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The Role Of Diagnosing The Location Of Accessory Pathways Using 15-Lead Ecg In Patients With Wolff-Parkinson-White Syndrome

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ABSTRACT

Objective: To evaluate the role of the 15-lead ECG with V3R, V4R, and V5R on the surface electrocardiogram in determining the location of accessory pathways in patients with Wolff-Parkinson-White (WPW) syndrome. Methods: A cross-sectional, diagnostic test evaluation study. 43 patients diagnosed with WPW syndrome, whose accessory pathway locations were predicted using a 15-lead surface ECG with V3R, V4R, and V5R, underwent electrophysiological studies and successful radiofrequency ablation at 3 major cardiology centers in Hanoi, Vietnam, from September 2022 to September 2023. Results: The QRS morphology on the right precordial leads (V3R, V4R, V5R) in patients with WPW syndrome had 3 main forms: RS or R form, QS or Qr form, and rS form. The QRS amplitude in V3R, V4R, and V5R being positive for the diagnosis of left-sided accessory pathway had a sensitivity of 80%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 78.3%. The QRS amplitude in V3R, V4R, and V5R being negative for the diagnosis of right-sided accessory pathway had a sensitivity of 100%, specificity of 80%, positive predictive value of 78.3%, and negative predictive value of 100%. The sensitivity, specificity, positive predictive value, and negative predictive value when applying the QRS morphology criterion at V4R as QS or Qr in determining the septal location were 93.3%, 96.4%, 93.3%, and 96.4%, respectively. The sensitivity, specificity, positive predictive value, and negative predictive value for right-sided septal pathways were 100%, 93.9%, 83.3%, and 100%, respectively. The sensitivity, specificity, positive predictive value, and negative predictive value for left-sided septal pathways were 60%, 100%, 100%, and 95%, respectively. Fluoroscopy time, procedure time, ablation time, and the number of ablation attempts were significantly reduced. Conclusion: Differentiating the location of accessory pathways on the tricuspid and mitral valve annuli has high accuracy, differentiating the location of accessory pathways in the septal region versus the free wall has high accuracy, helping to shorten procedure time and fluoroscopy time when using the criteria for predicting AP location by surface ECG with V3R, V4R, and V5R.

KEYWORDS: surface electrocardiogram, 15-lead ECG, localization of accessory pathways, electrophysiological study, radiofrequency ablation.

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INTRODUCTION

Wolff-Parkinson-White (WPW) syndrome is caused by the presence of an accessory pathway connecting the atria and ventricles, also known as the accessory pathway (Kent bundle), and is named after the three authors and called WPW syndrome.1, 2

Diagnosis of typical WPW syndrome is mainly based on the surface electrocardiogram (ECG). Other diagnostic methods include ECG exercise testing, 24-hour continuous ECG recording (Holter), and electrophysiological (EP) study.3 Among them, EP study is considered the gold standard in the diagnosis and treatment of WPW syndrome.

To date, surface ECG is the first and primary method in diagnosing WPW syndrome. Many studies have shown that surface ECG is very useful in localizing the accessory pathway (AP).4 This is very important for AP ablation treatment as it can shorten the procedure time, X-ray exposure time, and reduce complications related to the procedure for patients. There have been many studies in the world on the diagnosis and localization of AP based on surface ECG, but these diagrams are still quite complex to apply in practice. Some diagnostic diagrams are constructed by rather complex parameters5-14... In Vietnam, the author Si CD et al (2018) also conducted a study "Research on the value of surface electrocardiography in diagnosing the localization of accessory pathways in patients with typical WPW syndrome" quite detailed and specific;13, 14 However, the author did not mention the issue of V3R, V4R, V5R leads and until now there have been few studies evaluating the role of V3R, V4R, V5R leads in diagnosing the localization of accessory pathways in patients with WPW syndrome.

Therefore, we conducted this study with the main objective of evaluating the role of V3R, V4R, V5R leads on the surface

electrocardiogram in localizing the accessory pathway in patients with WPW syndrome.

SUBJECTS AND RESEARCH METHODS

Study subjects: Patients diagnosed with WPW syndrome and undergoing electrophysiological studies (EPs) for diagnosis and treatment at the Vietnam Natioanl Heart Institute - Bach Mai Hospital, Cardiology Center of University Medical Hospital, and Cardiovascular Center of E Hospital, from September 2022 to September 2023.

Selection criteria: Patients with EP results showing typical WPW syndrome and successful ablation, and who agreed to participate in the study.

Exclusion criteria: Patients with multiple APs on EP, patients with congenital heart disease by echocardiography before ablation, patients without clear signs of pre-excitation on the electrocardiogram before ablation, patients who have undergone WPW ablation, patients who did not have V3R, V4R, V5R leads recorded before ablation, and patients who did not agree to participate in the study.

RESEARCH METHODOLOGY

Study Design: Cross-sectional, diagnostic test evaluation study. Convenient sampling, with consecutive case collection in chronological order.

Sample Size: Applying the sample size estimation formula for diagnostic studies: 15 Choose a sensitivity (SN) of approximately 90%; specificity (Sp) of approximately 90%; statistical significance level $\alpha = 0.05$; $Z(1-\alpha/2)$ from the standard table = 1.96; The difference between sensitivity and specificity fluctuates above and below $w = 0.09$; The prevalence of the disease is 0.3%.2 From these data, the required sample size to estimate sensitivity Se = 43, specificity Sp = 43 can be estimated. Thus, sampling according to sensitivity or specificity requires a sample size ≥ 43.

Diagnostic Criteria for WPW Syndrome: Diagnosis is based on typical WPW syndrome ECG findings, including: 11 Short PR interval less than 0.12s with normal P wave. Widened QRS complex abnormally with duration ≥ 0.11s. Delta wave present, which is the slurred upstroke of the QRS complex. There may be secondary changes in the ST segment and T wave.

Heart with labeled locations: Tricuspid Valve, Mitral Valve, RAL (Right Anterior Lateral), RL (Right Lateral), RPL (Right Posterior Lateral), RPS (Right Posterior Septal), RMS (Right Mid Septal), RAS (Right Anterior Septal), LP (Left Posterior), LPL (Left Posterior Lateral), LL (Left Lateral), LAL (Left Anterior Lateral), RA (Right Anterior), RP (Right Posterior), CS (Coronary Sinus), MA (Mitral Annulus), TA (Tricuspid Annulus), HIS (His Bundle).

Electrophysiological Study (EPS): In recent years, using EP and endocardial mapping, not only can WPW syndrome be accurately diagnosed, but it also allows for precise identification of AP locations and the mechanism of conduction disturbances as well as other accompanying arrhythmias and risk stratification in patients with WPW syndrome (including hidden APs); thereby, these arrhythmias can be ablated with RF wave energy.8 Based on the conduction characteristics and location of the atrioventricular valve ring, many authors around the world have agreed to commonly divide APs into 3 regions with 10 AP locations which are RAL: Right Anterior Lateral; RL: Right Lateral; RPL: Right Posterior Lateral; RPS: Right Posterior Septal; RMS: Right Mid Septal; RAS: Right Anterior Septal; LP: Left Posterior; LPL: Left Posterior Lateral; LL: Left Lateral; LAL: Left Anterior Lateral; RA: Right Anterior; RP: Right Posterior; CS: Coronary Sinus; MA: Mitral Valve; TA: Tricuspid Valve; HIS: His Bundle. 14, 15-21

Location of accessory pathways on a left anterior oblique 30° X-ray image.

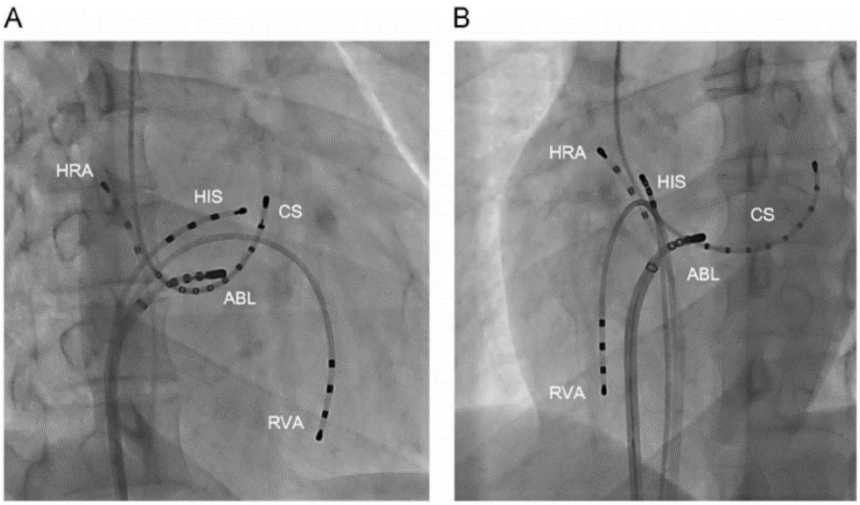


Figure 1. Placement of electrodes in the heart chambers at right (A) and left (B) anterior oblique angles on the fluoroscopy screen [Patient with Record Number 230059033]. Note: HRA – high right atrial electrode; His – His bundle electrode; CS – coronary sinus electrode; RVA – right ventricular apex electrode; ABL – ablation electrode.

Variables

- Qualitative variables: gender, clinical symptoms, comorbidities, electrical axis of the heart, delta wave presence, AP location.
- Quantitative variables: age, sinus rhythm cycle length, electrical axis group, PR interval, QRS duration, QRS amplitude, time and amplitude of waves,19 echocardiographic indices, procedure time, fluoroscopy time, ablation time, number of ablation attempts.19

Data Management and Processing: Data is entered, managed, and processed using statistical algorithms with SPSS 20.0 software. Qualitative results are presented as percentages, and quantitative results are presented as mean ± standard deviation or median and interquartile range depending on the distribution characteristics. Two-mean comparison using t-test for normal distribution and Mann-Whitney U test for non-normal distribution; proportion comparison using Chi-squared test or Fisher's exact test; differences are considered statistically significant when $p < 0.05$.

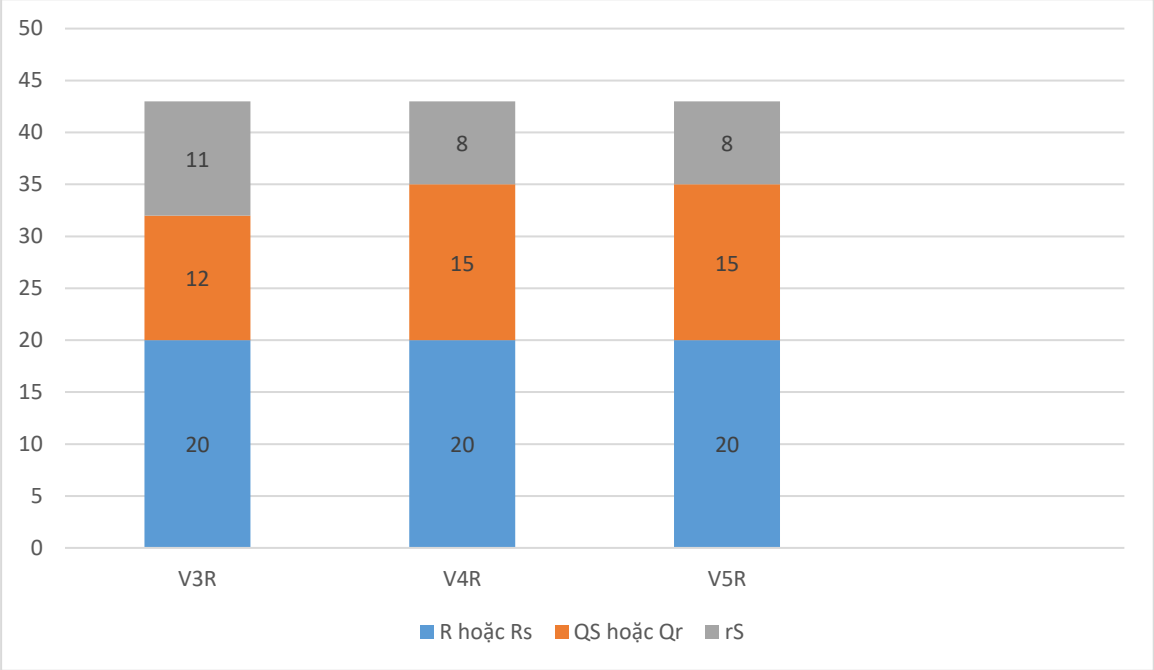
Research Ethics: All patients agreed to participate in the study after a clear explanation of the procedure's indications, benefits, and risks. Honesty with research results. Ensuring absolute confidentiality of patients' personal information. The study has received ethical approval from the Institutional Review Board. The research results are only used for patient examination and treatment. Results will be fed back to the research site.

RESULTS

3.1. Description of 15-lead ECG Characteristics with V3R, V4R, V5R

Our 43 patients included 21 males (48.8%) and 22 females (51.2%), with an average age of 43.2 ± 17.4 years, the oldest being 78 years old and the youngest 13 years old.

Figure 2. QRS morphologies at V3R, V4R, V5R (Note: Figure 3 shows that the QRS morphology at V3R, V4R, and V5R has 5 forms divided into 3 main shape groups: R or Rs form, QS or Qr form, and rS form. Among them, the QRS morphology at V4R and V5R in all cases is the same. The QRS morphology at V3R is slightly different compared to V4R, V5R).



3.2. Value of Surface ECG Leads V3R, V4R, V5R in Determining Accessory Pathway Location and Interventional Outcomes.

Sensitivity, specificity, positive predictive value, and negative predictive value of QRS amplitude at V3R, V4R, V5R in predicting left-sided or right-side accessory pathway location.

Table 1. Left-sided or Right-sided AP Location based on Positive QRS Amplitude V3R, V4R, V5R

QRS Amplitude at V3R, V4R, V5R	Left AP	Right AP	Total
Positive	20	0	20

Negative	5	18	23
Total	25	18	43

Diagnostic Value for Left-Sided Accessory Pathway with result Sensitivity 80%, Specificity 100%, Positive Predictive Value 100%, Negative Predictive Value 78.3%, Accuracy 88.4%, Area Under the Curve 0.9, Positive Likelihood Ratio 4, Negative Likelihood Ratio 0.2.
Diagnostic Value for Right-Sided Accessory Pathway with result Sensitivity 100%, Specificity 80%, Positive Predictive Value 78.3%, Negative Predictive Value 100%, Accuracy 88.4%, Area Under the Curve 0.9, Positive Likelihood Ratio 5, Negative Likelihood Ratio 0.0.

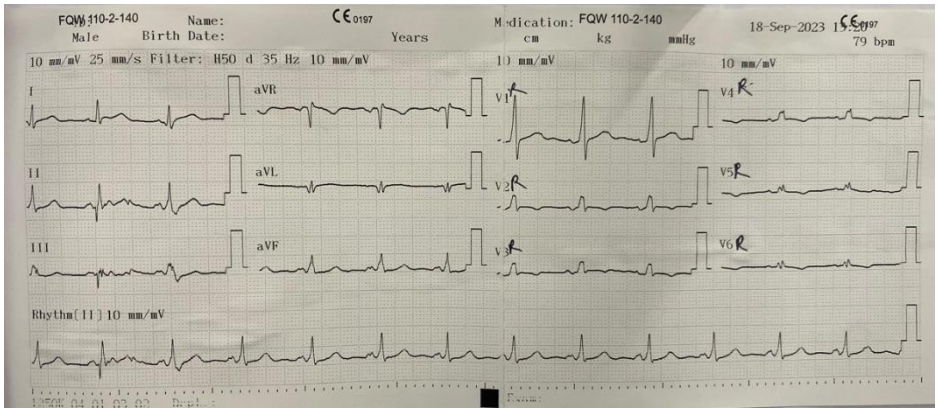


Figure 3. ECG with V3R, V4R, V5R showing a left free wall accessory pathway

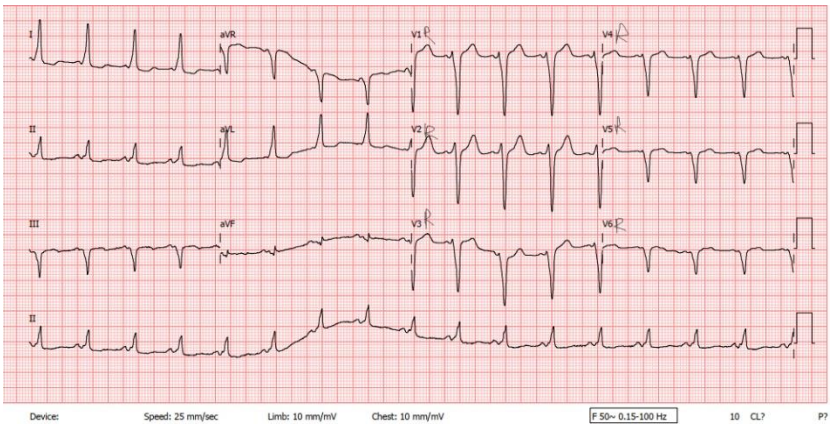


Figure 4. ECG with V3R, V4R, V5R showing a Right free wall accessory pathway

Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value of V4R QRS morphology in predicting accessory pathway location in the septal region or free wall.

Table 2. Septal AP Location Based on V4R QRS Morphology

AP Location	QS or Qr Morphology in V4R	Other Morphology	Total
Septal	14	1	15
Free Wall	1	27	28
Total	15	28	43

Diagnostic Value for Septal Accessory Pathway vs. Free Wall: Result with value of QRS morphology in V3R, V4R in predicting accessory pathway location in the septal region: Sensitivity 93.3%, specificity 96.4%, positive predictive value 93.3%, and negative predictive value 96.4%, Accuracy 95.3%, Positive Likelihood Ratio 20.30, and Negative Likelihood Ratio 0.07.

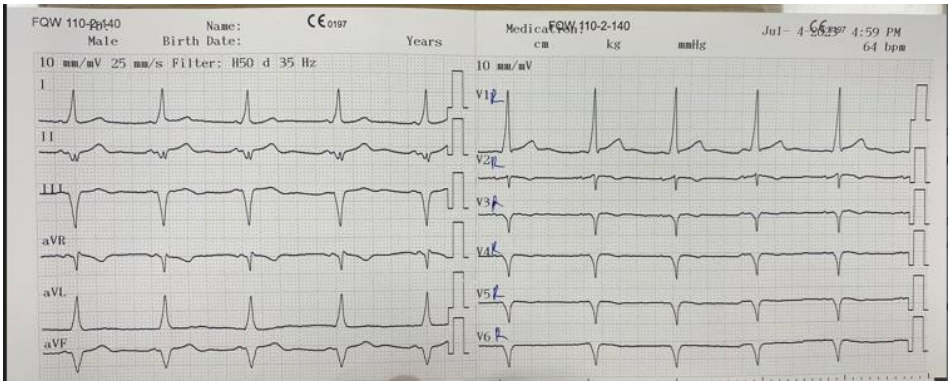


Figure 5. ECG with V3R, V4R, V5R showing QS morphology suggestive of a septal accessory pathway [Patient No. 8 – Record No. 2303124]

Diagnostic Value for Right or Left Septal Accessory Pathway

Table 3. Left or Right AP Location by V3R QRS Morphology

Predicted AP Location	Left Septal	Right Septal	Other	Total
Left Septal (rS or Rs)	3	0	0	3
Right Septal (QS or Qr)	1	10	1	12
Other	1	0	27	28
Total	5	10	28	43

Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value of V3R QRS Morphology in Predicting Right or Left Septal Accessory Pathway Location, with V4R showing QS or Qr morphology.

For Left Septal Pathway: Sensitivity 60%, Specificity 100%, Positive Predictive Value 100%, Negative Predictive Value 95%. For Right Septal Pathway: Sensitivity 100%, Specificity 93.9%, Positive Predictive Value 83.3%, Negative Predictive Value 100%.

Procedure Time, Fluoroscopy Time, Ablation Time, and Number of Ablation Attempts in the Group Where AP Location Was Determined Using V3R, V4R, and V5R Leads.

Table 4. Procedure Time, Fluoroscopy Time, Ablation Time, and Number of Ablation Attempts in the Group with Pre-Procedure AP Location Prediction and Confirmed Results.

Patient Group	Procedure Time (min)	Fluoroscopy Time (min)	Ablation Time (min)	Number of Ablation Attempts
Positive QRS Amplitude in V3R, V4R, V5R with Left-Sided AP on EP	52.50 ± 18.67	434.50 ± 251.10	335.50 ± 213.92	5.35 ± 2.94
Negative QRS Amplitude in V3R, V4R, V5R with Right-Sided AP on EP	65.56 ± 19.01	668.33 ± 353.26	469.38 ± 160.39	7.50 ± 2.83
p-value	0.040	0.023	0.002	0.005
Group with Correct Pre-Procedure AP Localization	58.68 ± 19.72	545.26 ± 322.05	375.83 ± 166.79	6.03 ± 2.56
All Patients	58.84 ± 18.86	559.58 ± 323.66	396.59 ± 190.21	6.37 ± 2.87
p-value	0.972	0.843	0.615	0.589

DISCUSSION

4.1. General Characteristics of the Study Population

In our study, the 43 patients had an average age of 43.2 ± 17.4 years, with the oldest being 78 years old and the youngest 13 years old, mostly in middle age. The proportion of males (%) was slightly lower than that of females (%) ($p > 0.05$). The age results in our study are also quite consistent with the studies of other authors.7, 14, 22, 23, 24

The gender distribution characteristics of these patients showed no difference ($p > 0.05$) and were also quite consistent with the results of other authors.12, 14; However, the male/female ratio may differ in some studies due to different characteristics of the ethnic population in each study.8, 9, 25

Characteristics of QRS Morphology at V3R, V4R, V5R: We found that the QRS morphology at V3R, V4R, and V5R all belong to one of two main types: type A (positive QRS) or type B (negative QRS), however, we divided them into 3 main morphological

groups: RS or R form, QS or Qr form, and rS form, because the morphology of the QRS at these leads also plays a role in guiding the diagnosis of the accessory pathway location, which we will discuss in more detail later. In our study, the QRS morphology at V4R and V5R in each case was the same, of which 20 cases had RS or R form, 15 cases had QS or Qr form, and 8 cases had rS form. The QRS morphology at V3R was slightly different from the two leads above, with 20 cases of RS or R form, 12 cases of QS or Qr form, and 11 cases of rS form. The difference in QRS morphology mentioned above is mainly for accessory pathways in the septal region or free wall near the septum. There is such a difference because of the anatomical location of the accessory pathways in the septal region and their depolarization direction compared to the location of the V3R lead, which is slightly different from the V4R and V5R leads.

4.2. The role of leads V3R, V4R, and V5R on the surface electrocardiogram in determining the location of the accessory pathway and interventional outcomes.

Compare the average QRS amplitude characteristics of V3R, V4R, and V5R being positive or negative with the left or right accessory pathway.

A comparison was conducted to evaluate the role of the average QRS amplitude of V3R, V4R, and V5R (positive or negative) in predicting whether the AP is left or right. The results showed that on the left side, 20/25 patients had a positive average QRS amplitude of V3R, V4R, and V5R, accounting for 80% of the total 25 left APs; whereas on the right side, 18 patients had a negative average QRS amplitude of V3R, V4R, and V5R, accounting for 100% of the total 18 right AP cases. Positive QRS amplitude of V3R, V4R, and V5R in diagnosing left-sided accessory pathways had a sensitivity of 80%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 78.3%. Meanwhile, negative QRS amplitude of V3R, V4R, and V5R in diagnosing right-sided accessory pathways had a sensitivity of 100%, specificity of 80%, positive predictive value of 78.3%, and negative predictive value of 100%. The accuracy of diagnosing accessory pathways on the right or left side using this method reached 88.4%. Compared to the study by Hamriti et al. (2022)12 on 109 WPW patients using 3 diagnostic algorithms: Easy-WPW (by the author), Arruda's algorithm,6 and Pambrun's algorithm,11 the accuracy in diagnosing left-sided accessory pathways was 92%, 82%, and 85%, respectively, and for right-sided accessory pathways, the accuracy was 95%, 69%, and 82%, respectively. Our study, with a diagnostic accuracy of 88.4% for both left and right-sided accessory pathways, shows that these are all significant values contributing to helping interventional physicians initially determine the location of the accessory pathway.

We found that most cases of right APs had a negative average QRS amplitude of V3R, V4R, and V5R; conversely, most left APs had a positive average QRS amplitude of V3R, V4R, and V5R. However, we still found 5 left APs with a negative average QRS amplitude of V3R, V4R, and V5R.

The EP results of these cases showed that all 5 patients had accessory pathways located in the left posterior septal region. It is easy to explain that APs in the right or left posterior septal regions are adjacent and close to each other, so sometimes electrocardiographic images suggesting the right side can be seen, but during electrophysiological studies, it is found on the left side and vice versa. This is because the posterior septal region has thick muscle mass, fibrosis-fatty tissue, and complex anatomy. This is consistent with the observations of many authors: for posterior septal APs, the degree of pre-excitation can be in a "mixed" form between left and right, depending on the degree of pre-excitation and depending on the electrophysiology of the basic QRS complex. In reality, in some cases of posterior septal APs, after mapping and ablation on the right (or left) failed, the operators switched to mapping on the left (or right) and achieved results.

Our research results show that applying the QRS amplitude criterion at V3R, V4R, and V5R in determining the location of left or right accessory pathways provides good value, is easy to apply and evaluate.

Sensitivity, specificity, positive predictive value, and negative predictive value of QRS morphology in V3R, V4R in predicting accessory pathway location in the septal region or free wall.

We used the QRS morphology in V4R and V3R to diagnose the AP location in the septal region and differentiate between right septal and left septal based on the characteristics of the location and direction of septal AP depolarization in the horizontal plane. For APs located in the septal region, the septal depolarization vector and the total ventricular depolarization vector move away from V4R, V5R; therefore, the QRS morphology in V4R and V5R is QS. The QRS morphology in V3R is slightly different between right septal and left septal, perhaps because the left septal AP still has a septal depolarization direction from left to right, so an R wave may appear, then the entire ventricle depolarizes with a total vector directed to the left, represented by an S wave, so it has an rS or Rs form depending on the degree of pre-excitation, whereas with the right septal AP, the septal depolarization direction is from right to left and the total ventricular depolarization vector is also directed to the left, so V3R, V4R, V5R all have a negative QS form.

In our study, the septal region had a QS QRS morphology in lead V4R in 14/15 cases (93.3%), with only 1 case having an rS form (6.7%) located in the septum. The sensitivity, specificity, positive predictive value, and negative predictive value when applying the QRS standard in V4R as QS or Qr in determining the septal location all yielded very high results, respectively 93.3%, 96.4%, 93.3%, 96.4%, the diagnosis has an accuracy of 95.3% for the septal pathway. These results are quite similar to the study by El Hamriti et al. (2022),12 Arruda et al. (1998)6 as well as Pambrun et al. (2018) 11 and higher than Chiang's study (1995) 7 with an accuracy of only 84.1%. Meanwhile, when applying the QRS transition region standard between V1V2 or V2V3,

only 9/15 (60%) of cases showed the accessory pathway located in the septal region, while the remaining 6/15 cases had a QRS transition before V1 or after V3. This is entirely possible because in the study by Fitzpatrick et al. (1994),5 the QRS transition ≤ V1 can still fall into the left posterior septal accessory pathway location, or when the QRS transition is after V3, especially between V3 and V4, the AP can still fall into the septal location. 5 We observed that up to 7/28 cases of AP located in the free wall also had a QRS transition between V1V2 or V2V3, similar to Fitzpatrick's research results, QRS transition between V1V2, the accessory pathway can still be located in different locations and need to assess other characteristics to determine its exact location.5 Therefore, when applying the QRS transition region standard between V1V2 or V2V3 in determining the septal location, the sensitivity, specificity, positive predictive value, and negative predictive value are quite low, respectively 60%, 75%, 56.3%, 77.8%. These values are much lower than previous studies by Si CD et al. (2018). 15-18

After determining the septal accessory pathway location using the QS or Qr morphology in V4R, we further identified whether the accessory pathway was on the right or left side of the septum using the QS or Qr morphology in V3R for right-sided septal pathways and the Rs or rS morphology for left-sided septal pathways. The results in Table 4 of our study show that the sensitivity, specificity, and positive predictive value for the left septal pathway were 60%, 100%, and 100%, respectively. Compared to the study by Kobza et al. (2005)26 using the negative delta wave criterion in lead DII to diagnose the left septal pathway and differentiate it from other septal locations, which had a sensitivity of 100% but specificity and positive predictive value of only 50% and 24%, respectively. The sensitivity, specificity, and positive predictive value for the right septal pathway in our criteria were 100%, 93.9%, and 83.3%, respectively. Compared to the study by Kobza et al. (2005) using one of the criteria of negative delta in DII or negative QRS in V1 or negative delta in aVR to differentiate the right septal pathway from other septal locations, which had a positive predictive value ranging from 84-92%.26 Thus, our results are also quite similar. There was one case we identified as being in the right septal region because V4R had a QS morphology and V3R had a QS morphology, but when EP results showed the accessory pathway was located in the right posterior wall, or another case had an rS form in both V3R and V4R but upon exploration it was a left posterior septal pathway. This is not at all surprising because in reality the posterior septal region and the free wall region adjacent to the septum are very close together, so it is easy to encounter similar characteristics of the transitional muscle bundles between these two regions.

Procedure time, fluoroscopy time, ablation time, and number of ablation attempts in the group with right-sided accessory pathways and the group with left-sided accessory pathways.

In 1986, the world began using RF to successfully ablate APs in WPW syndrome.27 Today, before intervention, predicting the AP location using surface ECG images to orient the AP location aims to quickly access the ablation target location as well as predict the problems that occur during the procedure to help shorten fluoroscopy time and intervention time for both the interventionalist and the patient.13

The AP ablation technique is based on delivering the catheter tip to contact a point on the mitral or tricuspid valve ring where the AP passes through. Based on the location of the electrode wire at the successful ablation site on the X-ray image taken in the left anterior oblique 30° view, we determine the anatomical location of the AP (Figures 1 & 2). We compared the results of AP localization through exploration and successful treatment with the initial predicted location set with the above parameters, showing fairly high accuracy.

Table 5: Comparison of Fluoroscopy Time and Procedure Time in Our Study with Other Studies:

Author(s)	Year	Fluoroscopy Time (minutes)	Procedure Time (minutes)
Lemery R et al. (n=60) [20]	1992	21.9 ± 9.0	66 ± 33
Calkins H et al. (n=250) [29]	1992	13.4 ± 7.5	47 ± 33
Dong Van Tran (n= 153) [14]	2006	117.5 ± 56.8	22.7 ± 13.4
Schwagten B et al. [30]	2010	8.71 ± 3.08	14.4 ± 4.7
Hocini et al. (n=33) [32]	2015	8.5	12.9
Shedira et al. (meta-analysis of 11 studies) [22]	2015	9.28	11.5
Chu SD (n=109) [15]	2018	4.87 ± 1.85	7.20 ± 4.00
Our Study (n=43)	2023	5.86 ± 1.88	9.29 ± 5.36

The table appears to have some formatting issues, with inconsistent spacing and alignment. We have attempted to interpret it as best as possible. Total procedure time as well as fluoroscopy time depend on the AP location and partly on the operator's experience. Thus, studies show that procedure time and fluoroscopy time of the authors tend to gradually decrease until the present time.

With this RF ablation treatment method, the procedure time and fluoroscopy time also depend heavily on the level, technique of the operator as well as experience and strategies in RF treatment, including the initial diagnosis of AP location by surface ECG, which is extremely helpful.

In our study, the average procedure time was 58.60 ± 18.81 minutes and the fluoroscopy time was 557.49 ± 321.63 seconds or 9.29 ± 5.36 minutes; these figures have been reduced significantly compared to previous studies because we have more experience after a long time of applying this method, the number of patients is large as well as equipment, facilities are increasingly modern,

especially the prediction of the accessory pathway location.

Compared with the study of Si CD 15 when using the accessory pathway location prediction diagram on 109 patients with typical WPW, the average procedure time was 48.7 ± 18.5 (minutes) and the average fluoroscopy time was 7.2 ± 4.0 (minutes), especially the average procedure time of the left-sided pathway group was 44.9 ± 14.5 (minutes) and the average fluoroscopy time was 7.0 ± 3.8 (minutes), which confirmed the help of limiting the unwanted effects of X-rays on the operator and the patient 33; the time in this study is shorter than in our study because this is a fairly detailed accessory pathway location prediction diagram with 10 locations that helped to locate the most detailed location. However, our study with a focus on expanding the predictive role of V3R, V4R, V5R has also shown certain value in locating the accessory pathway; the procedure time and fluoroscopy time are shorter, which helps ensure patient safety.

LIMITATIONS

Our study has some limitations such as our small sample size (n=43), which may affect the value of the results. However, we have tried to evaluate and compare with studies by authors at home and abroad with larger sample sizes and still found similar results. However, with the positive results obtained from here will help us better orient in the design and implementation of subsequent studies on this topic.

CONCLUSIONS

The QRS morphology on the right precordial leads (V3R, V4R, V5R) in patients with WPW syndrome has 3 main forms: RS or R form, QS or Qr form and rS form. The role of leads V3R, V4R, V5R on the surface ECG in determining the location of the accessory pathway in patients with Wolff-Parkinson-White syndrome:

Differentiating the location of the accessory pathway on the tricuspid valve annulus and the mitral valve annulus has high accuracy: Positive QRS amplitude in V3R, V4R, V5R with the diagnosis of left-sided accessory pathway has a sensitivity of 80%, specificity of 100%, positive predictive value is 100% and negative predictive value is 78.3%. Negative QRS amplitude in V3R, V4R, V5R with the diagnosis of right-sided accessory pathway has a sensitivity of 100%, specificity of 80%, positive predictive value is 78.3% and negative predictive value is 100%.

Differentiating the location of the accessory pathway in the septal region compared to the free wall has high accuracy: The values of sensitivity, specificity, positive predictive value, negative predictive value when applying the QRS standard in V4R form QS or Qr in determining the septal location all give results of 93.3%, 96.4%, 93.3%, 96.4%, respectively. Sensitivity, specificity, positive predictive value, negative predictive value with right septal pathway are 100%, 93.9%, 83.3%, 100%, respectively. Sensitivity, specificity, positive predictive value, negative predictive value with left septal pathway are 60%, 100%, 100%, 95%, respectively.

Fluoroscopy time, procedure time, ablation time and number of ablation attempts are significantly reduced when using the criteria for predicting AP location by surface ECG with V3R, V4R, V5R.

RECOMMENDATIONS

Through our research, we found that the 15-lead ECG, particularly with V3R, V4R, and V5R leads, is highly effective compared to the 12-lead ECG in determining the accessory pathway location in patients with Wolff-Parkinson-White syndrome. This is especially true for septal accessory pathways, where the 15-lead ECG demonstrates superior value compared to the standard 12-lead ECG. Therefore, it is entirely applicable in clinical practice.

Further research with a larger sample size is needed. Specifically, future studies could expand to include cases with multiple accessory pathways, accessory pathways located in the coronary sinus and the Marshall vein, cases accompanied by congenital heart disease, or cases with prior accessory pathway ablation.

REFERENCES

1. Arai A, Kron J. Current management of the Wolff-Parkinson-White syndrome. West J Med. 1990;152(4):383-391.
2. Narula OS. Wolff-Parkinson-White Syndrome. A review. circulation. 1973;47(4):872-887. doi:10.1161/01.cir.47.4.872.
3. Barbara J Drew, Robert M Califf, Elizabeth S Kaufman, Marjorie Funk. Practice standards for electrocardiographic monitoring in hospital settings: an American Heart Association scientific statement from the Councils on Cardiovascular Nursing, Clinical Cardiology, and Cardiovascular Disease in the Young: endorsed by the International Society of Computerized Electrocardiology and the American Association of Critical-Care Nurses. Circulation. 2004;110(17):2721-2746. doi:10.1161/01.CIR.0000145144.56673.59.
4. Fox DJ, Klein GJ, Skanes AC, Gula LJ, Yee R, Krahn AD. How to identify the location of an accessory pathway by the 12-lead ECG. Heart Rhythm. 2008;5(12):1763-1766. doi:10.1016/j.hrthm.2008.09.012
5. Fitzpatrick AP, Gonzales RP, Lesh MD, Modin GW. New algorithm for the localization of accessory atrioventricular connections using a baseline electrocardiogram. J Am Coll Cardiol. 1994;23(1):107-116. doi:10.1016/0735-1097(94)90508-8.
6. Arruda MS, McCLELLAND JH, Wang X, et al. Development and Validation of an ECG Algorithm for Identifying Accessory Pathway Ablation Site in Wolff-Parkinson-White Syndrome. Cardiovasc electrophysiol. 1998;9(1):2-12.

doi:10.1111/j.1540-8167.1998.tb00861.x
7. Chiang CE, Chen SA, Siong Teo W, et al. An Accurate Stepwise Electrocardiographic Algorithm for localization of Accessory Pathways in Patients With Wolff-Parkinson-White Syndrome from a Comprehensive Analysis of Delta Waves and R/S Ratio During Sinus Rhythm. The American Journal of Cardiology. 1995;76(1-2):40-46. doi:10.1016/S0002-9149(99)80798-X
8. Dar MA, Sheikh SH, Abid AR. Localization of accessory pathways according to AP Fitzpatrick ECG criteria in patients with Wolff-Parkinson-White syndrome in our population. Pakistan Heart Journal. 2008;41:22-27. doi:https://doi.org/10.47144/phj.v41i3-4.37
9. Basiouny T. Prospective Validation of A Sezer ECG Algorithm For Localization of Accrssory Pathways in Patients With Wolff-Parkinson-White Syndrome. AAMJ. 2012;10(3):1340-1348.
10. Taguchi N, Yoshida N, Inden Y, Yamoto T. A simple algorithm for localizing accessory pathways in patients with Wolff-Parkinson-White syndrome using only the R/S ratio. Journal of Arrhythmia. 2013;30(6). doi:10.1016/j.joa.2013.10.006
11. Pambrun T, El Bouazzaoui R, Combes N, et al. Maximal Pre-Excitation Based Algorithm for Localization of Manifest Accessory Pathways in Adults. JACC: Clinical Electrophysiology. 2018;4(8):1052-1061. doi:10.1016/j.jacep.2018.03.018
12. El Hamriti M, Braun M, Molatta S, et al. EASY-WPW: a novel ECG-algorithm for easy and reliable localization of manifest accessory pathways in children and adults. EP Europace. 2023;25(2):600-609. doi:10.1093/europace/euac216
13. Morady F. Radio-Frequency Ablation as Treatment for Cardiac Arrhythmias. Wood AJJ, ed. N Engl J Med. 1999;340(7):534-544. doi:10.1056/NEJM199902183400707.
14. Tran Van Dong. Treatment of Wolff-Parkinson-White syndrom by radiofrequency energy. Medical doctorate thesis. Vietnam military medical university; 2006.
15. Chu Dung Si. Study value on the 12-Lead ECG for the localizing of accessory pathways location in patient with typical WPW syndrome. Medical doctorate thesis. Vietnam military medical university; 2018.
16. Chu SD, Pham KQ, Tran DV. Development and evaluation of surface electrocardiogram in the septal accessory pathway localization in typical Wolff-Parkinson-White syndrome. Biomedical Research and Therapy 2018; 5 (9): 2680-2687.
17. Chu SD, Pham KQ, Tran DV. Development and evaluation of 12 - lead electrocardiogram in the left free wall of accessory pathway localization in patients with typical Wolff-Parkinson-White syndrome. Biomedical Research and Therapy 2018; 5 (11): 2832-2840.
18. Chu SD, Pham KQ, Tran DV. Value on Surface Electrocardiogram for the Right Free Wall in Localizing Accessory Pathway by Simple Parameters in Typical Wolff-Parkinson - White Syndrome. Journal of Cardiology & Cardiovascular Therapy 2018; 12 (3): 48-56.
19. Romulo F. Baltazar. Basic and Bedside Electrocardiography. 1st ed. Wolters Kluwer; 2009.
20. Murgatroyd F.D., Krahn AD. Handbook of Cardiac Electrophysiology : A Practical Guide to Invasive EP Studies and Catheter Ablation. 1st ed. Remedica; 2002.
21. Cosío FG, Anderson RH, Becker A, Borggrefe M. Living anatomy of the atrioventricular junctions. A guide to electrophysiological mapping. A Consensus Statement from the Cardiac Nomenclature Study Group, Working Group of Arrythmias, European Society of Cardiology, and the Task Force on Cardiac Nomenclature from NASPE. North American Society of Pacing and Electrophysiology. European Heart Journal. 1999;20(15):1068-1075. doi:10.1053/euhj.1999.1657
22. Brembilla-Perrot B, Holban I, Houriez P, Claudon O, Beurrier D, Vancon AC. Influence of Age on the Potential Risk of Sudden Death in Asymptomatic Wolff-Parkinson-White Syndrome. Pacing and Clinical Electrophysiology. 2001;24(10):1514-1518. doi:10.1046/j.1460-9592.2001.01514.x
23. James Kulig, Bruce A Koplan. Cardiology patient page. Wolff-Parkinson-White syndrome and accessory pathways. Circulation. 2010;122(15):e480-3. doi:10.1161/CIRCULATIONAHA.109.929372
24. Nakano M, Kondo Y, Kajiyama T, et al. Estimation of the accessory pathway location of the manifest Wolf-Parkinson-White syndrome using synthesized right-sided chest leads. J Interv Card Electrophysiol. 2020;59(1):43-48. doi:10.1007/s10840-019-00648-2
25. Shabnam Madadi, Pegah Salehi, Soudeh Roudbari, Masoud Roudbari. A Simple Algorithm for Predicting the Location of Right-Sided Accessory Pathways Based on ECG in WPW Patients. Iranian Heart Journal. 2021;22(4):71-79.
26. Kobza R, Hindricks G, Tanner H, et al. Paraseptal Accessory Pathway in Wolff-Parkinson- White-Syndrom: Ablation from the Right, from the Left or within the Coronary Sinus/Middle Cardiac Vein? J Interv Card Electrophysiol. 2005;12(1):55-60. doi:10.1007/s10840-005-5841-2
27. Borggrefe M, Budde T, Podczeck A, Breithardt G. High frequency alternating current ablation of an accessory pathway in humans. Journal of the American College of Cardiology. 1987;10(3):576-582. doi:10.1016/S0735-1097(87)80200-0
28. Lemery R, Hammill SC, Wood DL, Danielson GK. Value of the resting 12 lead electrocardiogram and vectorcardiogram for locating the accessory pathway in patients with the Wolff-Parkinson-White syndrome. Br Heart J. 1987;58(4):324-332. doi:10.1136/hrt.58.4.324.
29. Calkins H, Langberg J, Sousa J, et al. Radiofrequency catheter ablation of accessory atrioventricular connections in 250 patients. Abbreviated therapeutic approach to Wolff-Parkinson-White syndrome. Circulation. 1992;85(4):1337-1346. doi:10.1161/01.CIR.85.4.1337
30. Schwagten B, Jordaens L, Rivero-Ayerza M, et al. A Randomized Comparison of Transseptal and Transaortic Approaches for Magnetically Guided Ablation of Left-Sided Accessory Pathways: WPW ABLATION USING MAGNETIC NAVIGATION. Pacing and Clinical Electrophysiology. 2010;33(11):1298-1303. doi:10.1111/j.1540-

8159.2010.02810.x
31. Hocini M, Shah AJ, Neumann T, et al. Focal Arrhythmia Ablation Determined by High-Resolution Noninvasive Maps: Multicenter Feasibility Study. Cardiovasc electrophysiol. 2015;26(7):754-760. doi:10.1111/jce.12700
32. Ibrahim Ali Sherdia AF, Abdelaal SA, Hasan MT, et al. The success rate of radiofrequency catheter ablation in Wolff-Parkinson-White-Syndrome patients: A systematic review and meta-analysis. Indian Heart Journal. 2023;75(2):98-107. doi:10.1016/j.ihj.2023.02.001
33. Singer Igor. Clinical Manual of Electrophysiology. Williams & Wilkins; 1993.