Electrocardiographic Characteristics of Fasciculoventricular Pathways: Analysis of Five Cases

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**Introduction:*** Fasciculoventricular (FV) accessory pathways are rare variants of preexcitation syndrome and published data on the ECG of FV pathways are limited. The purpose of this study was to analyze the electrocardiographic characteristics of FV pathways.

**Methods:** We enrolled 5 patients (mean age, 26.8 ± 15.1 years; range 15–49 years, 2 male) with FV pathways which were diagnosed based on the standard electrophysiologic criteria. According to the standard criteria for the ECG classification of manifest Wolff-Parkinson-White (WPW) syndrome, the ECGs were classified as type A, B or C. The polarity of delta wave in each lead of each patient was divided into positive, flat or negative and was applied to the stepwise ECG algorithms of atrioventricular accessory pathway previously published by Fitzpatrick, Arruda and Iturralde.

**Results:** Type A was found in one patient (Case No 4), type B in one patient (Case No 5) and type C in three patients (Case No 1, 2 and 3). Based on stepwise ECG algorithm, all cases corresponded to the polarity of the delta wave in patients with right anteroseptal, posteroseptal, right anterolateral or left anterolateral AP. In all three cases exhibiting type C, the polarity of delta wave in lead V2 was flat.

**Conclusions:** ECGs of FV pathways may be misidentified as ECG of WPW syndrome, and may present with any preexcitation pattern of type A, B or C.

**Key words:** Variant preexcitation, Wolff-Parkinson-White syndrome, Mahaim fiber, Delta wave

**Introduction**

Fasciculoventricular (FV) accessory pathways (AP) are rare variants of preexcitation syndrome and connect the fascicle or, in rare cases, the most distal part of the atrioventricular (AV) node, with the ventricular septum. The FV fiber does not usually mediate tachycardia. However, in this era of therapeutic cardiac electrophysiology, one should be able to differentiate AV AP from an FV pathway. Published data on the ECG of FV pathways are limited. Thus, we analyzed the electrocardiographic characteristics of the patients with FV pathway to gain a better understanding of this largely unrecognized area.
Methods

Patient Population and Electrophysiologic Study

Our study consisted of 5 patients (8.9%) (mean age = 26.8 ± 15.1 years; range 15–49 years, 2 male) with FV pathways out of 56 patients with manifest ventricular preexcitation referred to our laboratory for electrophysiologic study or catheter ablation during the last 14 years.

All patients underwent electrophysiologic studies after having granted their written informed consent, and after discontinuation of antiarrhythmic drug therapy for at least 5 half-lives. Multilectrode catheters were placed in the high right atrium, the bundle of His and at the right ventricular apex. Bipolar intracardiac electrograms and 12-lead surface electrocardiogram were recorded and stored on computerized EP Work Mate™ (EP MedSystems, Inc., West Berlin, NJ, USA) recording system, after filtering between 30 and 500 Hz.

FV was diagnosed when the electrophysiologic findings met all of the following criteria: 1) (1) normal AH interval, (2) short (less than 35 ms) and fixed HV interval, (3) atrial pacing produced AH prolongation due to AV nodal delay without change of preexcitation degree.

Electrocardiographic Analysis

ECGs were recorded with a paper speed of 25 mm/s and a scale of 10 mm/mV. ECG analyses were performed by two independent cardiologists without the information of the electrophysiological findings. Standard 12-lead ECGs were analyzed to divide the polarity of the delta wave in each of the 12 leads into positive, negative or flat. First, according to the criteria of Rosenbaum et al8) and Ueda et al 9) for the ECG classification of manifest Wolff-Parkinson-White (WPW) syndrome, the ECGs were classified as type A, B and C. Second, to evaluate the difference of the polarity of the delta wave with that in patients with AV accessory pathway, the polarity of delta wave in each lead was applied to stepwise ECG algorithm of AV AP of Fitzpatrick et al,10) Iturralde et al11) and Arruda et al,12) respectively. Briefly, Fitzpatrick’s algorithm is based on the combination of the following criteria: 1) QRS transition > V2 and ≤ V3 (or in case of transition ≤ V2, the amplitude of R wave > S wave in lead I) and (2) the sum of polarities in leads II, III, aVF ≥ +2. Iturralde’s algorithm is based on the findings of the polarity of QRS complex in lead III, V1 and V2. Arruda’s algorithm is the combination of the following: (1) polarity of the delta wave in lead I, II, aVF and V1, (2) the amplitude of R wave < S wave in V1 and (3) the amplitude of R wave ≥ S wave in lead III.

Results

Demographic findings of the enrolled patients

Clinical profiles of the patients with FV pathways are listed in Table 1. Case No 1 (a 17-year-old female) and Case No 5 (a 49-year-old male) were asymptomatic and was referred for electrophysiological evaluation because of ventricular preexcitation noted during a routine examination. Case No 2 (a 15-year-old male) and Case No 4 (a 36-year-old female) were referred for catheter ablation because of recurrent paroxysmal supraventricular tachycardia. Case No 2 was diagnosed as slow-fast form AV nodal reentrant tachycardia and underwent successful slow pathway ablation. Case No 4 was diagnosed

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Complicated disease

None AVNRT None AVRT HCM


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<th>Table 2</th>
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ERPFV: effective refractory period of fasciculoventricular pathway.
as concealed WPW syndrome and AV reentrant tachycardia incorporating left-sided lateral AP and underwent successful ablation, and was complicated with hypertrophic cardiomyopathy. Case No 3 (a 17 year-old female) with a complaint of palpitation was referred for electrophysiologic evaluation and no significant abnormality except the existence of FV pathway.

Electrophysiologic characteristics of FV pathways

At basal state, the AH interval was 81.6 ± 14.5 ms (range: 60–96 ms) and the HV interval was 19.8 ± 7.3 ms (range: 10–27 ms) (Table 2, Figures 1 and 2). Each patient showed that the effective refractory period (ERP) of FV pathway was shorter than the ERP of the AV node (298 ± 71.9 ms, range: 190–330 ms).

Electrocardiographic characteristics of FV pathways

The PR interval was 124.4 ± 22.3 ms (range: 99–159 ms). The 12-lead ECG in enrolled patients applied to any of ECG classification types A, B or C; type A in Case No 4, type B in Case No 5 and type C in Cases No 1, 2 and 3 (Figures 3, 4, 5, 6 and 7). Only in Case No 3 we administered a bolus of dysopiramide (50 mg) and confirmed disappearance of delta wave.

When we applied Fitzpatrick’s criteria, the ECGs of Case 1, 2 and 3 were diagnosed as right anteroseptal AP, the ECG of Case No 4 as left anterolateral AP and the ECG of Case No 5 as right anterolateral AP. When we applied Arruda’s algorithm, the ECGs of Case No 1 and No 3 were diagnosed as posteroseptal tricuspid annulus/posteroseptal mitral annulus AP, the ECG of Case No 2 as

![Figure 1 Intracardiac electrograms during sinus rhythm of Case No 1 (Panel A), Case No 2 (Panel B), Case No 3 (Panel C) and Case No 5 (Panel D). Panel A: The interval of AH, HV and QRS complex was 90, 17 and 100, respectively. Panel B: The interval of AH, HV and QRS complex was 88, 18 and 94, respectively. Panel C: The interval of AH, HV and QRS complex was 96, 10 and 98, respectively. Panel D: The interval of AH, HV and QRS was 74, 27 and 150, respectively. II, V1 and V5: surface electrocardiogram, HRA 3-4 and 1-2: proximal and distal high right atrium, HBE 3-4 and 1-2: proximal and distal His-bundle regions, respectively.](image)
right anteroseptal AP, the ECG of Case No 4 as left lateral or anterolateral AP and the ECG of Case No 5 as right anterior or anterolateral AP. When we applied Iturralde’s algorithm, the ECGs of Case No 1, 2, 3 and 5 were diagnosed as right anterosuperior paraseptal AP and the ECG of Case No 4 as left inferior/left inferior paraseptal AP.

Discussion

We found FV pathways in 5 (8.9%) of 56 consecutive patients with ECGs showing ventricular preexcitation referred for electrophysiologic study. Previous studies in predominantly adult populations reported similar proportions: 6 (1.9%) of 308 patients,2) 2 (1.8%) of 111 patients,3) 4 (1.2%) of 332 patients,6) 5 (2.8%) of 180 patients,14) 8 (2%) of 392 patients7) and 11 (5.1%) of 215 children.15) Josephson described in his textbook that he had personally observed six cases in 35 years of practicing electrophysiology.1) Thus, FV pathways are extremely rare. A relatively high incidence of FV pathway may be observed in our population for the reason that there were some patients undergoing EPS for examination of ECG abnormality.

The classic findings of a FV pathway include prolongation of the AH interval without changes in the HV interval and a constant degree of preexcitation during incremental atrial pacing.1) This was found in all five patients. Enhanced AV nodal conduction was a common finding among the patients studied by Gallagher et al.3) However, our five cases showed normal AH interval lengthening and AV nodal behavior during incremental atrial pacing.

Figure 2 Intracardiac electrogram during sinus rhythm (Panel A) and high right atrium (HRA) pacing at 400-ms cycle length (Panel B).
Panel A: The interval of AH, HV and QRS complex was 60, 27 and 180, respectively. Panel B: Note that atrial pacing produced Wenckebach-type AH prolongation due to AV nodal delay without change of HV interval, suggesting no antegrade conduction over atrioventricular accessory pathway.
S: stimulus artifact, other abbreviations are as in Figure 1.
One of our five cases had AV reentrant tachycardia incorporating an AV accessory pathway. Gallagher et al reported associated WPW syndrome in 1 of 6 patients.1) Salee and Van Hare found multiple accessory pathways in 1 of 3 children,16) and the patient reported by Kottkamp et al also had a left lateral bypass tract.17) Sternick et al also reported associated bypass tracts and AV reentrant tachycardia in 2 of 4 cases.8) Taking into account all of these patients with FV pathways, including our patients, the incidence of associated WPW would be 31.6% (6/19 patients). Case No 4 was complicated with hypertrophic cardiomyopathy. The association of hypertrophic cardiomyopathy with FV pathway is rarely observed,18,19) but the etiological correlation remain unclear. Case No 2 was complicated with slow-fast form AV nodal reentrant tachycardia. As suggested by Choi et al, possibility of typical AV nodal reentrant tachycardia with FV pathway should be considered as a mechanism of supraventricular tachycardia in a patient showing preexcitation electrocardiogram.20)

The proximal insertion of the FV pathway suggests that it arises distal to the AV node at the site of the penetrating AV bundle.17) PR intervals of the patients with FV pathways are known to be normal.15) Relatively longer PR intervals in the FV pathway could also be explained by the proximal

![Figure 3](12-lead ECG of Case No 1. The P-delta interval was 115 ms, and the QRS width was 100 ms. The polarity of delta wave in V1 was classified as type C. Based on the algorithms of Fitzpatrick, Iturralde and Arruda, the ECG was diagnosed as right sided anteroseptal, right anversuperior paraseptal and posteroseptal tricuspid annulus/posteroseptal mitral annulus pathway, respectively.)

![Figure 4](12-lead ECG of Case No 2. The P-delta interval was 130 ms, and the QRS width was 94 ms. The polarity of delta wave in V1 was classified as type C. Based on the algorithms of Fitzpatrick, Iturralde and Arruda, the ECG was diagnosed as right sided anteroseptal, right anterosuperior paraseptal and anteroseptal pathway, respectively.)
insertion site of the FV pathway. However, 3 patients (60%) enrolled in our study and several in the previous studies had PR intervals less than 120 ms. \(^3,7,14\) Gallagher et al reported six patients with FV pathways with a PR interval < 0.12 seconds and electrophysiologic evidence of enhanced AV nodal conduction. \(^3\) In Sternick’s series, the mean PR interval was 0.10 ± 0.01 seconds (range 0.09–0.12), but no patient had enhanced AV nodal conduction. \(^7\) In Oh’s series, 20% of the patients enrolled in the study had PR intervals less than 120 ms. \(^14\) PR interval might depend on the proximal insertion site of the FV pathway in each patient.

FV pathways have no role in reciprocating tachycardia and only conduct anterogradely. \(^1,3\) Therefore, FV pathways are not indicated for catheter ablation, and we will be able to avoid unnecessary invasive procedures if we are able to diagnose it accurately by noninvasive tests such as ECG. However, since FV pathways commonly harbor the septal region, ECG presentation of FV pathways is expected to share some characteristics with septal AV pathways. In fact, applying previously published algorism in the differential diagnosis of septal APs for patients with FV pathways, they are categorized as anteroseptal or midseptal APs. \(^7,14\) In the present study, when we applied several ECG algoritms to localizing accessory AP in patients with WPW syndrome, all ECGs of the enrolled patients could be diagnosed as AV AP. Therefore, ECGs of patients with FV pathways can be misdiagnosed as AV AP when we apply the algorithm for WPW syndrome without consideration of the characteristics of FV pathways.
FV pathways are responsible for a variable preexcitation pattern on surface ECG, as shown in previous studies and the present study. Previous reports showed initial q waves in V₁ and a decrease in the height of the R wave,⁴,⁵,¹⁴ corresponding to type C and B in the present study, respectively. Oh et al¹⁴ reported that the polarity of delta waves in V₁ was flat in 4 patients (80%) with type B ECG, which was also observed in our Case No 5 with type B ECG. Sternick et al reported that the ECG of patients with FV pathway was similar to the ECG of patients with anteroseptal and midseptal accessory AV pathway. The major feature discriminating the former from the latter is only a narrower QRS complex. Thus, the ECG of patients with FV pathway reported in the previous literature represents either type B or C. To our knowledge, the preexcitation pattern of type A in patients with FV pathway, as seen in Case No 4, has never been reported. We speculate that the proximal insertion arising from the left bundle branch and the conduction time over the His-Purkinje system is relatively long, resulting in the ECG pattern presenting with right branch block QRS morphology during preexcitation through the FV pathway. Thus, our study suggests that FV pathways are responsible for any of the preexcitation patterns of type A, B or C on surface ECG.

Study limitations
There were several limitations in the present study. First, we did not evaluate the effect of ATP injection which is very useful as a method to assess the relationship between the FV pathway and its connection to the AV node-His-bundle system,⁶ and did not confirm the disappearance or morphological change of the delta wave following sodium channel blocker injection, except in Case No 3. Both methods may provide further confirmation of the diagnosis of FV pathway; however, these are not always needed to make the diagnosis of FV pathway.¹ First, since we did not explore to find the exact ventricular breakthough site over FV pathway by using electroanatomical mapping, we could not confirm that the FV pathway in patients presenting with type C broke though the ventricular septum. Third, we enrolled an asymptomatic young female (Case No 1) who might be not indicated as a candidate for an electrophysiologic study according to a recent guideline.²¹ Fourth, electrophysiologic findings shown in Figure 2 might be observed in a case with an AV AP with an antegrade effective refractory period of more than 400 ms, adjacent to FV pathway with a short antegrade effect refractory period. Finally, the number of enrolled patients in the study was too small to provide robust diagnostic criteria. However, the suggested findings would be helpful for collecting the further information.

Conclusions
ECGs of FV pathways may be misidentified as ECG of WPW syndrome, and may present with any of the preexcitation patterns of type A, B or C.
References


