Iranian Heart Journal; 2021; 22 (4)

Original Article

A Simple Algorithm for Predicting the Location of Right-Sided Accessory Pathways Based on ECG in WPW Patients

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ABSTRACT

Background: Several algorithms have been designed for the localization of pre-ablation accessory pathways (APs) in Wolff–Parkinson–White (WPW) syndrome based on QRS or delta-wave polarity in different (electrocardiographic) ECG leads. Due to the difficulty of catheter placement in the tricuspid ring, leading to increased likelihoods of ablation failure and recurrence in right-sided APs, it is essential to design an algorithm to correctly predict the location of these APs before ablation.

Methods: In this retrospective study, 294 known WPW patients with right-sided APs who had clear pre-excitation in the 12-lead ECG were divided into 8 anatomic zones and were then studied using ECG and electrophysiological characteristics.

Results: An algorithm was designed based on the sum of QRS and delta-wave polarity in the V_1 and inferior leads. The sensitivity and specificity of the proposed algorithm for predicting free-wall APs, including posterolateral and posterior APs, were 95% and 25%, respectively. Sensitivity and specificity were 72.7% and 95.8% for anterolateral and anterior APs, respectively, and 100% and 60% for lateral APs, respectively. In septal APs, the respective rates of sensitivity and specificity of the algorithm were 60% and 80% for the posteroseptal AP, 61% and 98% for the anteroseptal AP, and 31% and 90% for the midseptal AP.

Conclusions: The proposed algorithm provides a precise and simple way to differentiate between right-sided APs before performing ablation, thereby reducing ablation failure and recurrence. ***(Iranian Heart Journal 2021; 22(4): 71-79)***

KEYWORDS: Right-sided accessory pathway, Wolff–Parkinson–White syndrome, Electrocardiography, Electrophysiology, Radiofrequency ablation

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Received: June 8, 2020 **Accepted:** August 10, 2020

Wolff–Parkinson–White syndrome (WPW) was introduced in 1939 for the first time following the evaluation of 11 patients with a short PR segment and a bundle branch block pattern in their electrocardiography (ECG). [1] It is now known that WPW patients have an accessory pathway (AP) in the conduction system of the heart. This pathway creates an extra connection between the atrium and the ventricle other than the usual atrioventricular node. The criteria for diagnosing the condition include the presence of a short PR segment, an elongated QRS segment, and a delta wave. [2-4] Right-sided APs are situated around the tricuspid valve. They are classified into 8 subgroups: right anteroseptal, right midseptal, right posteroseptal, right posterior, right anterior, right anterolateral, right posterolateral, and right lateral. [5]

Patients with right-sided APs, suffer palpitations due to a variety of arrhythmias such as atrial fibrillation, atrioventricular reentry tachycardia, atrionodal ventricular tachycardia, atrial flutter, and rarely, ventricular fibrillation or tachycardia. [6]

The initial treatment for WPW is the ablation of the AP, but positioning the catheter in the tricuspid ring may prove extremely difficult. A successful and safe ablation procedure hinges on a clear definition of the electrophysiological features of these APs. [7] What also tends to complicate the situation is the high possibility of recurrence (14%–35%) and unsuccessful ablation (10%–19%). Predicting the exact location of APs is, therefore, essential to the prevention of these complications. [8]

The present study aimed to evaluate the features of right-sided APs with a view to creating a practical algorithm for the diagnosis of AP subgroups prior to ablation and boosting the rate of successful ablation.

METHODS

This cross-sectional study enrolled 294 WPW patients with right-sided APs who underwent ablation at Rajaie Cardiovascular Medical and Research Center between 2006 and 2018.

The inclusion criteria were composed of the presence of WPW according to ECG criteria, the presence of antegrade conduction, having symptoms related to the presence of WPW, and being a candidate for ablation. The exclusion criteria consisted of having the Ebstein anomaly, the presence of a bundle branch block, and having multiple APs.

The aims and the protocol of the study were clarified for the patients, who were fully reassured that no additional tests or procedures (other than the routine tests necessary for ablation) were needed and that no additional costs would be imposed on them. Written informed consent was obtained from all the patients, who received reassurances that their information would be kept confidential and that the investigation would not harm the process of their diagnosis and treatment in any way. This study was approved by the Ethics Committee of Iran University of Medical Sciences.

ECG recording of the entire study population was performed using paper at a speed of 25 mm/s and a voltage of 10 mm/mV. The first 40 ms of a pre-excited QRS wave in the frontal leads and the first 60 ms of the QRS wave in the limb leads were considered a delta wave. If the delta wave was above the isoelectric line, it was considered positive; and if it was below the line, it was regarded as negative. If the delta wave consisted of both positive and negative parts, it was considered isoelectric. All ECGs were evaluated separately by 3 electrophysiologists, blinded to the results of the electrophysiology study and ablation. Finally, the results were compared, and conclusions were drawn.

Electrophysiological studies were performed with quadripolar catheters at 5 mm intervals between the electrodes inserted through the right femoral vein into the right atrium and the right ventricle. Additionally, 2 decapolar catheters with 5 mm spacing between the electrodes were inserted via the right femoral vein pathway into the coronary sinus and the tricuspid valve.

Several electrophysiological features were studied and compared; they included the cycle length, the AH interval, the HV interval length, the AP antegrade effective refractory period, the AP retrograde effective refractory period, HRA, and the VA interval.

Ablation was performed using radiofrequency energy with both irrigated and non-irrigated tip catheters according to the position of the AP and the distance from the atrioventricular node.

Ablation was done at the site of a success signal defined as a fused atrioventricular potential in the sinus rhythm or earliest A during atrioventricular reentry tachycardia. In sites with the acceptable signal, ablation was performed for 2 minutes if pre-excitation disappeared or if the arrhythmia was terminated in less than 5 seconds. Otherwise, the operator searched for another good position. Thirty minutes after ablation, adenosine (6–12 mg) was injected in both the manifest AP and the atrioventricular reentry tachycardia site (during the V pacing). If there was no evidence of an AP, ablation was terminated

For the analysis of the data, the independent samples *t* test or its nonparametric form (the Mann–Whitney *U* test), the analysis of variance, and the χ^2 independent test (or the Fisher exact test) were used. The significance level was chosen to be a *P*-value of less than 0.05.

RESULTS

According to the inclusion and exclusion criteria of the study, 294 WPW patients, consisting of 61.4% female and 38.6% male patients, were selected. The mean age of the patients was 33.3±13 years. The youngest was 1 year old, and the oldest was 78 years old. The mean left ventricular ejection fraction was 50%. During the electrophysiological study, the incidence rate of induced atrial fibrillations was 8.5%. The frequency of each AP, the results of ablation, and the rate of recurrence are presented in Table 1. The right posteroseptal AP was the most frequent AP (54.4%), and the right lateral AP was the least frequent (0.9%). The posterior AP had the highest recurrence rate (26.7%), and the anteroseptal AP had the lowest rate of recurrence (7.1%) (Table 1, Fig. 1 & Fig. 2).

There were no significant differences concerning the electrophysiological characteristics between any of the APs (P>0.05) except AH in the anterior AP, which was 84±32 ms. The AH duration in the anterior AP was significantly shorter than that in all the other APs (P=0.002).

All APs were compared in terms of the HRA-VA interval. The duration was 112.5±51 ms in the right anterior AP during tachycardia, which was the shortest among all APs, with no significant difference (P=0.7) (Table 2 & Table 3).

Septal and free-wall APs were compared in terms of the V_1 delta-wave polarity, which was negative in 80.26% of the septal APs and positive in 85% of the free-wall APs, with the difference being significant (P=0.001).

Thereafter, the QRS polarity sum of the inferior leads (II, III, and aVF) was compared between the free-wall APs. It was negative in 76% of the posterior and posterolateral APs, but it was positive in 96% of the anterior, anterolateral, and lateral APs. This difference was also significant (P=0.001). Next, the QRS polarity sum of the inferior leads (II, III, and aVF) was compared between the septal APs. It was negative in 87% of the posteroseptal APs, while 79% of the anteroseptal, midseptal, and lateral APs had a positive QRS polarity sum (P=0.001).

The delta-wave polarity sum of the inferior leads in all the lateral APs was −1, 0, or 1. In 86% of the anterior and anterolateral APs, the sum was +2 and +3. The difference between the mentioned APs was of statistical significance (P=0.001).

The delta-wave polarity sum of the inferior leads was −1, 0, and −1 in 75% of the midseptal APs and +2 and +3 in 85% of the anterior and anteroseptal APs. The difference between these APs also constituted statistical significance (P<0.001) (Fig. 3).

Table 1. Accessory pathway frequencies, unsuccessful results, and recurrence rates after ablation

Accessory Pathways	Frequency	Unsuccessful Result	Recurrence Rate
Right anteroseptal	28(8.5%)	2(7.1%)	3(10.7%)
Midseptal	16(4.9%)	2(12.5%)	-
Posteroseptal	179(54.4%)	24(13.4%)	6(3.4%)
Posterior	30(9.1%)	8(26.7%)	-
Anterior	13(4%)	1(7.7%)	-
Anterolateral	9(2.7%)	1(11.1%)	-
Posterolateral	16(4.9%)	4(25%)	1(6.3%)
Lateral	3(0.9%)	-	-

Table 2. Electrophysiology characteristics and comparison between the APs

Characteristics	Anteroseptal	Midseptal	Posteroseptal	Anterior	Anterolateral	Lateral	Posterolateral	Posterior	*P*-value
Tachycardia cycle length	323±37	368±109	336±58	322±69	326±16	484	333±48	341±39	0.89
AH interval	92.46±16	117.5	120±65	84±32	100±16	213	150±14	166±59	0.002
VA interval	156±35	217±85	158±58	112±51	146±57	222	166±42	139±36	0.7
AP AERP	277±53	313±5	287±53	300±45	240±56	240	270±34	300±27	0.69
AP RERP	290	345±7	277±79	270	250±52	390	272±53	326±75	0.694
Recurrence rate	7.1%	12.5%	13.4%	7.7%	11.1%	-	25%	26.7%	0.49
Unsuccessful result	10.7%	-	3.4%		-		6.3%		
AV block	3.6%	-	1.7%	-	-	-	-	6.7%	0.51

ms, Millisecond; AP, Accessory pathway; AP AERP, Accessory pathway antegrade effective refractory period; AP RERP, Accessory pathway retrograde effective refractory period; AV, Atrioventricular

Table 3. Our algorithm's sensitivity, specificity, positive predictive value, and negative predictive value in differentiating between the accessory pathways

Accessory Pathways	Sensitivity	Specificity	Negative Predictive Value	Positive Predictive Value
Anteroseptal	61%	98%	72.7%	96.1%
Midseptal	31.3%	90%	14.7%	96.3%
Posteroseptal	60%	80%	78.1%	62.5%
Anterior Anterolateral	72.7%	95.8%	55.2%	98%
Lateral	100%	60%	5.5%	100%
Posterior Posterolateral	95.6%	25%	17.6%	97.1%

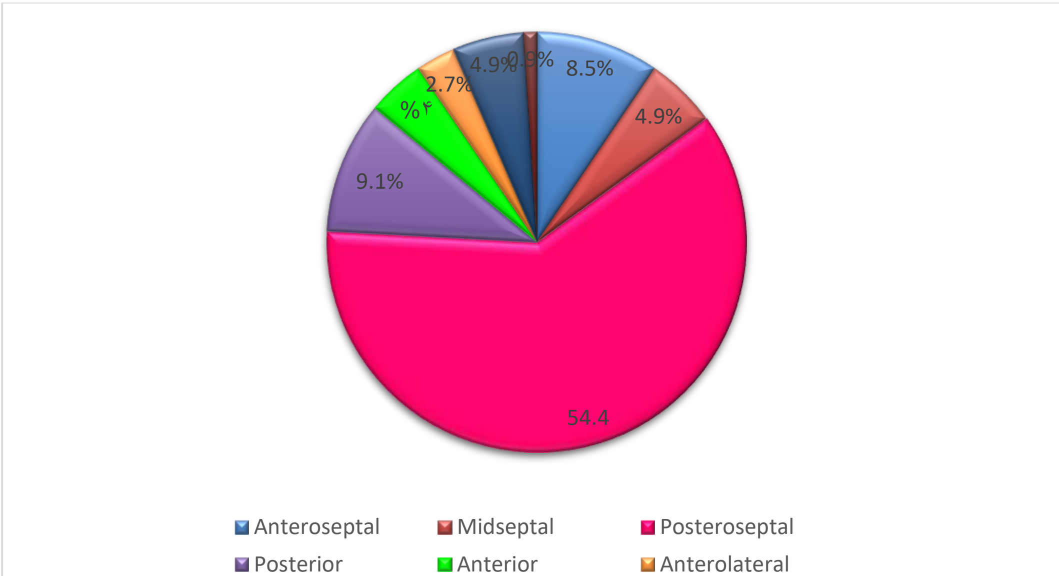

Figure 1. The frequencies of the right-sided accessory pathways in the study population are illustrated herein.

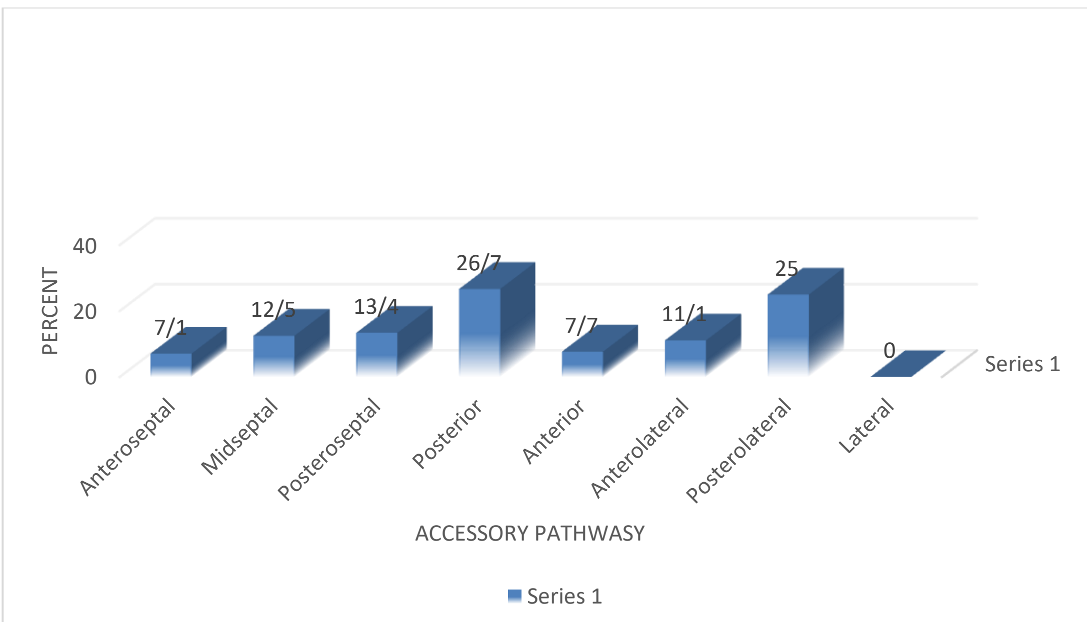

Figure 2. The figure shows the recurrence rates of accessory pathways after radiofrequency ablation in the study population.

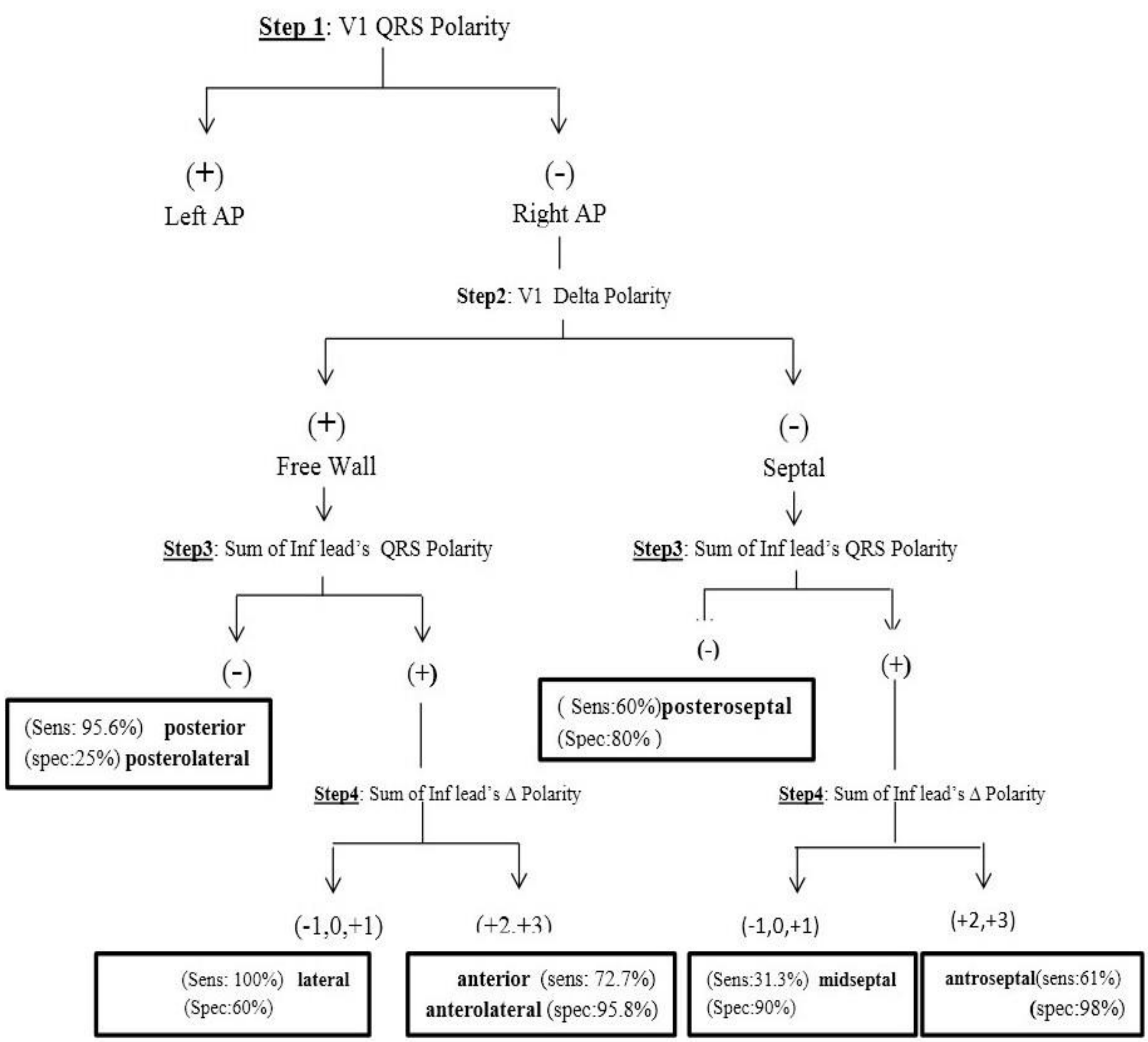

Figure 3. The image presents a step-by-step depiction of the proposed algorithm to predict the location of the right-sided accessory pathways in the study population.

DISCUSSION

The mean age of the patients in this study was 33.7 years, which is similar to that in a study by Raunt et al, [6] who also reported frequencies for all APs that are similar to those in our study. The right free-wall AP had the highest frequency, whereas the right anterior AP had the lowest frequency of all the APs.

Several algorithms have been created based on the polarities of the QRS complex or delta waves in previous studies to predict the exact location of different APs before ablation. Several other studies have drawn upon the R/S ratio in the V_1 lead. [9-15] We designed an algorithm based on a combination of QRS and delta-wave polarity in the V_1 and inferior leads.

We evaluated right-sided APs in this study and excluded cases with left-sided APs. In the first step, drawing upon previous investigations, [8] we classified APs into 2 groups: patients with a positive QRS in V_1 were categorized as the left-sided AP group, and patients with a negative QRS were classified in the right-sided AP group. In the second step, we divided right-sided APs into 2 groups according to the positivity of the delta wave in V_1. Positive delta waves originated from the free-wall AP, whereas negative delta waves stemmed from the septal AP. The delta-wave polarity in V_1 was used to classify APs into septal or free-wall APs. [12]

The third step was similar to that of septal and free-wall APs insofar as both positive and negative delta waves were classified according to the sum of the QRS polarity in the inferior leads. In free-wall APs, negative ones were posterior or posterolateral APs, while positive ones were divided into 3 subgroups: anterior, anterolateral, and lateral APs. In the septal AP group, a negative QRS complex was suggestive of a posteroseptal AP, while positive QRS complexes were divided into 2 groups: anteroseptal and midseptal APs.

Si Dung Chu et al [16] studied right free-wall APs and observed a positive QRS complex in right anterolateral and lateral APs and a negative QRS complex in posterolateral APs.

In the fourth step, based on the delta-wave polarity sum of the inferior leads, the free-wall and septal APs with a positive QRS complex in the previous step were divided into 2 groups. In the free-wall AP group, if the delta-wave polarity sum of the inferior leads was −1 or 0 or +1, the APs were considered to be on the lateral side; and if the delta-wave polarity sum of the inferior leads was +2 or +3, the APs were considered to be on the anterior and anterolateral sides of the tricuspid ring. In the septal AP group, if the delta-wave polarity sum of the inferior leads was −1 or 0 or +1, the AP location was considered to be midseptal; and if the delta-wave polarity sum of the inferior leads was +2 or +3, the APs were considered to be on the anteroseptal side of the tricuspid ring.

Haghjoo et al [9] evaluated septal APs. In their study, delta waves in II, III, and aVF were positive in anteroseptal APs. Delta waves were also positive in lead II and negative in lead III in midseptal APs. In the midseptal APs, 75% of the cases had negative or biphasic delta waves; and 25% of them had positive delta waves in the aVF lead.

In a study by Fitzpatrick et al, [14] whereas posteroseptal APs had a negative delta wave of 2 or more in the inferior leads, anteroseptal APs had 2 or more positive delta waves in the inferior leads. Moreover, midseptal APs had a delta-wave polarity sum of −1, 0, or +1. [17]

The rate of unsuccessful ablation and recurrence, respectively, was 4% and 16.1% in our study. In other studies, the ablation failure rate in right free-wall ablation is between 10% and 19%, and the recurrence rate ranges from 14% to 35%, which is high in comparison with the rates of left-sided AP ablation (3%–7% and 2%–6%, respectively). [18-20]

Right-sided APs are uncommon, and the rates of unsuccessful ablation and recurrence are high. In the present study, we introduced a practical algorithm to increase the rate of successful ablation and decrease the rate of recurrence. Our results demonstrated that the sensitivity of lateral (100%) and posterior and posterolateral (95.6%) APs was high; therefore, this algorithm is useful for screening the presence of these APs. Further, the specificity of this algorithm was high in the anteroseptal (98%), anterior and anterolateral (95.8%), and midseptal (90%) APs. Thus, our algorithm can be easily used to confirm the diagnosis in these APs. The positive predictive value was also high for

all APs, except the posteroseptal AP (96.1%, 96.3%, 62.5%, 98%, 100%, and 97.1% in the right anteroseptal AP, the right midseptal AP, the right posteroseptal AP, the right anterior and anterolateral APs, the right lateral AP, and the right posterior and posterolateral APs, respectively).
This algorithm can confirm the presence of an AP before ablation, but it is not as useful in a posterolateral AP. Accordingly, other methods should be drawn upon for the aforementioned APs. Furthermore, the negative predictive value was high in anteroseptal (72.7%) and posteroseptal (78.1%) APs, while it was too low in the other APs due to the small sample group in these APs.

CONCLUSIONS

The current study presents a simple algorithm based on the polarity of the delta and QRS waves in ECG to differentiate between right-sided APs. The proposed algorithm provides a precise and simple way to differentiate between right-sided APs prior to ablation, thereby reducing ablation failure and recurrence.

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