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Effective discrimination of wide QRS complex tachycardia with a new algorithm - the Prelocalization Series Algorithm

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Abstract

Background Electrocardiogram (ECG) plays a crucial role in the correct diagnosis of wide QRS complex tachycardia (WCT). Objective To evaluate the diagnostic value of a new WCT discrimination algorithm, herein referred to as the Prelocalization Series Algorithm.

Methods A retrospective analysis of 181 ECGs from WCT patients was conducted using the Prelocalization Series Algorithm, Brugada Series Algorithm, and Vereckei Series Algorithm. Initially, the algorithms were used to differentiate between ventricular tachycardia (VT) and supraventricular tachycardia (SVT). Subsequently, the VT cases preliminarily judged were further differentiated into VT or preexcited tachycardia (PXT). The results were compared with the clinically confirmed diagnoses to observe the diagnostic value of the three algorithms.

Results The Prelocalization Series Algorithm demonstrated higher AUC values (0.90 vs. 0.73 vs. 0.69), sensitivity (0.91 vs. 0.61 vs. 0.50), and accuracy (0.90 vs. 0.71 vs. 0.65) in diagnosing VT compared to the Brugada Series Algorithm and Vereckei Series Algorithm. The Prelocalization Algorithm's single process (without differentiating between VT and PXT) also showed higher AUC values (0.79 vs. 0.67 vs. 0.63), sensitivity (0.96 vs. 0.91 vs. 0.76), specificity (0.62 vs. 0.44 vs. 0.49), and accuracy (0.82 vs. 0.72 vs. 0.65) than the Brugada Four-Step Method and aVR lead method. The accuracy of the Prelocalization Series Algorithm in diagnosing VT (0.90 vs. 0.82) was higher than its single process algorithm.With all differences being statistically significant (all $P < 0.05$).

Conclusion The Prelocalization Series Algorithm is an effective new algorithm for discriminating WCT and can be attempted for diagnosing VT, SVT, and PXT.

Clinical trial number Not applicable.

Keywords Wide QRS complex tachycardia, Earliest ventricular origin, His-purkinje system, Preexcited tachycardia

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Background

Wide QRS complex tachycardia (WCT) refers to tachycardia with a QRS duration of ≥120ms and a heart rate > 100 bpm, including: ① ventricular tachycardia (VT) originating from different ventricular sites; ② supraventricular tachycardia (SVT) with functional or fixed bundle branch or fascicular block, and QRS widening caused by drugs or electrolyte disorders; ③ preexcited tachycardia (PXT); ④ pacemaker-related tachycardia. An accurate diagnosis of WCT is crucial for formulating appropriate treatment plans, and the conventional 12-lead electrocardiogram (ECG) is a commonly used diagnostic tool. Since the 1960s, the ECG differential diagnosis criteria for WCT have evolved into diagnostic processes and have been introduced successively. Although all methods and standards have demonstrated their diagnostic advantages and have promoted increasing work, each method has diagnostic shortcomings and practical limitations [1]. Additionally, because the earliest ventricular activation in VT and PXT is localized to the ventricular myocardium, their differentiation is more challenging. The author Ni et al. proposed a new diagnostic algorithm for ventricular arrhythmias (VA) and preexcited arrhythmias (PA), which showed advantages in AUC values, sensitivity, and accuracy in diagnosing VA compared to algorithms proposed by Steurer, Brugada, and Vereckei et al. based on QRS complex morphological characteristics, with statistically significant differences [2]. The diagnostic approach of the Prelocalization Series Algorithm in this study attempts to break through from the earliest ventricular origin site and combines its relationship with the His-Purkinje system and atrioventricular bypass tracts for interpretation. The VT and SVT, VT and PXT series algorithms conceived by the author are applied retrospectively for the first time, aiming to introduce an effective new series of algorithms for differentiating WCT.

Methods

Study population

A total of 181 cases of monomorphic WCT (QRS time ≥ 120ms, frequency > 100 beats/min) patients treated at the First Hospital of Jiaxing City, Zhejiang Province, China, from January 2018 to October 2024, were selected. The age of the patients ranged from 7 to 94 years (57.2 ± 16.1) years, with 68.0% being male. This study was approved by the Medical Ethics Committee of our hospital.

Electrocardiographic analysis

Each observer analyzed the ECGs using the three series of algorithms through the conventional 12-lead ECG and compared the results with the clinically confirmed diagnoses (electrophysiology or ECGs before and after the occurrence of WCT) to analyze the diagnostic value of the three algorithms in diagnosing VT.

Prelocalization series algorithm

(1)Algorithm to differentiate VT from SVT, analyze step by step according to ①~④, if it meets the criteria, it is preliminarily judged as VT, otherwise it is diagnosed as SVT.

① QRS complex in leads II, III, aVF is R-type, and lead aVR is QS-type.

② Any one of leads I, aVF, V6 is QS-type.

③ Leads I, aVF, V6 are all predominantly characterized by the S-wave.

④ V1 (V2) does not show typical bundle branch block characteristics. Typical bundle branch block pattern features in V1 (V2): (1) V1 shows typical right bundle branch block (RBBB) characteristics: if it shows rSR, or rsR, type, the r-wave should be sharp and the R-wave should be blunt; if it shows a single-phase R-wave, the ascending limb of the R-wave should have a notch, and it should meet the characteristic of the initial 40ms ventricular activation rate (Vi) / the final 40ms ventricular deactivation rate (Vt)>1. when it is difficult to judge, the initial conduction characteristics of V2 can be observed; if it shows a qR type, it should be accompanied by a notch on the ascending limb or no notch. (2) V1 shows typical left bundle branch block (LBBB) characteristics: V1 and V2 both show rS or V1 shows QS with V2 showing rS type (both must have a sharp r-wave) or both show QS type (RS < 70ms).

(2)Algorithm to differentiate VT from PXT, analyze step by step according to ⑤~⑧, if it meets the criteria, it is diagnosed as VT, otherwise it is diagnosed as PXT.

⑤ QRS complex in leads II, III, aVF is R-type, and lead aVR is QS-type.

⑥ At least two leads among I, aVF, V6 are mainly S-wave dominant.

⑦ Lead V2 shows ≥ 3 phase waves or has a returning branch (R-wave descending branch or S-wave ascending branch) notch.

⑧ The initial part of lead V5 shows a negative wave or has a returning branch notch.

Brugada series algorithm

(1)Algorithm to differentiate VT from SVT (Brugada Four-Step Algorithm [3]), analyze step by step according to ①~④, if it meets the criteria, it is preliminarily judged as VT, otherwise it is diagnosed as SVT.

① No RS shape in the precordial lead QRS complex.

② RS interval in the precordial lead > 100ms.

③ Atrioventricular dissociation.

④ Meet the characteristics of leads V1, V6: When RBBB pattern, V1 lead shows single-phase, double-phase waves, showing R, RS, or RSr shape, V6 lead shows R, QS, QR, R/S < 1; When LBBB pattern, V1 lead R-wave > 30ms,

RS > 60ms, or S-wave has a notch, V6 shows QS shape or QR shape.

(2)Algorithm to differentiate VT from PXT (Brugada Three-Step Algorithm [4]), analyze step by step according to ⑤~⑦, if it meets the criteria, it is diagnosed as VT, otherwise it is diagnosed as PXT.

⑤ QRS complex in leads V4~V6 is mainly negative wave.

⑥ At least one lead among V2~V6 shows QR type.

⑦ Atrioventricular dissociation.

Vereckei series algorithm

(1)Algorithm to differentiate VT from SVT (aVR lead Algorithm [5]), analyze step by step according to ①~④, if it meets the criteria, it is preliminarily judged as VT, otherwise it is diagnosed as SVT.

① Presence of an initial R wave.

② Width of an initial r or q wave > 40 msec.

③ Notching of the down-stroke of the QS wave.

④ Vi/Vt < 1.

(2)Algorithm to differentiate VT from PXT (Improved Verickei Algorithm [6]), analyze step by step according to ⑤~⑧, if it meets the criteria, it is diagnosed as VT, otherwise it is diagnosed as PXT.

⑤ Atrioventricular dissociation.

⑥ QRS complex in lead aVR starts positively and the area above the QRS complex baseline is greater than the area below the baseline.

⑦ At least one lead among V2~V6 shows QR type.

⑧ QRS complex in leads V4~V6 is mainly negative wave.

Development of the prelocalization series algorithm

First, we theoretically deduced the two processes of the Prelocalization Series Algorithm (VT and SVT, VT and PXT) in sequence, and then respectively conducted related electrophysiological verification of arrhythmia and retrospective application of WCT at the First Hospital of Jiaxing City, Zhejiang Province, China. It was found that it has high diagnostic value and has been continuously improved. This study is the first clinical retrospective application analysis of the Prelocalization Series Algorithm.

Statistical analysis

Data processing and analysis were conducted using Python software. ROC Curve Analysis: Utilizing the scikit-learn library in Python, we calculated the area under the receiver operating characteristic (ROC) curve (AUC) to assess and compare the performance of four arrhythmia diagnostic methods. Confidence Interval Estimation: Employing the statsmodels library, we computed the 95% confidence intervals (CI) for key statistical indicators such as accuracy, sensitivity, and specificity, providing a measure of reliability and stability for our estimates. Hanley-McNeil Test: A specialized Python implementation was used to calculate the test statistic based on the standard error of the AUC, allowing for the pairwise comparison of areas under two related ROC curves. Z-Test: This test was used to compare the sensitivity and specificity between the three diagnostic methods.

Results

Diagnostic results

A total of 108 cases (59.67%) of clinically confirmed VT, 48 cases (26.52%) of SVT, and 25 cases (13.81%) of PXT were retrospectively applied in WCT patients.

Comparison of VT diagnosis results among the three series of algorithms

The Prelocalization Series Algorithm showed higher AUC values, sensitivity, and accuracy in diagnosing VT than the other two algorithms, with statistically significant differences ($P < 0.05$), and there were no statistically significant differences between the two comparison algorithms, $P > 0.05$. See Fig. 1; Tables 1, 2 and 3.

Comparison of VT diagnosis results among the three single-process algorithms (differentiating VT from SVT, without differentiating VT from PXT)

The Prelocalization Algorithm showed higher AUC values, sensitivity, specificity, and accuracy in diagnosing VT than the other Brugada Four-Step Algorithms and aVR lead algorithms ($P < 0.05$). The sensitivity of the Brugada Four-Step Algorithms was higher than that of the aVR lead Algorithms, with statistically significant differences ($P < 0.05$). See Fig. 2; Tables 4, 5 and 6.

Comparison of accuracy results between the three single-process algorithms and the series algorithms

The accuracy of the Prelocalization Series Algorithm in diagnosing VT was higher than that of its single-process diagnosis, with statistically significant differences, $P < 0.05$, and there were no statistically significant differences between the two comparison algorithms, $P > 0.05$. See Table 7.

Discussion

The differential diagnosis of WCT has always been a hot topic in the field of electrocardiography. This is not only because there are many difficulties and challenges in the differential diagnosis, but also because making a rapid and accurate diagnosis of its pathogenesis has important clinical significance. Marek et al.'s study compared the sensitivity, specificity, and diagnostic accuracy of diagnosing VT using five WCT ECG methods and found that although the Brugada, Bayesian, Griffith, aVR algorithm,

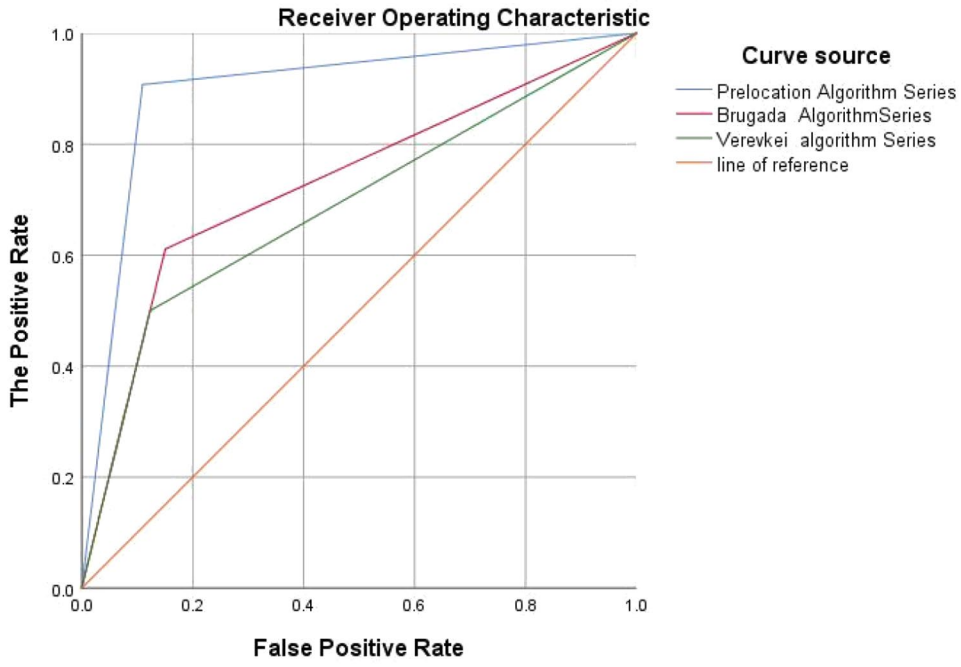

Fig. 1 ROC curves of the three series of algorithms for diagnosing VT and SVT + PXT

Table 1 Comparison of sensitivity, specificity, positive and negative likelihood ratios, and overall diagnostic accuracy of the three series of algorithms for VT diagnosis

Metrics	Pre-location algorithm Series	Brugada algorithm Series	Verevkei algorithm Series
AUC	0.90(0.85,0.95)	0.73(0.66,0.80)	0.69(0.61,0.77)
Accuracy	0.90(0.85, 0.94)	0.71(0.64, 0.77)	0.65(0.58, 0.72)
Specificity	0.89(0.80, 0.95)	0.85(0.75, 0.92)	0.88(0.78, 0.94)
Sensitivity	0.91(0.84, 0.95)	0.61(0.51, 0.70)	0.50(0.40, 0.60)
LR (+)	8.28	4.06	4.06
LR (-)	0.10	0.46	0.57

Table 2 Hanley-McNeil test comparing the differences in AUC values among the three series of algorithms

Comparison	*Difference*	*Z*	*P*
Pre-location vs. Brugada	0.17	5.98	<0.01
Pre-location vs. Verevkei	0.21	7.25	<0.01
Brugada vs. Verevkei	0.04	1.24	0.21

Table 3 Z-test comparing the differences in sensitivity, specificity, and accuracy among the three series of algorithms

Metrics	Comparison	*Difference*	*Z*	*P*
Sensitivity	Pre-location vs. Brugada	0.30	5.43	<0.01
	Pre-location vs. Verevkei	0.41	7.33	<0.01
	Brugada vs. Verevkei	0.11	1.65	0.0982
Specificity	Pre-location vs. Brugada	0.04	0.74	0.4597
	Pre-location vs. Verevkei	0.01	0.26	0.7963
	Brugada vs. Verevkei	-0.03	-0.48	0.63
Accuracy	Pre-location vs. Brugada	0.19	4.78	<0.01
	Pre-location vs. Verevkei	0.25	5.95	<0.01
	Brugada vs. Verevkei	0.06	1.13	0.2592

and II lead r-wave peak time (RWPT) criteria had significant differences in sensitivity and specificity, they all had a moderate accuracy rate (69~77%), and new algorithms/criteria were not more accurate than the classic Brugada algorithm [7]. The recently developed limb lead algorithm [8] and the Basel algorithm [9], despite being commendable, still have limitations in differentiating between VT and PXT. The Prelocalization Series Algorithm's approach to differentiation endeavors to initiate from the anticipated site of earliest ventricular activation, integrating its relationship with the His-Purkinje system and atrioventricular bypass tracts, along with pertinent electrophysiological features, to facilitate diagnosis(Fig. 3). First, the algorithm for VT and SVT was theoretically deduced, trying to identify VT originating from the non-left and right bundle branches as much as possible. Through 268 cases of idiopathic VA electrophysiological verification through three-dimensional electroanatomical (CARTO) mapping were found to have higher sensitivity (0.98 vs. 0.87 vs. 0.80) in diagnosing VA than the Giriffith algorithm and aVR lead algorithm, with statistically significant differences, and the predicted earliest ventricular origin site was highly consistent with the results of CARTO mapping. Subsequently, the diagnostic algorithm for VT and PXT was theoretically deduced, trying to identify VT originating from the atrioventricular valve ring as much as possible. Through 205 cases of CARTO mapping of idiopathic VA and electrophysiological examination of the maximum ventricular pre-excitation

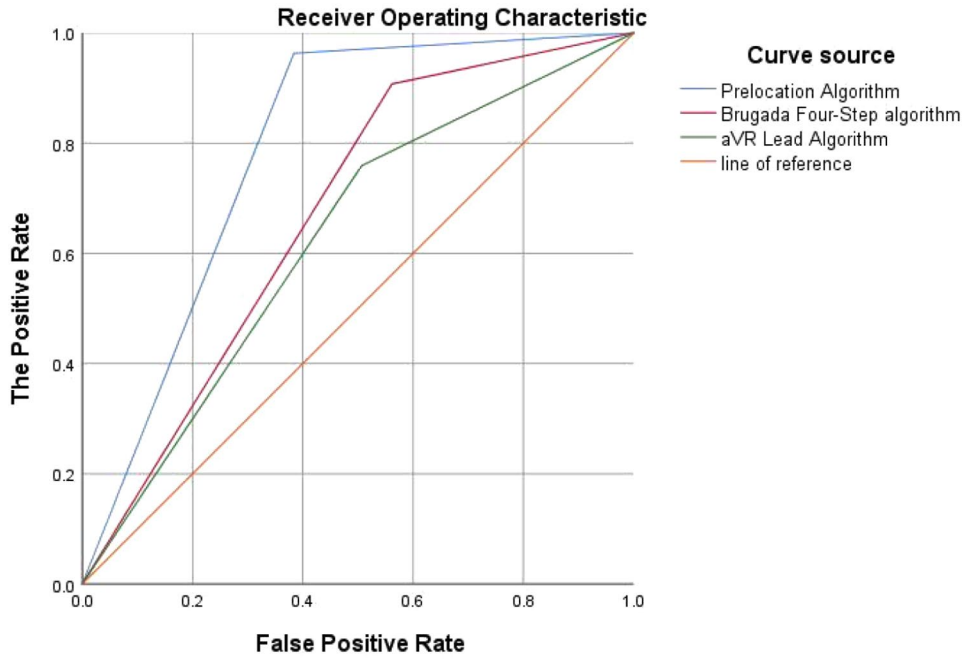

Fig. 2 ROC curves of the three single-process algorithms for diagnosing VT and SVT + PXT

Table 4 Comparison of sensitivity, specificity, positive and negative likelihood ratios, and overall diagnostic accuracy of the three single-process algorithms for VT diagnosis

Metrics	Pre-location algorithm	Brugada Four-Step algorithm	aVR Lead algorithm
AUC	0.79(0.72,0.86)	0.67(0.59,0.76)	0.63(0.54,0.71)
Accuracy	0.82(0.76, 0.88)	0.72(0.65, 0.78)	0.65(0.58, 0.72)
Specificity	0.62(0.50, 0.73)	0.44(0.32, 0.56)	0.49(0.37, 0.61)
Sensitivity	0.96(0.91, 0.99)	0.91(0.84, 0.96)	0.76(0.67, 0.84)
LR (+)	2.51	1.62	1.50
LR (-)	0.06	0.21	0.49

Table 5 Hanley-McNeil test comparing the differences in AUC values among the three single-process algorithms

Comparison	*Difference*	*Z*	*P*
Pre-location vs. Brugada	0.117	3.577	<0.01
Pre-location vs. aVR Lead	0.163	4.918	<0.01
Brugada vs. aVR Lead	0.047	1.318	0.188

Table 6 Z-test comparing the differences in sensitivity, specificity, and accuracy among the three single-process algorithms

Metrics	Comparison	*Difference*	*Z*	*P*
Sensitivity	Pre-location vs. Brugada	0.056	2.160	0.031
	Pre-location vs. aVR Lead	0.204	5.864	<0.01
	Brugada vs. aVR Lead	0.148	3.859	<0.01
Specificity	Pre-location vs. Brugada	0.178	3.449	0.001
	Pre-location vs. aVR Lead	0.123	2.378	0.017
	Brugada vs. aVR Lead	0.055	1.047	0.295
Accuracy	Pre-location vs. Brugada	0.105	2.394	0.017
	Pre-location vs. aVR Lead	0.171	3.776	0.000
	Brugada vs. aVR Lead	0.066	1.361	0.173

Table 7 Z-test comparing the differences in accuracy between the three single-process algorithms and the series algorithms

Algorithm series	*Difference*	*Z*	*P*
Pre-location algorithm	-0.077	-2.133	0.0330
Brugada	0.011	0.2323	0.816
Verevkei	0.0	0.0	1.0

degree of PA, it was found that the sensitivity (0.83 vs. 0.23 vs. 0.25) and accuracy (0.83 vs. 0.48 vs. 0.46) in diagnosing VA were higher than the Steurer algorithm and Vereckei algorithm, which were improved through QRS complex morphological characteristics, with statistically significant difference. This study attempted to retrospectively apply and compare the series of WCT algorithms proposed by the same author (Brugada, Vereckei, Ni) to differentiate VT from SVT and VT from PXT. The results found that the Prelocalization Series Algorithm had higher sensitivity and accuracy in diagnosing VT than the Brugada and Vereckei series algorithms, and the single-process Prelocalization Algorithm's various diagnostic indicators were all higher than the Brugada Four-Step Algorithms and aVR lead Algorithms, but the accuracy was lower than the series algorithm, with all differences being statistically significant.

The theoretical derivation and retrospective application process of the Prelocalization Series Algorithm are described and compared in this paper. Step 1, 5: The right ventricular outflow tract is located in the anterior upper part of the right ventricle, and the left ventricular outflow tract is the anteromedial part of the left ventricle, located in the high ventricular bottom, where there is no

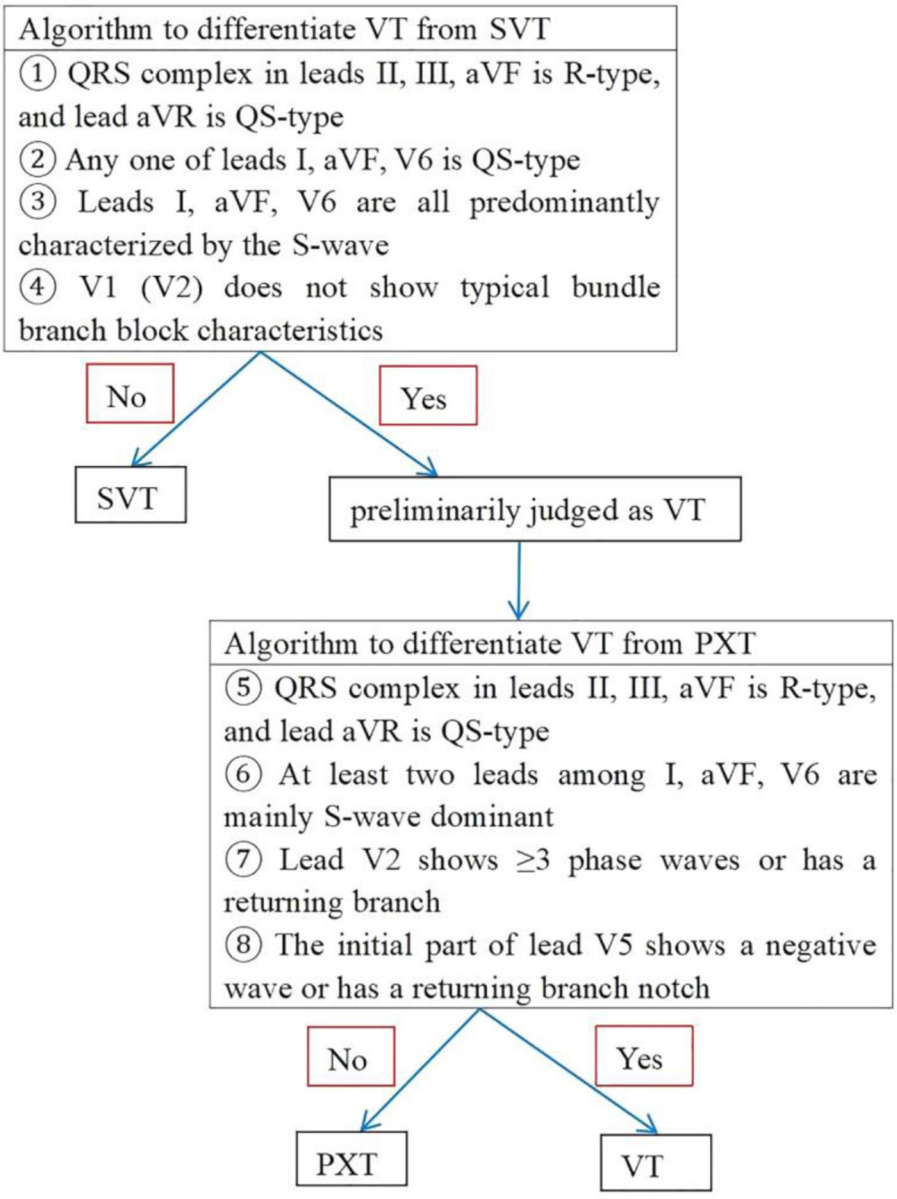

Fig. 3 Image of the prelocalization series algorithm

anatomical basis for the conduction system and atrioventricular bypass tracts, and the overall direction of ventricular depolarization expansion points downward (leads II, III, aVF show R-type, aVR shows QS type, often accompanied by lead aVL showing QS type), However, both theoretically and as confirmed by electrophysiological evidence, the adjacent anterior lateral wall and right anterior septal ventricular pre-excitation will also show this pattern. In the application of VT and SVT differentiation, it was found that the aVR lead algorithm had difficulty in differentiating some ventricular outflow tracts because the QS-type S-wave of VT had no notch or the notch was on the top of the QRS, and the start and end parts were sometimes difficult to judge accurately, affecting the judgment of the Vi/Vt ratio. In the differentiation of VT and PXT, it was found that because it is located high in the ventricle, leads V4~V6 are mostly R-wave dominant, and both comparison algorithms have difficulty in identifying it, but the Prelocalization Series Algorithm did indeed have difficulty in differentiating some PXTs transmitted by the left free wall bypass tract in front of the ventricular outflow tract in this study because they are close to the ventricular outflow tract. It is thought that if the R voltage difference between leads III and aVF is more obvious, it may be more inclined to PXT because the left free wall bypass tract is more to the left than the ventricular outflow tract. Step 2, 3, 6: Lead I points from right to left in the limb lead, if it shows QS type or

is mainly S-wave dominant, it suggests that the earliest ventricular excitement is located in the most left free wall of the ventricle or close to the left free wall. If it is mainly R-wave dominant, it suggests that the origin is close to the septum. Lead aVF points down from top to bottom, if it shows QS type or is mainly S-wave dominant, it suggests that the earliest excitement is located in the lowest part of the ventricle or close to the lower part of the ventricle. If it is mainly R-wave dominant, it suggests that the origin is close to the upper part of the ventricle. Lead V6 points to the left back (near the apex) in the chest lead, if it shows QS type or is mainly S-wave dominant, it suggests that the earliest ventricular excitement is close to the apex, if it is mainly R-wave dominant, it suggests that the origin is close to the base. In the differentiation of VT and SVT, lead I, aVF, V6 showing QS type and lead I, aVF, V6 all being mainly S-wave dominant were selected as the basis for the diagnosis of VT. Although the earliest excitement source of these sites is most likely to be VT, it may also be PXT transmitted by the left ventricular free wall or posterior septum, etc., or SVT combined with myocardial infarction, etc. Therefore, in the differentiation of VT and PXT, lead I, aVF, V6 with at least 2 leads mainly S-wave dominant were selected as the basis for the diagnosis of VT It was found in the application process that some VTs involved in the His-Purkinje system had faster initial depolarization speed than the ventricular myocardial origin, and the aVR lead algorithm was judged as SVT because Vi/Vt > 1, while the improved Vereckei algorithm and Brugada Three-Step Algorithm were judged as PXT in the differentiation of VT and PXT because some patients did not necessarily show negative waves in leads V4~V6. In the application process, the Prelocalization Series Algorithm had good recognition for VTs originating from the His-Purkinje system of the left ventricle, but there were difficulties in differentiating some PXTs of the left ventricular free wall (because leads I, V6 can both be mainly S-wave dominant) and the left posterior septum (leads I, aVF can be mainly S-wave dominant). Therefore, it is thought that adjusting to lead V5 may improve the diagnostic specificity of PXTs in the left free wall. Although the improved Vereckei algorithm increased the aVR lead differentiation and improved the recognition of VTs originating from the left ventricle, it was judged as VT for some PXTs involving the left free wall bypass tract because the earliest ventricular depolarization vector or the comprehensive depolarization vector pointed to the aVR lead. In step 4: It is anticipated that the focus falls on the adjacent septal region (the step that most requires differentiation from SVT). At this point, the typical bundle branch block characteristics of V1 (V2) need to be differentiated in conjunction with conduction and waveform features.As the most important step in differentiating from SVT, the Prelocalization Algorithm compared to the Brugada Four-Step Algorithm has improved the diagnosis of RBBB characteristics (added the diagnosis when V1 shows R-type and qR type), and refined the LBBB pattern, emphasizing the diagnostic value of sharp r-waves, and removed the diagnostic basis of lead V6. In the differentiation of VT and SVT, it was found that the Brugada Four-Step Algorithm could easily be judged as VT because some SVTs could show a single R-wave in lead V1 or show a qR biphasic wave combined with anterior (inter) wall myocardial infarction. The aVR lead Algorithm could easily be misjudged as VT in some SVTs showing LBBB or non-specific intraventricular conduction block pattern because notches could appear on the descending limb of the S-wave in lead aVR. The Prelocalization Algorithm combined with leads V1, V2 further indicated the recognition of SVT. Steps 2, 3, and 4 combined conduction characteristics and waveform characteristics helped to improve the diagnostic sensitivity of VTs involved in the His-Purkinje system. Step 7: According to some VTs originating from the left ventricle (adjacent to the left bundle branch) that can show a pattern similar to RBBB and can also show the "left rabbit ear" sign, lead V2 showing ≥ 3 phase waves or accompanied by a returning branch notch was selected as the basis for the diagnosis of VT. Step 8: According to the atrioventricular bypass tract located at the base of the atrioventricular valve ring, the depolarization vector often points to the apex, lead V5 is close to the apex, in addition, it was also observed that VTs originating from high in the ventricle could show a notch on the descending limb of lead V5. Therefore, selecting the initial negative wave of lead V5 or accompanied by a re-entry branch notch as the basis for the diagnosis of VT. However, in the electrophysiological verification of VT and PXT differentiation, the diagnostic efficacy of this step was reduced (especially the notch on the returning branch of lead V5), and in the application process, it was found that some PXT patients could show a returning branch notch, but it should be pointed out that the bluntness may not necessarily be accompanied by a notch.

Accordingly, the method behind the Prelocalization Series Algorithm for predicting the earliest ventricular origin site of WCT through ECG is: first, predict the origin of the ventricular outflow tract through leads II, III, aVF showing R-type, aVR showing QS type, and the rest through leads I, aVF, V6, V1 leads respectively from 4 dimensions to predict the earliest ventricular origin area, and combine electrophysiological characteristics to simplify the series algorithm as much as possible (steps 1 and 5 are the same, steps 2, 3, 6 observe the same leads, steps 7, 8 are simple). Although the series process has many steps, if this study's WCT patients use the single-process algorithm for VT and SVT (steps 1~4), it is found that although the Prelocalization single-process algorithm has

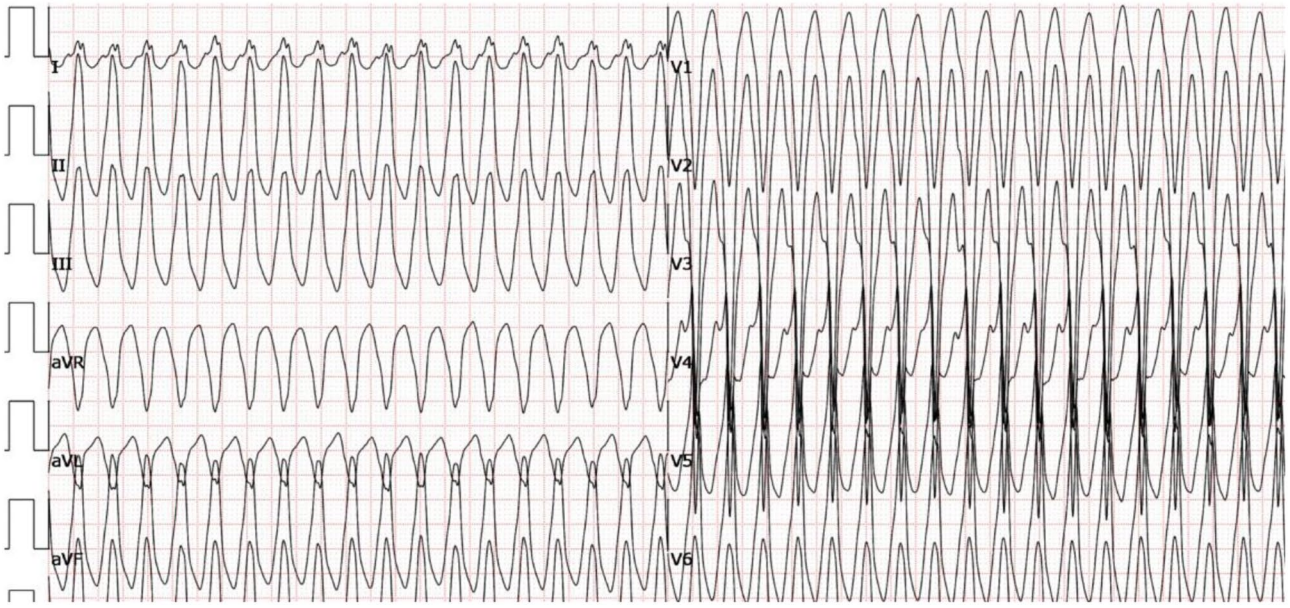

Fig. 4 WCT (VT), the Prelocalization Series Algorithm diagnosed VT because of steps 1, 5 (leads II, III, aVF show R-type, aVR shows QS type). The Brugada Series Algorithm initially judged VT because of step 4 (V1 lead RS time>60ms), and diagnosed PXT because it did not match steps 5~7 VT pattern. The Vereckei Series Algorithm initially judged VT because of step 4 (vi/vt < 1), and diagnosed PXT because it did not match steps 5~8 VT pattern

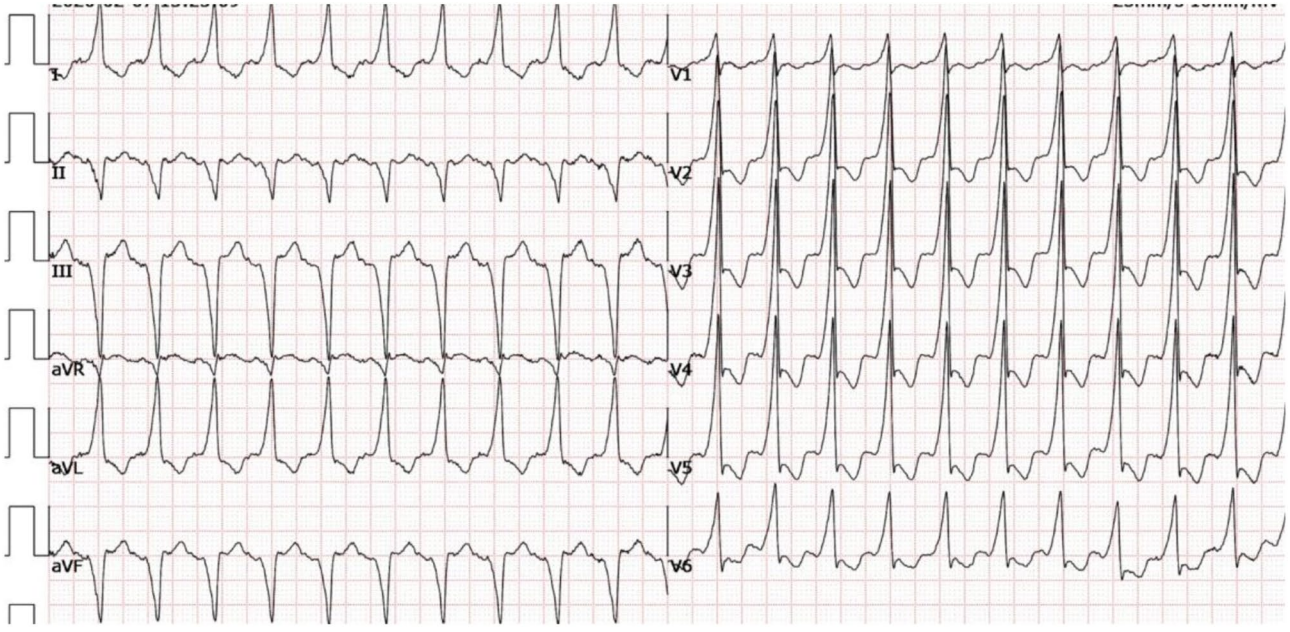

Fig. 5 WCT (PXT), the Prelocalization Series Algorithm initially judged VT because of step 2 (lead aVF shows QS type), and diagnosed PXT because it did not meet steps 5~8 VT pattern. The Brugada Series Algorithm initially judged VT because of step 4 (V1 lead shows a biphasic wave), and diagnosed PXT because it did not match steps 5~7 VT pattern. The Vereckei Series Algorithm initially judged VT because of step 2 (q wave > 40ms), and diagnosed PXT because it did not match steps 5~8 VT pattern

higher AUC values, sensitivity, specificity, and accuracy in diagnosing VT than the Brugada Four-Step Algorithm and aVR lead Algorithm, its accuracy is lower than the Prelocalization series algorithm, with statistically significant differences, meaning that the series process is better than the single process. Figures 4, 5, 6, 7, 8 and 9 show specific cases of retrospective application.

Clinical applications

The Prelocalization Series Algorithm can be employed for rapid differential diagnosis of WCT by

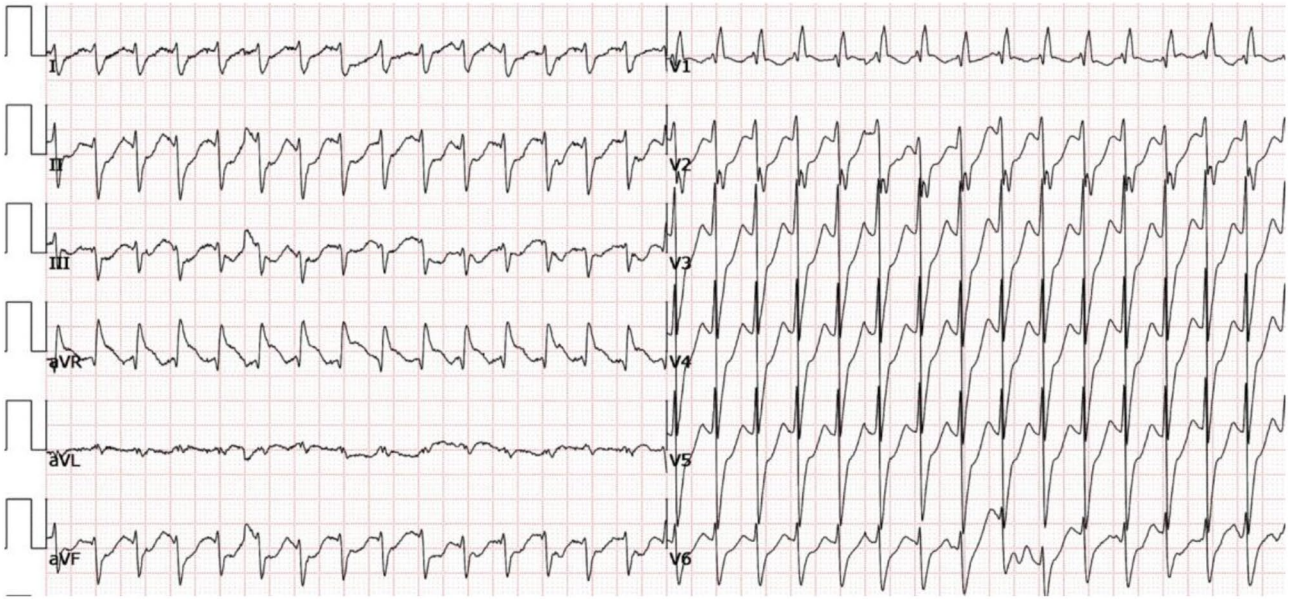

Fig. 6 WCT (VT), the Prelocalization Series Algorithm diagnosed VT because of steps 3, 6 (leads I, aVF, V6 are mainly S-wave dominant). The Brugada Series Algorithm diagnosed VT because of steps 4, 5 (V6 lead R/S < 1, leads V4~V6 are mainly negative waves). The Vereckei Series Algorithm diagnosed SVT because of step 4 (Vi/Vt > 1)

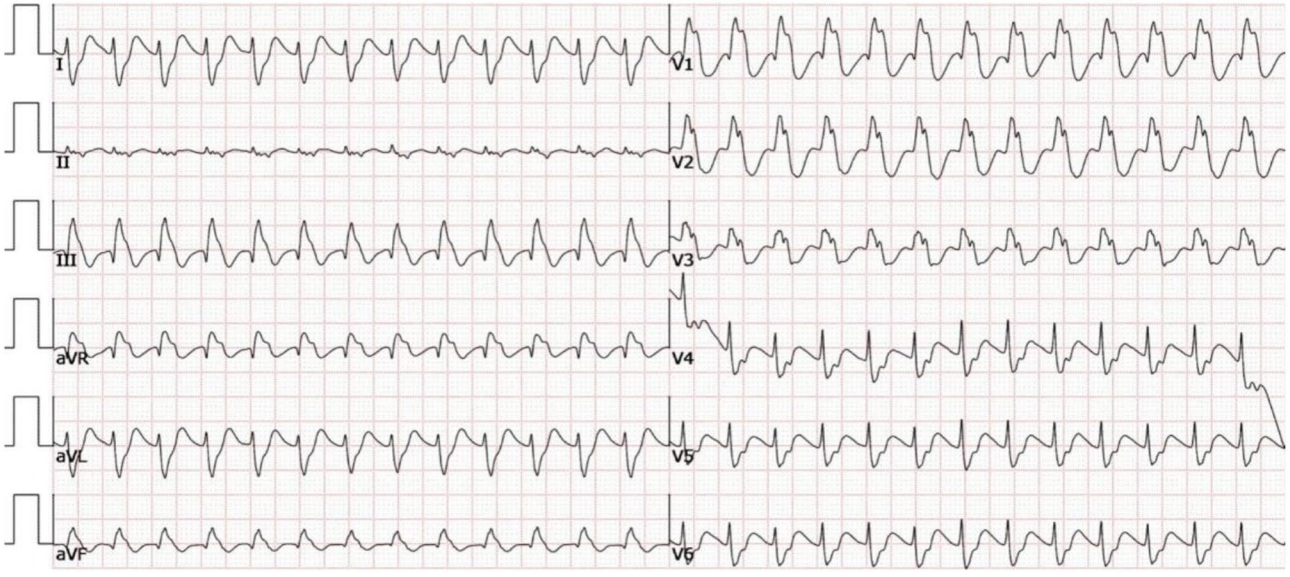

Fig. 7 WCT (VT), the Prelocalization Series Algorithm initially judged VT due to step 4 (V1 showing a qR pattern with a descending branch notch), and diagnosed VT due to step 7 (V2 lead showing a returning notch on the R wave). The Brugada Series Algorithm initially judged VT due to step 4 (V1 lead showing a biphasic wave), and diagnosed PXT as it did not match the VT patterns in steps 5 to 7. The Vereckei Series Algorithm diagnosed SVT due to step 4 (vi/vt > 1)

both electrophysiology and non-electrophysiology practitioners.

Limitations

The Prelocalization Series Algorithm still has limitations in differentiating SVT cases that are complicated by severe organic heart disease and electrolyte disturbances. In this study, one patient had Brugada syndrome accompanied by abnormal ventricular depolarization, and another had severe hyperkalemia. The algorithm also faces challenges in differentiating VT originating from the left and right bundle branches and their adjacent regions, as well as WCT originating from the atrioventricular valve ring and its adjacent areas. This study is a single-center research with a limited number of WCT cases enrolled, a relatively low proportion of VT cases,

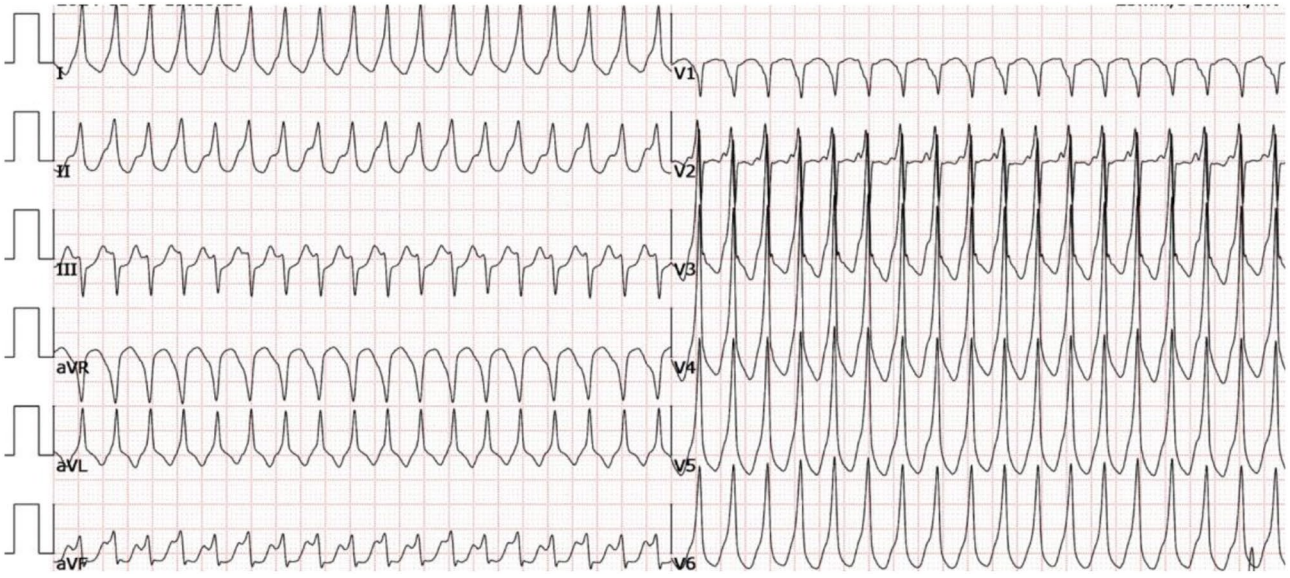

Fig. 8 WCT (VT), the Prelocalization Series Algorithm initially judged VT due to step 4 (V1 lead not showing a sharp r-wave), and diagnosed PXT as it did not match the VT patterns in steps 5 to 8. The Brugada Series Algorithm initially judged VT due to step 4 (V1 lead showing a notched S wave), and diagnosed PXT as it did not match the VT patterns in steps 5 to 7. The Vereckei Series Algorithm initially judged VT due to step 4 (vi/vt < 1), and diagnosed PXT as it did not match the patterns in steps 5 to 8

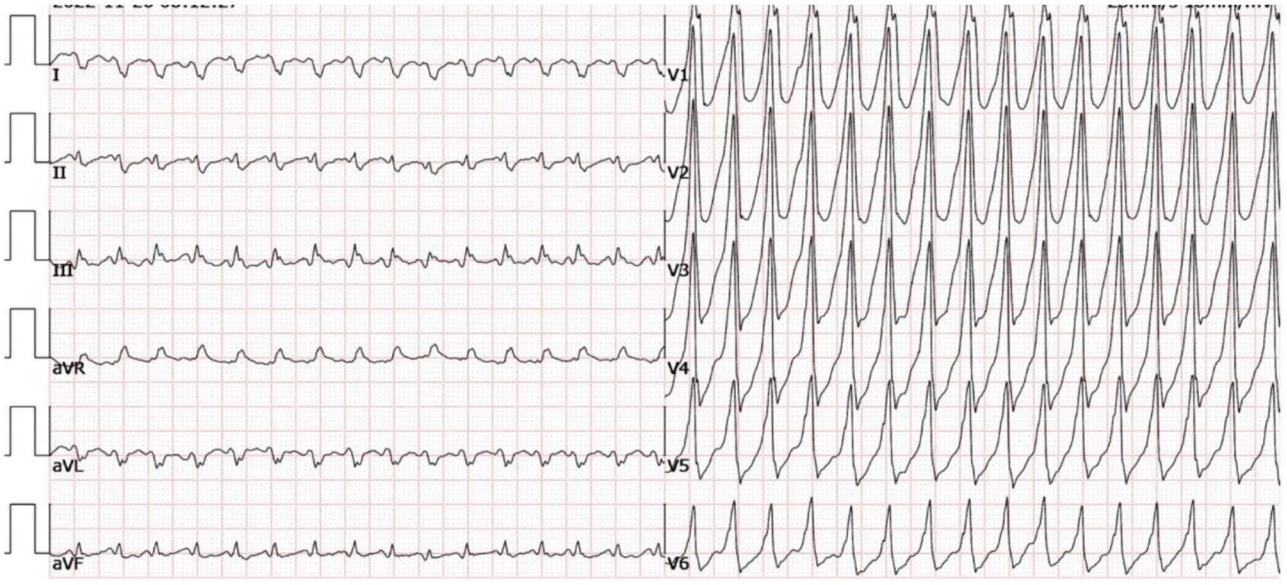

Fig. 9 WCT (PXT), the Prelocalization Series Algorithm initially judged VT due to step 4 (V1 not conforming to the typical RBBB pattern), and diagnosed PXT as it did not match the VT patterns in steps 5 to 8. The Brugada Series Algorithm initially judged VT due to step 4 (V1 lead showing a monophasic wave), and diagnosed PXT as it did not match the VT patterns in steps 5 to 7. The Vereckei Series Algorithm diagnosed VT due to steps 1 and 6 (V1 lead showing an R pattern)

and some PXT cases were provoked by programmed stimulation, which is higher than the actual incidence rate and may impact the diagnostic efficacy of the compared methods in practical use.

Conclusion

The Prelocalization Series Algorithm innovatively proposes a new approach to differential diagnosis. After validation through intracardiac electrophysiological study, its retrospective application demonstrated higher sensitivity and accuracy in diagnosing VT compared to the Brugada and Vereckei series algorithms. The Prelocalization single-process algorithm outperforms the Brugada

Four-Step Method and aVR lead method, but its accuracy is lower than that of the series algorithm. Compared to other methods, the Prelocalization Series Algorithm mainly improves the identification of VTs originating from the ventricular outflow tract and parts of the left and right ventricles, especially those related to the His-Purkinje system, and shows some improvement in differentiating SVTs with underlying organic heart diseases. Therefore, it is a new algorithm that can be attempted for the differential diagnosis of WCT and will aid in further distinguishing VT from PXT. However, differentiating SVTs complicated by severe organic heart disease and electrolyte disturbances, VTs originating from the left and right bundle branches and their adjacent regions, and WCTs originating from the atrioventricular valve ring and its adjacent areas remains challenging. The Prelocalization Series Algorithm awaits further validation through larger, multi-center studies.

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Author contributions
NHL drafted the manuscript, PHH reviewed and edited the paper, ZCL, HY and WZY revised the article critically, ZXL and PXW participated in the data collection and analysis. All authors read and approved the final manuscript.

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Data availability
All data supporting the findings of this study are available from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of the First Hospital of Jiaxing Affiliated Hospital of Jiaxing University (approval number: 2024-KY-138). The work was conducted in accordance with the World Medical Association Declaration of Helsinki. Written informed consent was obtained from all participants involved in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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