

Original Article

“M” shape P wave in lead V1 in atrial tachycardia of right inferior pulmonary vein origin: a case report with literature review

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Abstract: Focal atrial tachycardia (AT) is the least common type of supraventricular tachycardia (SVT), which could be successfully treated with catheter radiofrequency ablation (CA) in majority of patients. P-wave morphology (PWM) of the surface electrocardiogram (ECG) has been proved a very helpful tool to predict the localization of focal AT. Some studies demonstrated that ATs of the left-sided pulmonary veins (PV) and left atrial appendage (LAA) manifested broader, notched P-wave in lead V1 and/or in the inferior leads, compared with ATs of right-sided pulmonary veins origin. The current study presented that AT of the right inferior pulmonary vein origin exhibited a broader, notched P-wave in lead V1. The patient had been successfully treated with CA and no recurrence events were detected during the subsequent follow-up.

Keywords: Atrial tachycardia, electrocardiogram, P-wave morphology, catheter radiofrequency ablation

Introduction

Focal atrial tachycardia (AT) is an unusual form of supraventricular tachycardia (SVT) arising from defined anatomic locations and sites within the atria. Catheter radiofrequency ablation (CA) can effectively eliminate AT in majority of cases. Although AT may arise from anywhere within the atria, most of which are prone to be distributed to typical anatomic locations. In the right atrium, these sites include the crista terminalis, coronary sinus (CS) ostium, tricuspid annulus, perinodal region, right atrial septum, and right atrial appendage [1-7]. In the left atrium, sites of origin include the pulmonary veins (PVs), left atrial appendage (LAA), mitral annulus, CS body, and left atrial septum, especially the PVs [1-7]. The surface ECG is a very helpful tool in guiding mapping to particular areas of interest. Several algorithms for localizing AT based on P-wave morphology (PWM) have been developed [1, 8, 9]. P-wave is generally described as positive, negative, isoelectric, biphasic (positive-negative or negative-positive), and a full description will include the presense of notching. Analysis of the initial P-wave vector is

top-drawer, and maneuvers such as administration of intravenous adenosine, transient ventricular pacing, or carotid sinus massage will allow a clear demonstration of the “unencumbered” PWM by avoiding fusion of the P-wave and T-wave. Whether these algorithms can accurately predict the focus of AT needs to be further investigated, presented herein is a 35-year-old male patient, who suffered from palpitations and shortness of breath for four years. His ECG revealed frequent premature atrial contractions (PACs) and paroxysmal AT. P-wave in lead V1 is positive, broader and notched, showing “M” shape. It seems that AT arised form left sided PV or LAA. Finally, we successfully localized the origin site of AT at right inferior PV and the AT, as well as PACs disappeared after ablation. No recurrence arrhythmia events were detected during the subsequent follow-up.

Case report

A 35-year-old male patient, who had a history of recurrent episodes of palpitations for four years, was admitted in our hospital on 15th Sep

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Table 1. P-wave morphology

ECG lead												
I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6	
+	-	-	-	+	-	+	+	+	+	+	+	
Broader												
Notched												

+ = Positive, - = negative.

2015. He had no history of hypertension, diabetes, ischemic heart disease and hyperthyroidism. Echocardiogram revealed that cardiac structure and function were in normal range. Holter monitoring demonstrated frequent episodes of AT triggered by PACs with rapid ventricular response, leading to palpitation, shortness of breath and chest discomfort. Because AT significantly impacted quality of life and could not be controlled by β -blocker and propafenone, catheter ablation of AT was recommended and informed consent was obtained.

Before the operation, we analyzed the PWM of ECG of this patient. P-wave morphology on the body surface ECG was assessed as previously described [1, 8, 9]. The P waves were described on the basis of the deviation from baseline during the T-P interval as being: (i) positive, if there was a positive deviation from the isoelectric baseline; (ii) negative, if there was negative deviation; (iii) biphasic, if there were both positive and negative deflections from the baseline; and (iv) flat, if there were no deflections from the baseline. ECG revealed ectopic P waves that were positive, broader and notched in lead V1 (**Table 1; Figure 1**), suggested a left sided focus, perhaps arising from left PV or LAA. However, positive ectopic P waves in lead I and aVL suggested right PV origin. P waves were negative in inferior leads suggesting inferior PV origin. Because it was controversial, so we decided to depend ultimately on detailed mapping.

Intracardiac electrograms were recorded using an electrophysiology system (Prucka CardioLab™ General Electric Health Care System Inc, USA). One decapolar mapping catheter (Biosense Webster, Diamond Bar, CA) was positioned in the coronary sinus (CS) through the right jugular vein access, using the standard Brockenbrough technique [10], atrial transseptal puncture was performed under fluoroscopic

guidance and two L1-type Swartz sheathes (St Jude Medical, Minneapolis, MN) were transeptally introduced into LA via right femoral vein. Intravenous unfractionated heparin 5000 U was administered immediately after atrial transseptal puncture and followed 1000 U/h to maintain an activated clotting time (ACT) of 300-350 S, the ACT level was monitored every 30 min. In addition, heparinized saline solution was continuously infused through the transseptal sheath (3 mL/min) to avoid formation of thrombi or air emboli. One decapolar circular mapping catheter (Lasso, Biosense Webster) was placed at left atria to record left atria and PV potentials. LA geometry was reconstructed and each PV ostium was tagged on it. There are frequent premature atrial beats which are exactly alike previous during operation. Activation mapping (electroanatomical mapping) was done with a Lasso catheter (Biosense Webster Inc.) to find out the earliest endocardial activation site relative to the surface P wave in the LA. The CARTO (Biosense Webster) electroanatomical mapping system was used to facilitate mapping and assessment of anatomic location. High-density mapping was done in the area with early activation in the LA, especially the LAA, left PV and right PV. Interestingly, there was no early activation in LAA and left PV. Finally, the earliest activation site was localized at the antetheca of right inferior PV ostium (**Figure 2**). It preceded the onset of P-wave by 25 ms on the surface ECG. A 3.5 mm saline-irrigated catheter (SmartTouch, Thermocool, Biosense Webster) was transeptally advanced into LA via Swartz sheathe. It was delivered at the earliest activation within the antetheca of right inferior PV ostium, RF current was delivered point by point at a target temperature 43°C, maximum power of 35 W (Stocker generator, Biosense Webster Inc, Diamond Bar, CA, USA), and an infusion rate of 17 mL/min. After ablation, the PAC and AT disappeared. Dabigatran was initiated immediately 3 hours after the procedure with the dosage of 150 mg twice daily. Holter monitoring revealed no recurrence of AT during the follow-up.

Discussion

Generally, two types of AT can be defined by electrophysiological mechanisms [11]: focal AT and macroreentrant AT. Focal AT is a relative rare rhythm disorder, seen in less than 10% of electrophysiological studies. The mechanism of

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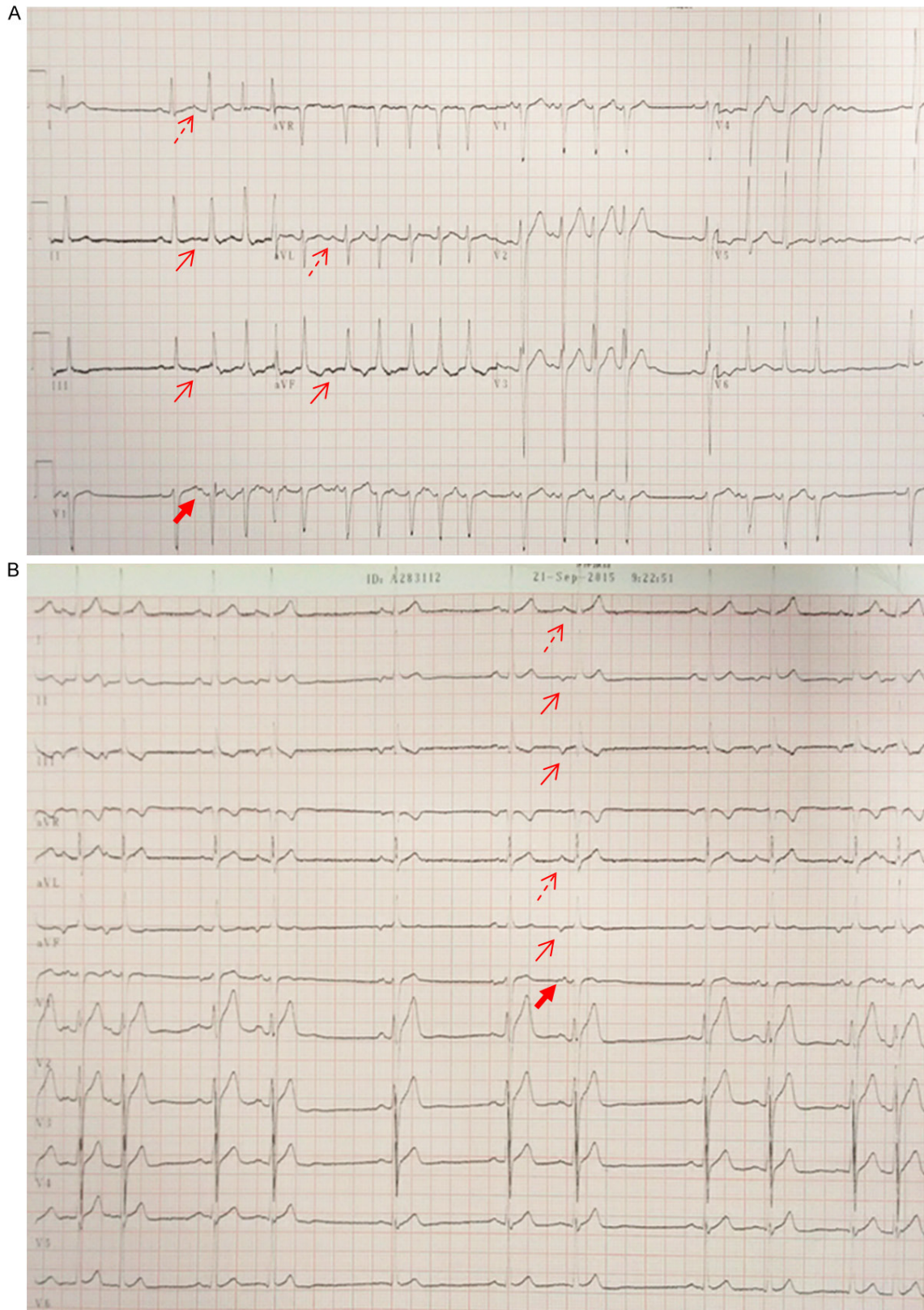


Figure 1. ECG of AT (A) and PAC (B) of this case. P waves were positive, broader and notched in lead V1 (thick arrow), positive in lead I (dash arrow), aVL (dash arrow) and negative in inferior leads (thin arrow). PWM of AT and PAC are identical.

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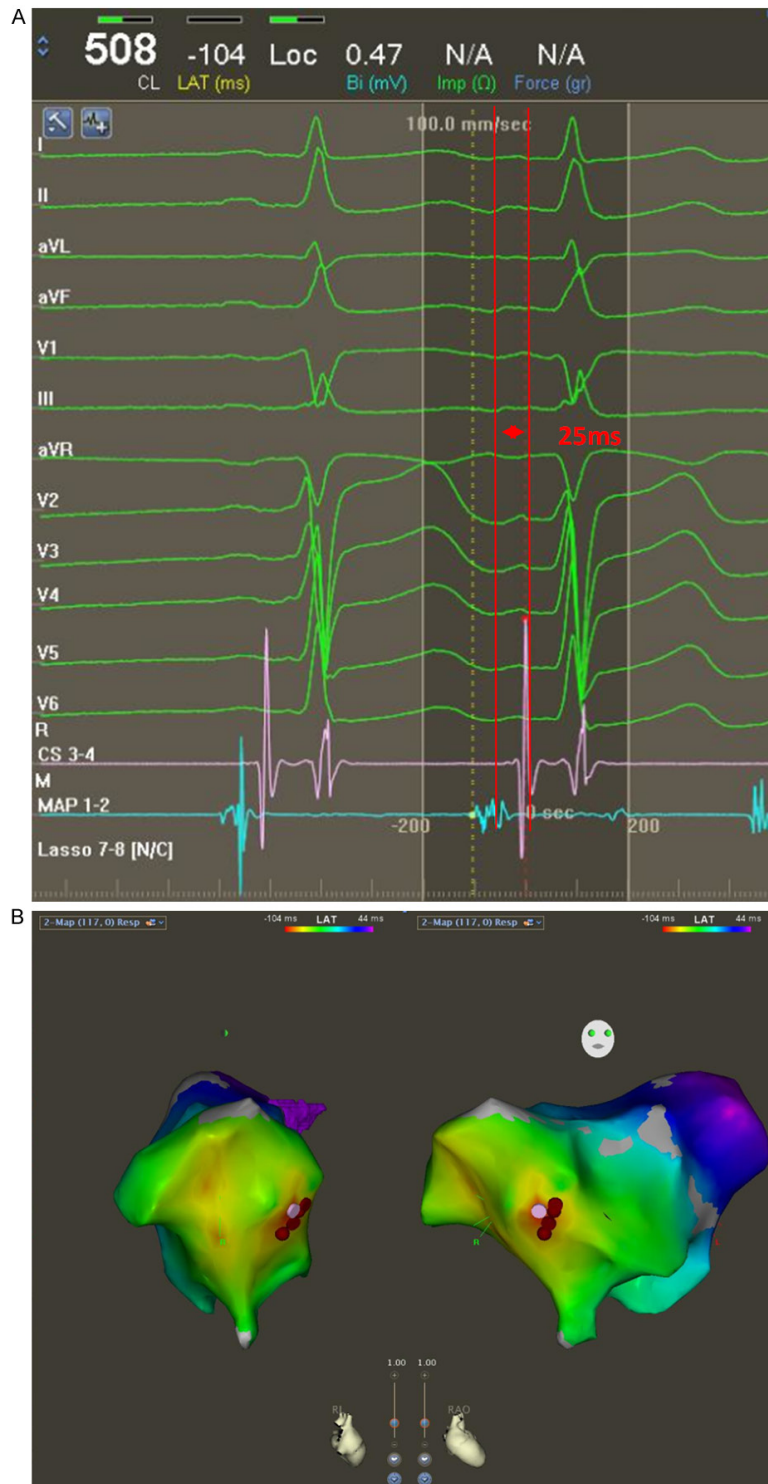


Figure 2. The earliest activation site was localized within the right inferior pulmonary vein during the mapping (B), the local potential (A) of target was fractionated and 25 ms earlier than the onset of P wave of surface ECG (B, pink point).

focal AT include increased automaticity, triggered activity and microreentrant. Chen, et al,

[12] summarized the major criteria of classification were whether 1) automatic AT could be initiated only by isoproterenol; 2) AT related to reentry or triggered activity could be initiated or terminated by programmed electrical stimuli; 3) only AT related to triggered activity had early or delayed after depolarization recorded in the monophasic action potential; and 4) only AT related to reentry had entrainment phenomenon during atrial pacing. In this case, the first PWM of AT was identical to the rest P waves in morphology (Figure 3). And the “warming up” and “cooling down” phenomenon could be identified (Figure 3). Subsequently, we speculated that the underlying mechanism of AT was enhanced automaticity.

Focal AT is usually resistant to antiarrhythmic drugs and could result in tachycardiomyopathy. However, it has been demonstrated to be successfully ablated with minimal risk [13]. Left focal ATs frequently originate from the PV ostia [14]. The identification of a PV origin of ATs allows specific preparation (including the predicted need for transseptal puncture) of the ablation procedure in this type of tachycardia, with the added risk of systemic embolism associated with left atrial ablation [15]. According to RE-LY trial, a dabigatran dose of 300 mg/day was superior to warfarin in regarding to stroke prevention in non-valvular AF, and 220 mg/day was not inferior to warfarin, meanwhile, the use of dabigatran for CA of AF could shorten the duration of hospital stay [16]. One

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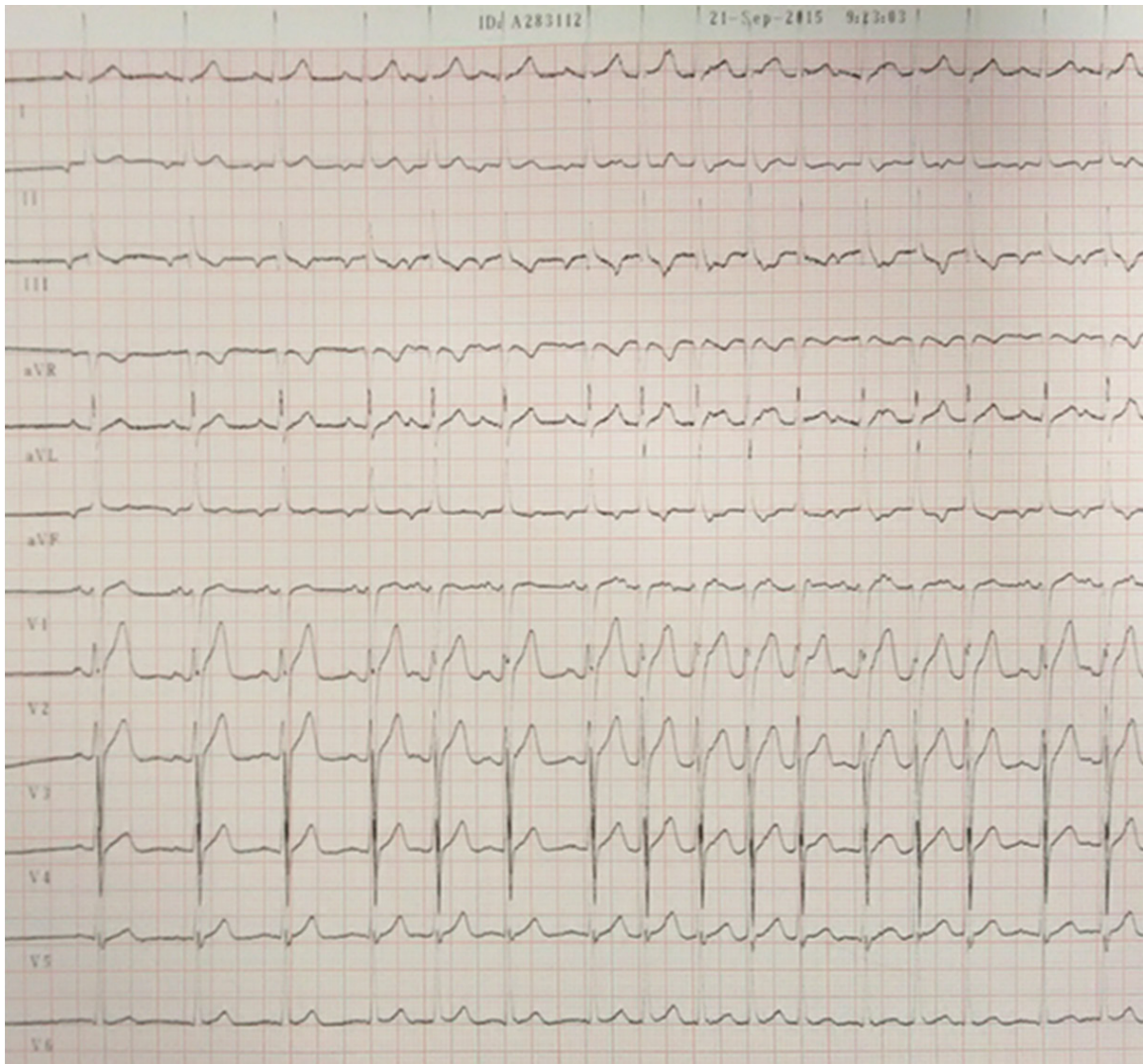


Figure 3. The first PWM of AT was identical to the rest P wave. AT manifested “warming up” phenomenon at the beginning of episode.

advantage of dabigatran use is not necessary to routine monitor coagulation assays [17]. So, we treated this case with dabigatran after the procedure to avoid formation of thrombi.

Differentiating the atrium of origin prior to ablation is necessary. Tang et al [9]. studied 31 consecutive patients undergoing catheter ablation for atrial tachycardia and found that a positive or biphasic P-wave in aVL predicted a right atrial focus with a sensitivity of 88%, specificity of 79%, positive predictive value of 83%, and negative predictive value of 85% (**Table 2**). Three patients with right superior pulmonary vein (RSPV) foci had positive P-waves in aVL. However, in these patients the P-wave in V1 was biphasic during sinus rhythm and changed

to positive during tachycardia in comparison with superior crista terminalis foci, where this change did not occur. They also noted that a positive P-wave in V1 predicted a left atrial focus with a sensitivity of 93%, specificity of 88%, positive predictive value of 87%, and negative predictive value of 94% (**Table 2**). An isoelectric or negative P-wave in lead I was 100% specific for a left atrial focus, but was only present in 50% of patients with left atrial foci. Kistler et al [1]. developed an algorithm to localize focal atrial tachycardia from any location. This algorithm prospectively identified 93% of focal tachycardia anatomic origins correctly. In this algorithm, V1 was most useful in differentiating right from left atrial tachycardias. A negative or biphasic (positive-negative)

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Table 2. Evaluation of Predictive Parameters of P-Wave Morphologies in ECG

Author	Parameters in ECG	Site of Origin	Se (%)	Sp (%)	PPV (%)	NPV (%)
Tang et al (1995)	Positive or biphasic in aVL	Right atrium	88	79	83	85
	Positive in V1	Left atrium	93	88	87	94
Kistler et al (2006)	Negative or biphasic (positive-negative) in V1	Right atrium	69	100	100	66
	Positive or biphasic (negative-positive) in V1	Left atrium	100	81	76	100
	Broader, notched in V1 and inferior leads	Left-sided PV	–	–	–	–
	Broader, notched in V1 and inferior leads, inverted P-wave in I	LAA	–	–	–	–
Qian et al (2011)	Positive in inferior leads and negative in aVR	Area A	95	90	83	97
	Negative in inferior leads and positive in aVR	Area B	88	89	84	92
	Positive in aVL	Right atrium	91	79	91	79
	Positive in V1	Left atrium	95	64	55	96
	From negative to positive across the precordial leads	RAA	100	98	88	100
	From positive to negative across the precordial leads	CS ostium	55	95	86	79
	Flat or negative in I and aVL	Extreme left origin	79	94	79	94

Area A: High atrial origins, including high CT, superior PVs, and RAA. Area B: Right low septal origins, including CS ostium and inferior tricuspid annulus.

P wave in V1 predicted a right atrial origin with 100% specificity, 100% positive predictive value, 69% sensitivity, and 66% negative predictive value (Table 2). Conversely, a positive or negative-positive biphasic P-wave in V1 had 100% sensitivity, 81% specificity, 76% positive predictive value, and 100% negative predictive value for a left atrial origin (Table 2). Compared with the right-sided veins, the left-sided veins have a broader, notched P-wave in V1 and in the inferior leads (Table 2). Right-sided PV foci usually have a positive P-wave in lead I. The superior pulmonary veins invariably have a positive P-wave in the inferior leads. The inferior veins may have inverted, low amplitude positive or isoelectric inferior P-waves. The LAA is closely approximated with the left superior pulmonary vein. A PWM that suggests a LSPV focus (broad upright and notched in V1 and inferior leads) together with a deeply inverted P-wave in lead I will most usually indicate an LAA focus (Table 2). In this series, PWM could not distinguish reliably between tachycardias located in close proximity to the septum (left vs right septal or perinodal). Qian et al [18], found that most of the P waves in inferior leads and lead aVR were consistently opposite, especially for the high atrial and right low septal origins. Positive P waves in inferior leads and negative P waves in lead aVR indicated high atrial origins with a 95% sensitivity and a 90% specificity. Negative P waves in inferior leads and positive P waves in lead aVR suggested right low septal origins with good sensitivity and specificity (88% and 89%, respectively). Consequently, they defined two areas in the atria that had similar ECG patterns: Area A (High CT, superior PVs, and RAA) and Area B (CS

ostium and inferior TA). Concerning the adjacent locations of the two defined areas, lead aVR may not be typically positive or negative. For the foci close to Area A, a flat or negative P wave in leads I and aVL can predict extreme origins (Table 2). For the foci close to Area B, lower CT-originated AT showed a nonpositive P wave in lead aVR and positive P waves in most of the precordial leads. Migration feature of P-wave polarities in precordial leads was also found to be specific for prediction of some AT origins. The P-wave amplitudes of the PV- and RAA-originated ATs in precordial leads. From lead V1 to V6, PV P waves were always positive but progressively flattened. For the RAA origin, P wave in lead V1 was negative and became progressively positive from V1 to V6. The predictive accuracies were both over 90%. Also the migration from positive to negative in precordial leads was a specific feature of CS ostium-originated AT (Table 2). In our study, ECG revealed ectopic P waves that were positive, broader and notched in lead V1, suggested a left sided focus, arising from left PV or LAA probably. Positive P waves in lead I and aVL supported right PV origin. Negative P waves in inferior leads indicated focus of inferior PVs. Because it was controversial, so we decided to carry out detailed mapping to precisely localize the origin. To our knowledge, there is no report about “M” type PWM in lead V1 in AT with right inferior pulmonary vein origin. The exact mechanism for this phenomenon could be attributable to complicated anatomical structure surrounding the origin.

It is not easy to differentiate the origins of focal ATs from the adjacent structures by using ECG

alone. In addition, P-wave is often superimposed on the T-wave and a complete isoelectric TP segment is not often appreciated in most clinical AT. So Uhm et al [19]. developed an algorithm which combined with the clinical features and the ECG characteristics to differentiate the ATs originating from the left superior pulmonary vein (LSPV) vs. the LAA, and from the right superior pulmonary vein (RSPV) vs. the superior vena cava (SVC). In our study, the foci of AT was the antetheca of right inferior PV ostium which was adjacent to CS ostium and non-coronary aortic cusp (NCC). The PWM in I and aVL is also positive if the AT originating from CS ostium or NCC. AT originating from CS ostium, PWM is highly characteristic with deeply inverted (negative) P-waves in II, III, and aVF and usually isoelectric-positive or negative-positive in V1, with variable precordial transition [20]. AT originating from NCC, PWM is negative or indifferent in the inferior leads II, III, and aVF and biphasic in the precordial leads V1 and V2 [21-23]. The main electrophysiological characteristics of the AT originating from NCC is incessant pattern. The PWM were positive in V1 and low amplitude negative in inferior leads of our case, which indicated the possibility of CS ostium and NCC origin was rare.

AT of PV origin also has special clinical and electrophysiological characteristics. A study [24] demonstrated that when a clinical suspicion of atrial tachycardia is established in a patient below the age of 50 years, with no cardiomyopathy or atrial dilatation, the presence of prolongation (≥ 110 ms) and a notch on the sinus P wave is suggestive of an origin in the pulmonary vein (sensitivity 68%-79% and specificity 69%-70%). In our study, the patient was 35 years old without structural heart disease and left atrial enlargement, sinus P wave manifested as notched morphology with duration greater than 110 ms, which was compatible with above-mentioned characteristics.

The optimal therapeutic approach to an AT arising from a PV remains poorly defined. In the era of pulmonary vein isolation (PVI) for the treatment of AF, the approach to ablation around the PV ostia has evolved and became the routine method [24]. The complication of PV stenosis is rare when care is taken to limit the ablation to the atrial aspect of the ostia [26]. One study [27] described the long-term outcome of 26 patients with an AT originating from a PV. Ten

patients underwent focal ablation and the remaining 16 underwent single PVI for the treatment of this arrhythmia. ATs arising from the PVs can be successfully treated with single vein isolation or focal ablation with a low risk of recurrence or the development of AF. Targeted PVI achieved better long-term success when compared to focal ablation; PVI may be the preferred approach when the focus of the AT arises from a site deep within the PV where targeted ablation may result in significant morbidity such as phrenic nerve paralysis or occlusion of a pulmonary venous branch. In our case, because the focus was at the ostium of the right inferior pulmonary vein, we chose the focal ablation. To our pleasure, there is no recurrence events during the subsequent follow-up.

Disclosure of conflict of interest

None.

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