J Clin Cardiol. 2026;7(2):150-156.

Journal of Clinical Cardiology

Original Research

Accuracy of Common Electrocardiographic Algorithms in Predicting Posteroseptal Accessory Pathway Location and Guiding Ablation Approach

Marwan S. Mahmoud, MD[1,*], Antony Sameh Rassmy, MBchB[1], Salah Atta, MD[1]

[1]Cardiovascular Medicine Department, Assiut University Heart Hospital, Faculty of Medicine, Assiut University, Assiut, 71515, Arab Republic of Egypt

[*]Correspondence should be addressed to Marwan Sayed Mahmoud, Marwancordio@aun.edu.eg

Received date: June 26, 2026, **Accepted date:** September 01, 2026

Citation: Mahmoud MS, Rassmy AS, Atta S. Accuracy of Common Electrocardiographic Algorithms in Predicting Posteroseptal Accessory Pathway Location and Guiding Ablation Approach. J Clin Cardiol. 2026;7(2):150–156.

Abstract

Introduction: The primary line of management for symptomatic accessory pathway is catheter ablation. For effective mapping and ablation, accurate localization of the Accessary Pathway (AP) is critical but usually challenging, especially for the posteroseptal region.

Aim: We aimed at studying the accuracy of different surface ECG algorithms in determining the site of posteroseptal AP in comparison with Electrophysiological study (EPS) and the ablation approach.

Methods: We included 65 patients with possible manifest posteroseptal AP in a prospective observational study. Provisional determination of the site of AP was done using the Arruda et al. algorithm, the Fitzpatrick et al. algorithm, and the Pambrun et al. algorithm in both basal and maximal preexcitation conditions (using atrial pacing during EPS) and compared with the EPS localization. The ablation approach, either left or right was also recorded.

Results: The current study included 65 patients with manifest posterospetal AP. Among them 48.5% were males with a mean age of 33±11 years. We have found that Pambrun's algorithm and Fitzpatrick's algorithm (during resting ECG) had perfect agreement and accuracy [k 0.879 & 0.844, accuracy 95.4% (CI 87.1–99.0%) & 93.9% (CI 84.9–98.3%) respectively] and ablation approach [k 0.953 &0.864, accuracy 98.5% (CI 91.7–99.9%) & 96.9% (CI 89.3–99.6%) respectively], followed by Fitzpatrick's algorithm (during maximal preexcitation). However, Arruda's algorithm had moderate agreement both during resting and maximal preexcitation conditions.

Conclusion: Pambrun's and Fitzpatrick's algorithms (resting ECG) showed the highest accuracy and strongest agreement with EPS for localization of posteroseptal AP and ablation approach, indicating their superior reliability for noninvasive prediction of the posteroseptal AP site.

Keywords: Wolff-Parkinson-White syndrome, Catheter ablation, Electrocardiography, Electrophysiological techniques, Accessory pathway

Introduction

Wolff–Parkinson–White (WPW) syndrome is a pre-excitation disorder caused by the presence of an accessory atrioventricular pathway, which allows electrical impulses to bypass the atrioventricular node and conduct directly from the atria to the ventricles. On surface electrocardiography (ECG), ventricular pre-excitation is classically characterized by a shortened PR interval, the presence of a delta wave, and QRS complex widening. These accessory pathways can provide the substrate for atrioventricular reentrant tachycardia and, in certain patients, may increase the risk of sudden cardiac death [1]. The prevalence of WPW syndrome ranges from 0.1% to 0.5% globally, with a higher incidence in males [2]. The primary line of treatment for symptomatic WPW syndrome is catheter ablation [3]. The accurate localization of the Accessary Pathway (AP) is critical for effective mapping and ablation. There are numerous strategies for localizing AP using ECG. Among the most widely used are the Arruda, Fitzpatrick, and Pambrun algorithms, which use combinations of delta-wave polarity, QRS morphology, and R/S-wave relationships in different precordial and limb leads [4]. The accuracy of different algorithms is variable. Pambrun et al. reported 63% accuracy for the Arruda algorithm compared to 90% accuracy for the Pambrun algorithm [5]. Posteroseptal APs usually present diagnostic challenges due to the complex anatomy of the posteroseptal region requiring either a right or left approach for ablation [6]. Also, the ability of surface ECG algorithms to distinguish between the right and left side approaches for posteroseptal AP ablation is limited. This could be due to their close anatomical proximity to the atrioventricular node and His–Purkinje system, resulting in relatively subtle differences in ventricular activation patterns. In addition, the septal region has complex three-dimensional anatomy, with accessory pathways potentially located at different sites around the septal structures, while small variations in pathway location can produce similar pre-excitation patterns on the surface ECG [7]. In the current study, we aimed at studying the accuracy of different surface ECG algorithms in determining site of the posteroseptal AP in comparison with Electrophysiological Study (EPS) and the ablation approach.

Patients and Methods

Sixty-five patients with possible manifest posteroseptal AP were included in a prospective observational study. All patients were appropriate for EPS and ablation. All patients signed informed written consent prior to participating in the study. The study was approved by the Faculty of Medicine's ethical council (IRB no: 04-2023-200550, approval date 11 December 2023). Patients with structural or congenital heart disease were excluded. Also, prior failed ablation or patients with multiple APs were exclusion criteria.

Baseline 12-lead ECG was recorded for every patient at least one day before the EP study. ECG was recorded at 25 mm/sec paper speed and 10 mm/mV gain. Localization of the site of AP was done using the Arruda et al. algorithm [8], the Fitzpatrick et al. algorithm [9], and the Pambrun et al. algorithm [5] in the basal preexcitation condition. However, localization of site of AP during maximal preexcitation was done using atrial pacing during EPS. ECG interpretation was performed independently by two observers who were blinded to the EPS findings and the final accessory pathway location. In cases where there was disagreement between the two observers, a third experienced observer reviewed the ECG to resolve the discrepancy and reach a final interpretation. The results were subsequently compared with EPS findings to assess the diagnostic accuracy of the individual algorithms.

EPS was conducted using minimal sedation and local anesthesia. The femoral vein was used to insert quadripolar electrode catheters into the RV apex, His bundle location, and a deflectable decapolar catheter into the coronary sinus. The position of the ablation catheter was documented fluoroscopically in both the left anterior oblique (40°) and right anterior oblique (45°) projections. The final accessory pathway location was determined by conventional electrophysiological mapping, with the site demonstrating the earliest ventricular activation during sinus rhythm and/or the earliest atrial activation during appropriate pacing used to identify the pathway location. Ablation was done using the following parameters (power 40–50 watt, Temperature 50–65°C, and duration of 120 sec). The final localization was confirmed by the successful ablation site and the response to radiofrequency ablation. All electrophysiological procedures were performed by experienced electrophysiologists in a tertiary electrophysiology center, using the institution's established procedural protocols. The ablation approach (right- or left-sided) was also recorded. Agreement between each of the three ECG algorithms and EPS findings regarding AP localization and ablation approach was evaluated using Cohen's kappa coefficient. The 95% confidence intervals were calculated using the exact binomial (Clopper–Pearson) method. Statistical analyses were performed using SPSS software version 24.0 (IBM SPSS Corp., Chicago, IL, USA).

Sample size

The sample size was calculated using G*Power software (version 3.1.9.4). The calculation was based on an assumed effect size of 0.70, a significance level (α) of 0.05, and a statistical power of 80% ($1-\beta = 0.80$). Based on these assumptions, the required minimum sample size was 50 patients, but we included here 65 patients.

The primary endpoint was the accuracy of the ECG algorithms in predicting the anatomical location of the AP, using the EPS localization as the reference standard.

Results

The current study included 65 patients with manifest posteroseptal AP. Among them 48.5% were males with a mean age of 33±11 years. All patients had normal echocardiography and no medical history of clinical significance.

Site of APs

Table 1 shows the distribution of APs as predicted by different algorithms compared with EPS. We have found that Pambrun's algorithm and Fitzpatrick's algorithm (during resting ECG) had perfect agreement (Kappa 0.879 & 0.844 respectively), followed by Fitzpatrick's algorithm (during maximal preexcitation) (Kappa 0.684). However, Arruda's algorithm had moderate agreement both during resting and maximal preexcitation conditions (Kappa 0.547 & 0.502 respectively). Regarding accuracy, Pambrun's algorithm had the highest accuracy (95.4%) followed by Fitzpatrick's Algorithm (during resting and maximal pre-excitation), with accuracy 93.9% & 84.6% respectively. However, Arruda's algorithm had the lowest accuracy (see **Table 2**).

Table 1. Comparison of the different algorithms by EP Site (showing number of AP in each group and degree of agreement).

	Site of AP according to EPS				p-value	Kappa (Agreement)	Interpretation of Agreement
Algorithm / Predicted Site	**CS No**	**LPS No**	**RPS No**	**Total No**			
Arruda's Algorithm (resting ECG)					0.000	0.547	Moderate agreement
CS	3	0	5	8			
LPS	0	24	0	24			
PS	0	6	7	13			
RPS	0	0	20	20			
Arruda's Algorithm (maximal pre-excitation)					0.000	0.502	Moderate agreement
CS	3	2	3	8			
LPS	0	22	0	22			
PS	0	6	7	13			
RPL	0	0	3	3			
RPS	0	0	19	19			
Fitzpatrick's Algorithm (resting ECG)					0.000	0.844	Almost perfect agreement
CS	0	0	0	0			
LP	1	0	0	1			
LPS	0	30	0	30			
PS	0	0	1	1			
RPS	0	0	31	31			
RPS/RPL	2	0	0	2			
Fitzpatrick's Algorithm (maximal pre-excitation)					0.000	0.684	Substantial agreement
CS	0	0	0	0			
LP	1	2	0	3			
LPS	0	28	0	28			
PS	0	0	2	2			
RP	0	0	3	3			
RPS	0	0	27	27			
RPS/RPL	2	0	0	2			
Pambrun's Algorithm					0.000	0.879	Almost perfect agreement
CS	0	0	0	0			
LPS	1	30	0	31			
RPS	0	0	32	32			
RPS/RPL	2	0	0	2			

*Significantly different as P value ≤0.05. AP site abbreviations: CS: Coronary Sinus; LPS: Left Posteroseptal; LP/LPL: Left Posterior/Posterolateral; PS: Posteroseptal; RP/RPL: Right Posterior/Posterolateral; RPS: Right Posteroseptal; RA: Right Anterior; ECG: Electrocardiography

Table 2. Accuracy of different mapping algorithms in determining the site of AP.

Algorithm	Accuracy	95% CI
Arruda – resting ECG	72.3%	59.8–82.7%
Arruda – maximal preexcitation	67.7%	54.9–78.7%
Fitzpatrick – resting ECG	93.9%	84.9–98.3%
Fitzpatrick – maximal preexcitation	84.6%	73.5–92.4%
Pambrun	95.4%	87.1–99.0%

The 95% CIs above are calculated using the exact binomial (Clopper–Pearson) method. CI: Confidence Interval; ECG: Electrocardiography.

Ablation approach

Table 3 shows the distribution of APs as detected with different algorithms compared with the ablation approach. We have found that Pambrun's algorithm and Fitzpatrick's algorithm (during resting ECG) had perfect agreement in determining the ablation approach for posteroseptal AP (Kappa 0.953 & 0.864 respectively), followed by Fitzpatrick's Algorithm (during maximal preexcitation) (Kappa 0.725). However, Arruda's algorithm had moderate agreement both

Table 3. Degree of agreement of different algorithms in determining ablation approach, showing number of AP in each group and degree of agreement.

AP Site (Algorithm)	Right Septal AP group (n=35)	Left Septal AP group (n=30)	p- value	Kappa (Agreement)	Interpretation of Agreement
Arruda's algorithm (resting ECG)					
CS	8 (22.86%)	0 (0%)	0.000	0.600	Moderate agreement
PS	7 (20%)	6 (20%)			
LPS	0 (0%)	24 (80%)			
RPS	20 (57.14%)	0 (0%)			
Arruda's algorithm (maximal pre-excitation)					
RPL	3 (8.6%)	0 (0%)	0.000	0.466	Moderate agreement
PS	7 (20%)	6 (20%)			
LPS	0 (0%)	20 (66.7%)			
RPS	25 (71.4%)	4 (13.3%)			
Fitzpatrick's algorithm (resting ECG)					
PS	1 (2.86%)	0 (0%)	0.000	0.864	Almost perfect agreement
LPS	0 (0%)	30 (100%)			
LP	1 (2.86%)	0 (0%)			
RPS/RPL	2 (5.71%)	0 (0%)			
RPS	31 (88.57%)	0 (0%)			
Fitzpatrick's algorithm (maximal pre-excitation)					
PS	2 (5.7%)	0 (0%)	0.000	0.725	Substantial agreement
LPS	0 (0%)	28 (93.3%)			
LP	1 (2.9%)	2 (6.7%)			
RP	3 (8.6%)	0 (0%)			
RPS	29 (82.8%)	0 (0%)			
Pambrun's algorithm					
LPS	1 (2.9%)	30 (100%)	0.000	0.953	Almost perfect agreement
RPS/RPL	2 (5.7%)	0 (0%)			
RPS	32 (91.4%)	0 (0%)			

*Significantly different as P value ≤0.05. AP site abbreviations: CS: Coronary Sinus; LPS: Left Posteroseptal; LP/LPL: Left Posterior/Posterolateral; PS: Posteroseptal; RP/RPL: Right Posterior/Posterolateral; RPS: Right Posteroseptal; RA: Right Anterior; ECG: Electrocardiography during resting and maximal preexcitation conditions (Kappa 0.600 & 0.466, respectively). Regarding accuracy, Pambrun's Algorithm (had the highest accuracy (98.5%) followed by Fitzpatrick's Algorithm (during resting and maximal preexcitation) (96.9% & 95.4% respectively). However, Arruda's algorithm had the lowest accuracy (see **Table 4**).

Table 4. Diagnostic accuracy of the different algorithms for determining left versus right septal approach.

Algorithm	Accuracy	95% CI
Arruda – Resting ECG	67.7%	54.9–78.8%
Arruda – Maximal preexcitation	73.9%	61.5–83.9%
Fitzpatrick – Resting ECG	96.9%	89.3–99.6%
Fitzpatrick – Maximal preexcitation	95.4%	87.1–99.0%
Pambrun's algorithm	98.5%	91.7–99.9%

Note: 95% confidence intervals were calculated using the exact binomial (Clopper–Pearson) method.

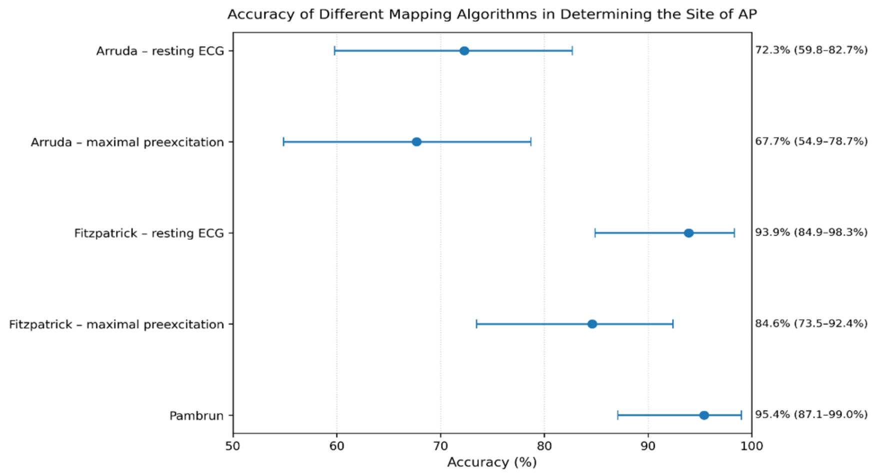

Figure 1. Shows a forest plot for diagnostic accuracy and confidence interval for ECG algorithms for posteroseptal AP localization.

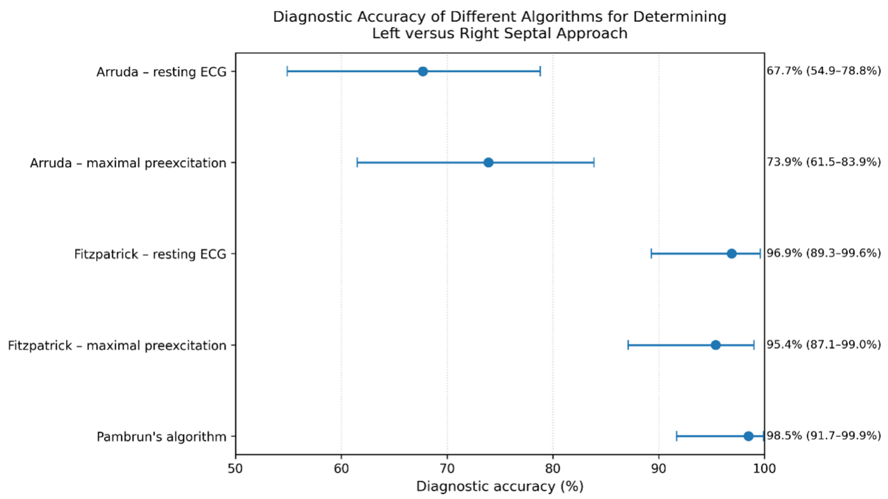

Figure 2. Shows a forest plot for diagnostic accuracy and confidence interval for ECG algorithms for determining left versus right septal approach.

Discussion

Radiofrequency catheter ablation is a well-established curative treatment for WPW syndrome. Consequently, accurate preprocedural localization of the AP is clinically important for optimizing procedural planning and improving ablation outcomes [4].

Posteroseptal APs, in particular, provide distinct challenges due to their proximity to important conduction structures and the difficulty of discriminating between right- and left-sided approaches for ablation. Katsouras et al. [10] have evaluated the extent of agreement among three electrocardiographic algorithms—those developed by Chern-En Chiang, Fitzpatrick, and Xie were evaluated for the localization of accessory pathways in patients with overt preexcitation and mentioned that the degree of agreement was limited for right and left posteroseptal regions. This indicates the challenges of this area.

In the current study, we compared the accuracy of different 12-lead ECG algorithms in determining the site of posteroseptal AP compared with EPS and the ablation approach.

We have found that Pambrun's algorithm and Fitzpatrick's algorithm (during resting ECG) had perfect agreement with the highest accuracy for determining both the site of AP compared with the EPS and ablation approach, followed by Fitzpatrick's algorithm (during maximal pre-excitation). However, Arruda's algorithm had moderate agreement both during resting and maximal preexcitation conditions with lowest accuracy.

The algorithm proposed by Pambrun et al. [5] was derived from a cohort of 207 patients with a single manifest AP. In that study, the authors prospectively evaluated the performance of the Pambrun algorithm against the Arruda algorithm, which is based on basal pre-excitation patterns. The Pambrun algorithm demonstrated significantly higher accuracy than the Arruda algorithm (90% vs. 63%, $P<0.001$). Furthermore, agreement with electrophysiological findings was excellent for the Pambrun algorithm ($\kappa>0.75$, $P<0.05$), whereas only fair agreement was observed with the Arruda algorithm ($0.40<\kappa<0.75$, $P<0.05$). These results are consistent with the findings of the present study.

In contrast to our findings, Krishna et al. [4] evaluated the accuracy and effectiveness of the Pambrun algorithm and reported that it was less accurate than the established Arruda algorithm for AP localization. However, their study included all AP locations rather than focusing exclusively on posteroseptal APs. Notably, they observed that the Arruda algorithm frequently misclassified right-sided pathways, including right posteroseptal, right posterolateral, and right anterolateral APs, which is consistent with our observations. They also reported a moderate level of agreement between the Arruda algorithm and EPS findings ($\kappa=0.645$).

Also, Senoner et al. [11] studied the accuracy of ECG-based algorithms (Arruda, Milstein, and Fitzpatrick) and mentioned that predictive accuracy was 53.2%, 65.6%, and 44.7%, respectively. This was also applied to all types of APs. However, in the current study, the accuracy was higher for the posteroseptal region.

The discrepancies between our findings and those reported by Krishna et al. and Senoner et al. may be explained by several methodological and clinical differences between the studies. First, differences in the study populations and inclusion criteria may have influenced the diagnostic performance of the ECG algorithms. While some previous studies included accessory pathways from multiple anatomical locations, the present study specifically evaluated patients with posteroseptal accessory pathways, representing a more anatomically focused and potentially challenging subgroup. Second, differences in electrophysiological techniques and the criteria used to define the true accessory pathway location may have contributed to variations in reported accuracy. The final localization in our study was based on detailed EPS assessment and the successful ablation site, whereas differences in mapping strategies and procedural endpoints may have been used in previous studies. Third, operator experience and institutional expertise in electrophysiological mapping may affect both pathway localization and interpretation of ECG patterns. Finally, differences in sample size and study design may contribute to variability in diagnostic accuracy estimates, particularly in studies with relatively small numbers of patients within individual accessory pathway locations. Therefore, the differences between our results and previous reports should be interpreted in the context of these population, methodological, and procedural differences rather than as evidence that one approach is universally superior.

Importantly, to the best of our knowledge, this is the first study to thoroughly analyze the accuracy of these algorithms for discriminating between right-and left-sided approaches for posteroseptal AP ablation. Determining the ablation approach from the start can reduce procedure time, eliminate unnecessary mapping from both sides of the septum, and limit problems associated with transseptal puncture or retrograde aortic access. Furthermore, earlier selection of the appropriate approach may reduce fluoroscopy time and increase patient safety.

However, the study was conducted at a single tertiary referral center, which may have resulted in specific patient referral patterns and a study population that does not fully represent patients managed in other institutions or healthcare settings. In addition, the level of electrophysiological expertise, operator experience, local mapping strategies, and institutional practices may influence both the interpretation of ECG algorithms and the determination of the AP location by EPS.

Limitations

Our findings should be interpreted as single-center results requiring external validation. Future multicenter studies involving diverse patient populations, different electrophysiology laboratories, and operators with varying levels of experience are warranted to confirm the reproducibility and generalizability of the observed diagnostic accuracy. The relatively small sample size limits the statistical power of the study and precludes meaningful subgroup analyses. Third, the study population was restricted to patients with manifest posteroseptal accessory pathways, which may limit the applicability of the findings to concealed pathways.

Clinical Implications

The main clinical implication is that surface ECG analysis may provide useful information not only for predicting the anatomical location of posteroseptal accessory pathways but also for anticipating the most likely ablation approach (right-sided versus left-sided) before the electrophysiological procedure.

Our findings also suggest that the diagnostic performance of the algorithms may differ depending on whether the objective is exact anatomical localization or simply prediction of the appropriate ablation approach. An algorithm may occasionally misclassify the precise anatomical site while still correctly predicting the side from which successful ablation can be approached.

Conclusion

Surface ECG–based localization algorithms demonstrate variable accuracy for localization of posteroseptal APS when compared with EPS findings. Among the tested algorithms, Pambrun's and Fitzpatrick's (using resting ECG) showed the highest accuracy and strongest agreement with EPS localization and ablation approach, indicating their superior reliability for noninvasive prediction of the AP site. Arruda's algorithm showed only moderate agreement under both resting and pacing conditions. These results suggest that Pambrun's and Fitzpatrick's algorithms may be preferred tools for preprocedural assessment and planning of ablation in posteroseptal WPW patients.

Author Contributions

Marwan S. Mahmoud's contributions include clinical work, data interpretation, statistical analysis, manuscript preparation, writing, and revision. Antony Sameh Rassmy made contributions to data collection, clinical, and statistical work. Salah Atta edited and approved the manuscript while also contributing to clinical work, design, and concept development.

References

1. Elendu C, Babarinde FO, Babatunde OD, Babawale EA, Hassan JI, Ikeji VI, et al. Risk stratification and management of arrhythmias in patients with Wolff-Parkinson-White syndrome. Ann Med Surg (Lond). 2025 Mar 7;87(5):2702–17.
2. Chhabra L, Goyal A, Benham MD. Wolff-Parkinson-White Syndrome. [Updated 2023 Aug 7]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK554437/
3. Brugada J, Katritsis DG, Arbelo E, Arribas F, Bax JJ, Blomström-Lundqvist C, et al. 2019 ESC guidelines for the management of patients with supraventricular tachycardia the task force for the management of patients with supraventricular tachycardia of the European Society of Cardiology (ESC) developed in collaboration with the Association for European Paediatric and Congenital Cardiology (AEPC). European Heart Journal. 2020 Feb 1;41(5):655–720.
4. Krishna SV, Satish OS. Accuracy of Different Surface Electrocardiogram Algorithms for Localization of Accessory Pathway in Comparison to Invasive Electrophysiological Localization: An Observational Study. Journal of Indian College of Cardiology. 2024 Jul 1;14(3):88–91.
5. Pambrun T, El Bouazzaoui R, Combes N, Combes S, Sousa P, Le Bloa M, et al. Maximal Pre-Excitation Based Algorithm for Localization of Manifest Accessory Pathways in Adults. JACC Clin Electrophysiol. 2018 Aug;4(8):1052–61.
6. Lebloa M, Pascale P. Preprocedural discrimination of posteroseptal accessory pathways ablated from the right endocardium from those requiring a left-sided or epicardial coronary venous approach. Arrhythm Electrophysiol Rev. 2022 Apr;11:e07.
7. Di C, Li L, Wang Q, Wu Y, Zhang Y, Lin W. Revisiting Para-Septal Accessory Pathways: A Unified Anatomic, Electrocardiographic, and Electrophysiologic Framework for Typical and Variant Subtypes. J Cardiovasc Electrophysiol. 2026 Jan;37(1):165–76.
8. Arruda MS, McClelland JH, Wang X, Beckman KJ, Widman LE, Gonzalez MD, et al. Development and validation of an ECG algorithm for identifying accessory pathway ablation site in Wolff-Parkinson-White syndrome. J Cardiovasc Electrophysiol. 1998 Jan;9(1):2–12.
9. Fitzpatrick AP, Gonzales RP, Lesh MD, Modin GW, Lee RJ, Scheinman MM. New algorithm for the localization of accessory atrioventricular connections using a baseline electrocardiogram. J Am Coll Cardiol. 1994 Jan;23(1):107–16.
10. Katsouras CS, Greakas GF, Goudevenos JA, Michalis LK, Kolettis T, Economides C, et al. Localization of accessory pathways by the electrocardiogram: which is the degree of accordance of three algorithms in use? Pacing Clin Electrophysiol. 2004 Feb;27(2):189–93.
11. Senoner T, Pfeifer B, Barbieri F, Adukauskaite A, Dichtl W, Bauer A, et al. Identifying the Location of an Accessory Pathway in Pre-Excitation Syndromes Using an Artificial Intelligence-Based Algorithm. J Clin Med. 2021 Sep 26;10(19):4394.