length of ≥20 ms. QRS alternans is defined as beat-to-beat oscillations in QRS amplitude of ≥1 mm in more than 1 lead. Data are presented as counts with percentages. Plus-minus values represent standard deviation. AVRT: atrioventricular reentrant tachycardia, AVNRT: atrioventricular nodal reentrant tachycardia

Discussion

The present results demonstrated that a Lewis lead configuration, which is a bipolar chest lead, may help to detect retrograde P waves on the ECG during tachycardia in patients with PSVT. This distinctive lead configuration could be useful for distinguishing AVRT from typical AVNRT (slow-fast AVNRT) by measuring the RP interval. A presumptive diagnosis prior to the catheter ablation procedure is important for selecting the appropriate ablation strategy and risk stratification prior to ablation.

Identifying P waves is valuable for differential diagnosis among arrhythmias such as atrial fibrillation, ventricular tachycardia, and PSVT. For differential diagnosis of PSVT, recognizing the position of retrograde P waves has been re-

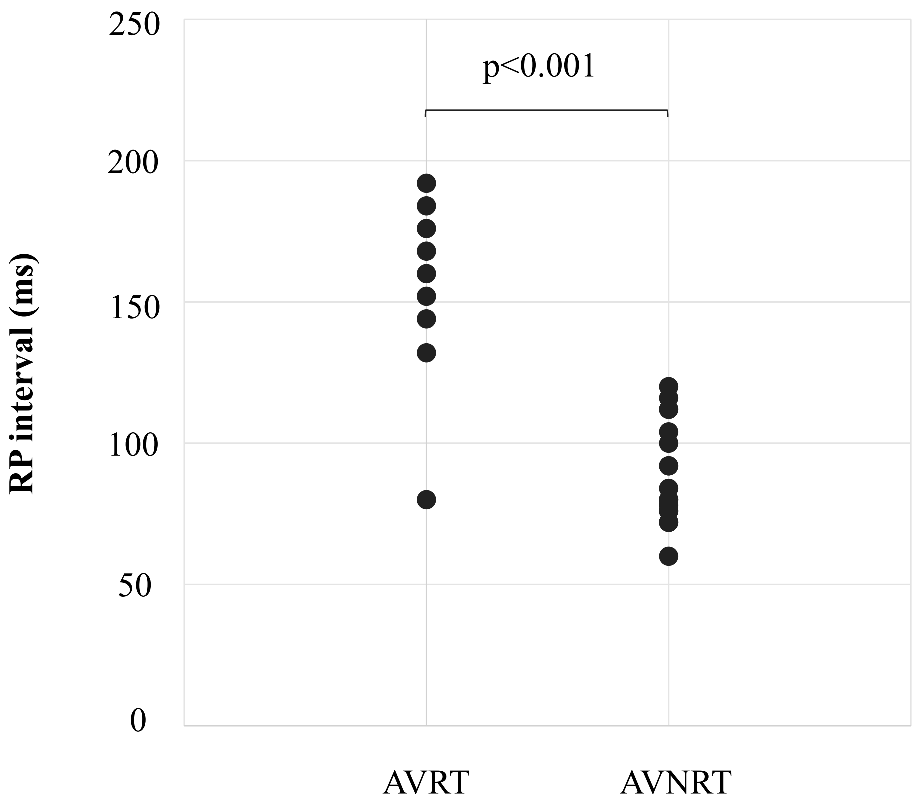

Figure 4. Comparison of the RP intervals in patients with AVNRT and AVRT. The RP interval is the time from the beginning of the R wave to the beginning of the next P wave. The plots indicate the length of the RP interval. The RP interval is significantly longer in AVRT than in AVNRT (88±17 vs. 154±34 ms, p<0.001).

Table 3. Accuracy of Diagnosis with Lewis Leads for Distinguishing AVRT from Typical AVNRT.

	Sensitivity	Specificity	Positive predictive value	Negative predictive value
AVRT RP interval ≥100 ms in the Lewis lead	89%	71%	57%	94%

AVRT: atrioventricular reentrant tachycardia, AVNRT: atrioventricular nodal reentrant tachycardia ported to be useful. In cases of orthodromic AVRT, the retrograde pulse conducts from the ventricular muscle to the atrium through the accessary pathway. The retrograde P wave can be identified after the QRS wave during the tachycardia, so-called short RP tachycardia. On the other hand, in cases of typical AVNRT, the retrograde impulse travels through the fast pathway. The simultaneous activation timing of the atrium through the retrograde fast pathway to ventricular activation veils the retrograde P wave within the QRS wave. These different properties of retrograde conduction to the atrium enable the differential diagnosis between AVRT and AVNRT. Generally, the RP interval of typical AVNRT is shorter than that of AVRT.

There are several algorithms for the diagnosis of AVNRT by retrogradely conducted P waves during tachycardia, such as the presence of pseudo-r' deflection in lead V1 or pseudo-S waves in inferior leads (1, 2). However pseudo-r' and pseudo-S waves were identified in only 37% (11 of 30) and 20% (6 of 30) of patients with AVNRT, respectively, in the present study. On the other hand, the retrograde P-wave could be found in 70% (21 of 30) with the Lewis lead in the present study.

The Lewis lead is a distinct bipolar chest lead with the right arm electrode applied to the right side of the sternum at the second intercostal space and the left arm electrode applied to the fourth intercostal space. This particular lead configuration was invented by Thomas Lewis to magnify P waves caused by atrial excitation during atrial fibrillation (3). The placements of the original Lewis leads are different from our configuration shown in Fig. 1B. The original Lewis leads were transposed from the left arm and right arm to either the right side of the sternum or the manubrium to enhance the recording of atrial activity. In the present study, the original Lewis lead was modified to record a clearer P wave, as other articles concerning the Lewis lead have described. Several case reports have suggested that the Lewis lead can be used to detect P waves dissociated from ventricular beats during ventricular tachycardia (4,6-8). Atrioventricular dissociation is one of the characteristic features of ventricular tachycardias, not of supraventricular tachycardias. Our aim was to use the Lewis lead in the differential diagnosis between AVRT and AVNRT by identifying the retrograde P wave.

The visibility of retrograde P waves is higher in Lewis leads than in the standard leads. P wave amplitude during sinus rhythm was compared between Lewis lead I and standard lead I. P wave amplitude was significantly higher in the Lewis lead than in the standard lead. However, P wave amplitude in Lewis lead I was not greater than the largest P amplitude on the standard 12-lead ECG. The vector of the Lewis lead configuration may also play an important role in the detection of retrograde P waves during tachycardia.

In the present study, an attempt was made to identify the retrograde P wave with the Lewis lead and measure the RP interval during tachycardia. An RP interval of greater than 100 ms was more likely AVRT than AVNRT, with sensitivity of 89% and specificity of 71%. ECG interpretation including this method could be useful for differential diagnosis between AVRT and AVNRT.

Limitations

There were several limitations associated with the present study. First, atypical AVNRT and atrial tachycardia were excluded. Therefore, this algorithm with the Lewis lead configuration could not be used for all kinds of PSVT. However, these arrhythmias are rare for PSVT and show long RP intervals during tachycardia.

Second, the ECG was recorded with the Lewis lead during EPS, not in daily medical care. A further prospective study is therefore warranted to confirm the utility of the Lewis lead configuration for diagnosing PSVT in clinical practice.

Finally, only the RP interval was used to distinguish between AVRT and typical AVNRT. The morphology of a retrograde P wave is useful for the differential diagnosis of PSVT. The positive P wave in lead V1, so-called pseudo-r', and the negative P waves in the inferior leads, so-called pseudo-S indicate the retrograde VA conduction during AVNRT. The majority of retrograde P waves in the Lewis lead were positive in the present study. Although it is not certain that this morphology is useful for the diagnosis, further investigation is needed to establish the P wave morphology in the Lewis lead for making a differential diagnosis.

Conclusion

A Lewis lead configuration may help make a difficult differential diagnosis among the reentrant supraventricular tachycardias owing to its ability to locate P waves.

The authors state that they have no Conflict of Interest (COI).

Acknowledgement

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References

1. Tai CT, Chen SA, Chiang CE, et al. A new electrocardiographic algorithm using retrograde P waves for differentiating atrioventricular node reentrant tachycardia from atrioventricular reciprocating tachycardia mediated by concealed accessory pathway. J Am Coll Cardiol **29**: 394-402, 1997.
2. Jaeggi ET, Gilljam T, Bauersfeld U, Chiu C, Gow R. Electrocardiographic differentiation of typical atrioventricular node reentrant tachycardia from atrioventricular reciprocating tachycardia mediated by concealed accessory pathway in children. Am J Cardiol **91**: 1084-1089, 2003.
3. Lewis T. Clinical Electrocardiography. 5th ed. Shaw and Sons, London, 1931: 87-100.
4. Bakker AL, Nijkerk G, Groenemeijer BE, et al. The Lewis lead: making recognition of P waves easy during wide QRS complex tachycardia. Circulation **119**: e592-e593, 2009.
5. Josephson ME. Clinical Cardiac Electrocardiography. 3rd ed. Lippincott Williams and Wilkins, Philadelphia, 2002: 169-271.

6. Ali H, Epicoco G, De Ambroggi G, Lupo P, Foresti S, Cappato R. A narrow QRS tachycardia and cannon A waves: what is the mechanism? Ann Noninvasive Electrocardiol **22**: e12423, 2017.

7. Rodrigues de Holanda-Miranda W, Furtado FM, Luciano PM, Pazin-Filho A. Lewis lead enhances atrial activity detection in wide QRS tachycardia. J Emerg Med **43**: e97-e99, 2012.

8. Mizuno A, Masuda K, Niwa K. Usefulness of Lewis lead for visualizing p-wave. Circ J **78**: 2774-2775, 2014.

Intern Med 61: 1645-1651, 2022