Journal of Electrocardiology 55 (2019) 34–40

Contents lists available at ScienceDirect

Journal of Electrocardiology

journal homepage: www.jecgonline.com

Impact of fasciculoventricular bypass tracts on the diagnosis and treatment of concomitant arrhythmias and cardiac diseases☆

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ARTICLE INFO

Keywords:
Fasciculoventricular bypass tracts
Atrial fibrillation
Atrial flutter
Atrioventricular bypass tracts
Ventricular preexcitation

ABSTRACT

Background: Fasciculoventricular (FV) bypass tracts (BTs) are the rarest form of ventricular preexcitation. Although they are not involved in clinically significant reentrant tachycardia, they may cause diagnostic and therapeutic confusion if not properly understood. This study aimed to assess the impact of FV BTs on the diagnosis and treatment of concomitant arrhythmias and cardiac diseases.

Methods: Twenty-two patients with FV BTs who underwent electrophysiologic (EP) study were evaluated. The prevalence of concomitant arrhythmias and cardiac diseases in FV BTs was evaluated. The mechanisms of concomitant arrhythmias were determined by EP study and cardiac diseases were diagnosed by echocardiography.

Results: One patient had FV BT with complete infra-Hisian atrioventricular (AV) block that mimicked a slow ventricular escape rhythm. Two patients had FV BT with atrial fibrillation or atrial flutter, which was misinterpreted as AV BT requiring emergency DC cardioversion. Eight patients had accompanying AV BTs. In 2 patients with AV BTs, unnecessary RF application was delivered after successful ablation of AV BT because conduction through a FV BT was mistaken for conduction through a residual AV BT. Five patients had no concomitant arrhythmia; however, two of them had hypertrophic cardiomyopathy with symptoms requiring beta-blocker. Patients had not been prescribed beta-blockers to avoid a proarrhythmic response before the EP study because the FV BTs mimicked AV BTs.

Conclusion: FV BTs were frequently accompanied by AV BTs or other arrhythmias and cardiac diseases. They may cause misdiagnosis and inappropriate therapy and even unnecessary RF delivery when misinterpreted as AV BTs.

Introduction

Fasciculoventricular (FV) bypass tracts (BTs) are the rarest variants of preexcitation (1.2%–5.1%) [1–5]. They connect the His bundle or bundle branches to the ventricular septum. Although FV BTs are not involved in clinically significant reentrant tachycardia because of the close proximity to the normal conduction system [6], they may be occasionally associated with rapidly conducting atrioventricular (AV) BTs [7]. Thus, this association may lead to diagnostic and therapeutic misapplication if not properly clarified. This study aimed to assess the impact of FV BT on the diagnosis and treatment of concomitant arrhythmias and cardiac diseases.

Methods

Study patients and electrophysiologic (EP) study

From March 1, 1999 to February 28, 2018, 22 patients with FV BTs were diagnosed via EP study in Asan Medical Center and Ulsan University Hospital. These patients underwent EP study after discontinuing antiarrhythmic drug for ≥5 drug half-lives. Through the right and left femoral veins, quadripolar electrode catheters were positioned in the upper right atrium, right ventricle, and His bundle region, and a decapolar catheter was advanced into the coronary sinus. Recordings of the 12 lead surface electrocardiography (ECG) and intracardiac

☆ Conflicts of interest: none.

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https://doi.org/10.1016/j.jelectrocard.2019.04.002
0022-0736/

electrograms were made using the CardioLab EP System (Prucka Engineering, Inc.). The ECG and intracardiac electrograms were analyzed independently by two authors (YGK and GBN). The diagnostic criteria for FV BTs were 1) normal AH interval and short HV interval (<35 ms), 2) demonstration of fixed preexcitation with decremental AV node conduction (AH interval prolongation), and 3) preexcitation during a His extrasystole [6]. The protocol of this retrospective study was approved by the Institutional Review Board at Asan Medical Center (IRB No. 2018-1292) and Ulsan University Hospital (IRB No. 2018-09-022). Written informed consent was obtained before the EP study.

Concomitant arrhythmias and cardiac diseases

The EP study determined the mechanisms of concomitant arrhythmias. Structural cardiac defects were ruled out by echocardiography. The prevalence of concomitant arrhythmias and cardiac diseases in FV BTs were evaluated. Moreover, we assessed the impact of FV BTs on the diagnosis and treatments of concomitant arrhythmias and cardiac diseases. We also evaluated the applicability of the ECG characteristics of FV BTs compared to anteroseptal or midseptal AV BTs according to previous studies [4,8]. The ECG characteristics of FV BTs were 1) QRS width ≤ 120 ms, 2) PR interval > 110 ms, 3) width of R wave in V1 < 35 ms, and 4) amplitude of S wave in V1 < 20 mm.

Statistical analysis

Categorical variables are expressed as absolute numbers and percentages. Continuous variables are expressed as mean ± standard deviation. Statistical analyses were performed using SPSS version 21.0 (SPSS, Inc., Chicago, Illinois).

Results

Baseline characteristics of the study patients

The mean patient age was 39.6 ± 18.3 years and 7 patients (31.8%) were male (Table 1). None of the patients had reentrant tachycardia associated with FV BTs. All the patients had a normal left ventricular ejection fraction.

Concomitant arrhythmias and cardiac diseases

Seventeen patients (77.3%) had concomitant arrhythmias (Table 1). One patient (4.5%) had a FV BT with a complete infra-Hisian AV block which mimicked a slow ventricular escape rhythm (Fig. 1). Three patients (13.6%) had FV BTs with spontaneous atrial fibrillation (AF) or atrial flutter (AFL). Eight patients (36.4%) had accompanying AV BTs. Five of them (22.7%) had concealed AV BTs (right lateral AV BTs in 2 patients and left lateral AV BTs in 3 patients) participating in orthodromic AV reentrant tachycardia, and 3 patients (13.6%) had manifest AV BTs. In the patients with manifest AV BTs, 2 had right posteroseptal AV BTs which demonstrated a short effective refractory period, producing a rapid ventricular response during induced AF or AFL, and 1 had left lateral AV BT which participated in orthodromic AV reentrant tachycardia. Six patients (27.3%) had AV nodal reentrant tachycardia (typical AV nodal reentrant tachycardia in 3 patients and atypical AV nodal reentrant tachycardia in 3 patients).

Four patients (18.2%) had concomitant cardiac diseases (Table 1). One patient had Ebstein's anomaly accompanying manifest AV BT (right posteroseptal site) and 3 patients had hypertrophic cardiomyopathy (HCM).

Table 1
Baseline characteristics, concomitant arrhythmias and cardiac diseases of patients with fasciculoventricular bypass tract.

Patient NO.	Age (years)	Gender	Concomitant		Treatment	Impact of FV bypass tract on diagnosis and treatment
			Arrhythmias	Cardiac diseases		
1	18	F	Complete AV block (Infra-hisian level)	(−)	Permanent pacemaker implantation	
2	25	M	AV BT associated ORT (concealed right lateral AV BT)	(−)	Ablation of AV BT	
3	46	M	AV BT associated ORT (concealed right lateral AV BT)	(−)	Ablation of AV BT	
4	52	F	Ventricular preexcitation (right posteroseptal AV BT with short ERP) with induced AF/AFL	Ebstein's anomaly	Ablation of AV BT	Unnecessary additional ablation
5	43	F	AV BT associated ORT (concealed left lateral AV BT)	HCM	Ablation of AV BT	
6	16	F	Ventricular preexcitation (right posteroseptal AV BT with short ERP) with induced AF/AFL	(−)	Ablation of AV BT	Unnecessary additional ablation
7	50	F	AF	(−)	PV isolation	Unnecessary DC cardioversion
8	54	M	CTI-dependent AFL	(−)	CTI ablation	Unnecessary DC cardioversion
9	20	M	(−)	(−)		
10	60	F	AF	(−)	PV isolation with linear ablation of roof and CTI	
11	19	M	Ventricular preexcitation with AV BT associated ORT (left lateral AV BT)	(−)	Ablation of AV BT	Unnecessary second EP study
12	80	F	(−)	HCM		Could not use beta-blocker
13	51	F	AV BT associated ORT (concealed left lateral AV bypass tract)	(−)	Ablation of AV BT	
14	25	F	Atypical AVNRT (fast/slow)	(−)	Slow pathway ablation	
15	50	F	Typical AVNRT (slow/fast)	(−)	Slow pathway ablation	
16	26	F	Typical AVNRT (slow/fast)	(−)	Slow pathway ablation	
17	40	F	Typical AVNRT (slow/fast)	(−)	Slow pathway ablation	
18	57	F	AV BT associated ORT (concealed left lateral AV bypass tract)	(−)	Ablation of AV BT	
19	46	F	(−)	HCM		Could not use beta-blocker
20	59	M	(−)	(−)		
21	14	F	Atypical AVNRT (slow/slow)	(−)	Slow pathway ablation	
22	19	M	(−)	(−)		

AF: atrial fibrillation; AFL: atrial flutter; AV: atrioventricular; AVNRT: atrioventicular nodal reentrant tachycardia; BT: bypass tract; CTI: cavotricuspid isthmus; ERP: effective refractory period; HCM: hypertrophic cardiomyopathy; ORT: orthodromic reciprocating tachycardia; PV: pulmonary vein; RFCA: radiofrequency catheter ablation.

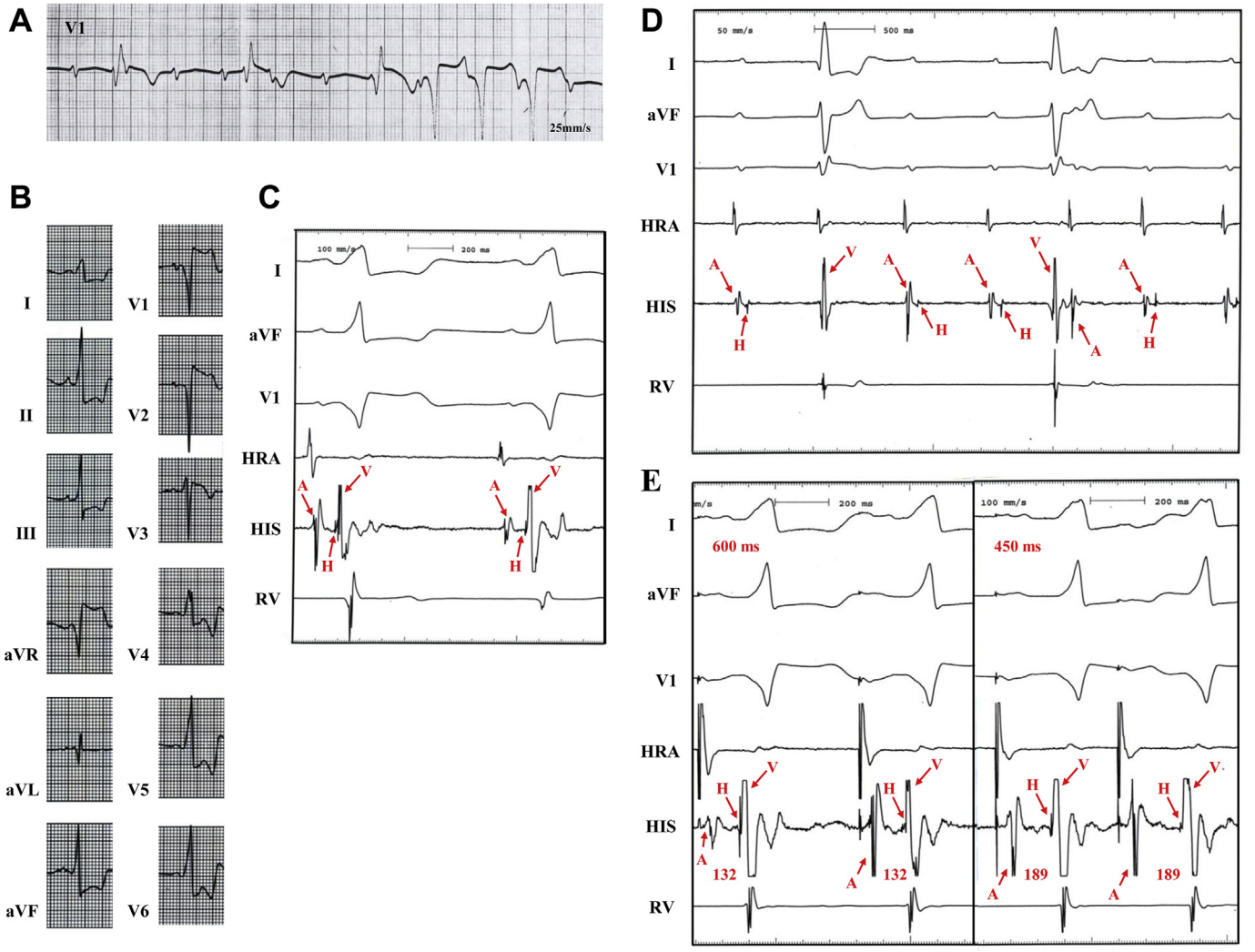

Fig. 1. Patient 1 visited the emergency room for the evaluation of presyncope. A: Intermittent complete AV block accompanied by ventricular escape rhythm with a RBBB pattern followed by normal AV conduction with ventricular preexcitation. B: Normal PR interval and ventricular preexcitation. The polarity of the delta waves suggests the presence of an anteroseptal AV BT. C: AH and HV interval were 93 ms and 18 ms during normal sinus rhythm with ventricular preexcitation. D: Immediately after the ventricular pacing, complete infra-Hisian AV block developed transiently. The QRS morphology of the ventricular escape rhythm showed RBBB pattern. E: As atrial pacing cycle lengths were decreased from 600 ms to 450 ms, AH interval increased from 132 ms to 189 ms. However, the degree of ventricular preexcitation and HV interval remained constant. A: atrial potential; AV: atrioventricular; BT: bypass tract; H: His bundle potential; HIS: His bundle electrogram; HRA: high right atrium; RBBB: right bundle branch block; RV: right ventricular electrogram; V: ventricular potential.

Clinical implication of FV BTs

Although FV BTs did not participate in the reentrant tachycardia, FV BTs had a clinically relevant effect on the diagnostic and therapeutic processes. In 2 patients with AF or AFL, FV BTs were misinterpreted as AV BTs requiring emergency DC cardioversion (Fig. 2). In 2 patients with accompanying manifest AV BTs (right posteroseptal site), unnecessary RF applications were delivered after successful AV BT ablation because conduction through FV BT was mistaken for conduction through residual AV BT (Fig. 3). In 1 patient with accompanying manifest AV BT (left lateral site), successful AV BT ablation was performed. However, post-ablation ECG showed ventricular preexcitation through FV BT. Ventricular preexcitation through AV BT before ablation was subtle and it was challenging to differentiate the ventricular preexcitation through AV BT from that through FV BT by ECG alone (Fig. 4). In this patient, an unnecessary second EP study was performed 1 day after ablation. Two patients had HCM without concomitant arrhythmia. In the recent 2011 ACCF/AHA guideline for the diagnosis and treatment of HCM, beta-blockers are recommended as first-line agents because of their negative inotropic effect and their ability to attenuate adrenergic-induced tachycardia (Class I, level of evidence: B) [9]. However, the patient could not be administered a beta-blocker before the EP study because FV BTs were misinterpreted as AV BTs.

Application of previously published ECG characteristics of FV BTs

We evaluated the diagnostic performance of four ECG characteristics of FV BTs, compared to anteroseptal or midseptal AV BTs, as suggested by previous studies (Table 2) [4,8]. Three ECG characteristics (QRS width, PR interval, and S wave amplitude in V1) were relatively applicable (sensitivity; 72.7–86.4%); however, R wave width in V1 was not applicable (sensitivity; 23.5%). Particularly, in HCM patients, ECG characteristics were not applicable (Supplemental Table 1). No HCM patient met the criteria for the R wave width and S wave amplitude in V1. The means of QRS width, PR interval, R wave width in V1, and S wave amplitude in V1 for all the patients with FV BTs were 108.5 ± 14.1 ms, 122.1 ± 16.6 ms, 42.0 ± 12.1 ms, and 12.9 ± 6.9 mm, respectively.

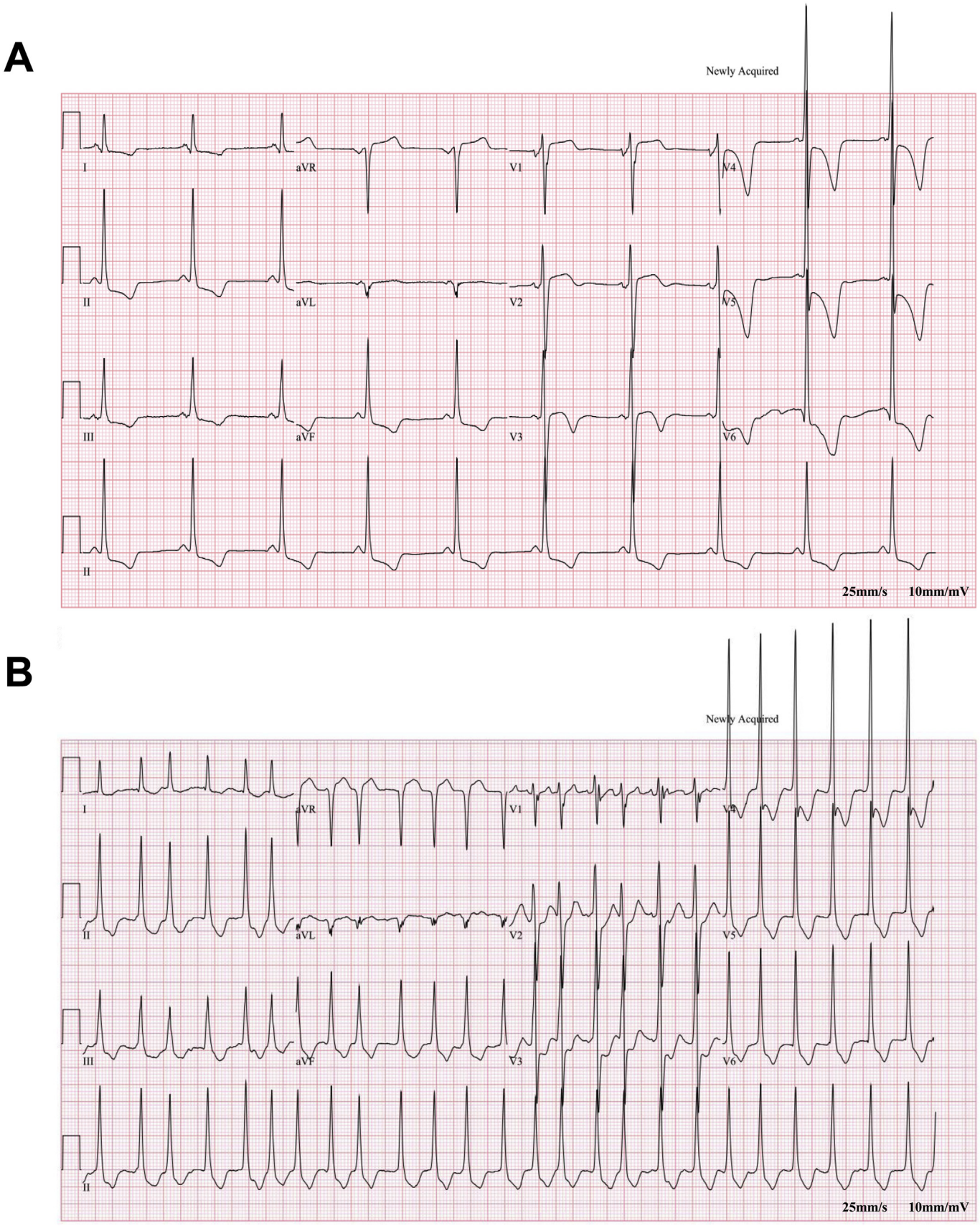

Fig. 2. Twelve lead ECG of baseline (A) and AF (B) in a patient with a FV BT (Patient 7). Unlike in the AV BT, there was no delta wave augmentation or variation during AF, which should have suggested the diagnosis of FV BT. AF: atrial fibrillation; AV: atrioventricular; BT: bypass tract; ECG: electrocardiography; FV: fasciculoventricular.

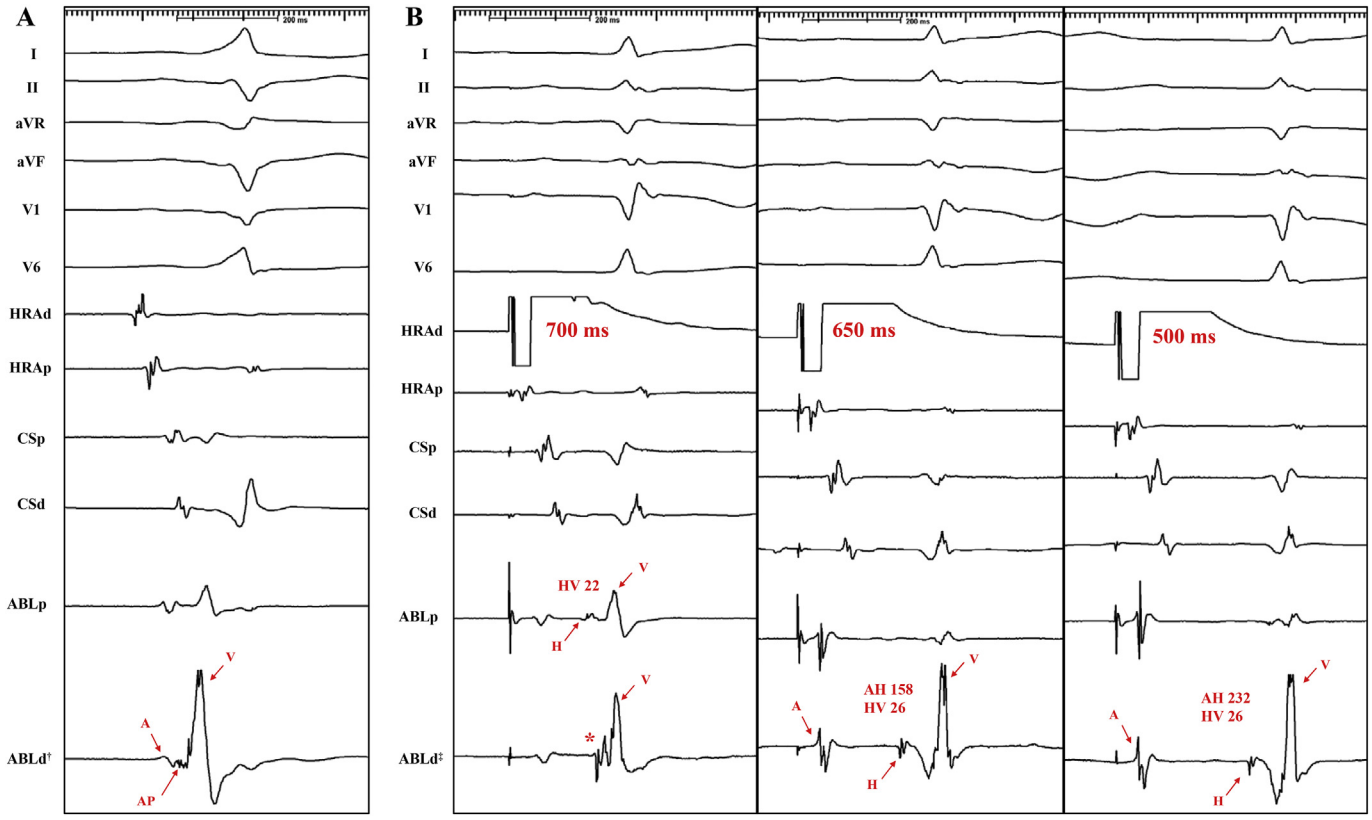

Fig. 3. Patient 4 with Ebstein's anomaly and a manifest right posteroseptal AV BT. A: Surface ECG shows a negative delta wave in leads aVF and V1. There was an accessory pathway potential at the ablation catheter. B: Although a delta wave disappeared after a successful right posteroseptal AV BT ablation, HV interval remained short (22 ms) and a sharp potential (*) recorded at the ablation catheter (near the right bundle branch region) mimicked residual AV BT activity (left panel). This led to unnecessary additional RF delivery. Proximal His bundle potential was recorded by withdrawal of ablation catheter (middle and right panel). Finally, subsequent pacing study revealed prolongation of the AH interval (from 158 ms to 232 ms) with a fixed HV interval (26 ms) during HRA pacing at 500 ms (right panel) compared to HRA pacing at 650 ms (middle panel), which was compatible with a FV BT. This case emphasizes the importance of careful identification of the His bundle, right bundle branch, and BT potentials for accurate differential diagnosis. A: atrial potential; AP: atrioventricular bypass tract potential; AV: atrioventricular; BT: bypass tract; CS: coronary sinus electrogram; d: distal; FV: fasciculoventricular; H: His bundle potential; HRA: high right atrium; p: proximal; V: ventricular potential. †Ablation catheter was positioned at the right posteroseptal site. ‡Ablation catheter was positioned at the His area.

Discussion

This study aimed to investigate the effect of FV BTs on the diagnosis and treatment of concomitant arrhythmias and cardiac diseases. The main findings of this study are as follows: 1) FV BTs are frequently accompanied by arrhythmias or cardiac diseases (prevalence 86.4%), 2) although FV BTs did not play a role in clinically significant reentrant tachycardia, they might cause misdiagnosis and inappropriate therapy if misidentified, and 3) the ability of 12 lead ECG for distinguishing FV BTs from AV BTs is limited.

In the present study, the prevalence of concomitant arrhythmias was 77.3% in patients with FV BTs and is consistent with findings from previous studies. Gallagher et al. reported that 5 out of 6 patients (83.3%) with FV BTs had concomitant arrhythmia [1]. Sternick et al. reported that 5 patients (62.5%) with FV BTs had concomitant arrhythmia among 8 patients with FV BTs [4]. We found that 34.6% of patients had accompanying AV BTs. Previous studies also reported similar results (33%) [7]. The prevalence of concomitant cardiac diseases was 18.2% in the current study and is also consistent with findings from previous studies (15.8–27.3%) [4,5].

FV BTs have not been found to play a role in reentrant tachycardia and we also noted that none of the patients had reentrant tachycardia associated with FV BTs. However, our results suggest that FV BTs might lead to misdiagnosis and inappropriate therapy for accompanying arrhythmias or concomitant cardiac diseases. FV BTs led to unnecessary DC cardioversion in patients with AF or AFL and interfered with the administration of essential medication (beta-blocker) in patients with HCM when the FV BTs were misinterpreted as AV BTs. In patient with manifest left lateral AV BT, ventricular preexcitation through AV BT was subtle. Therefore, it is difficult to differentiate the ventricular preexcitation through AV BT from that through FV BT by ECG and this resulted in an unnecessary second EP study, although successful AV BT ablation was achieved (actually, we did not consider FV BT and did not conduct a diagnostic maneuver for FV BTs during the first EP study). Further, unnecessary RF applications were delivered after successful ablation of AV BTs in patients with manifest right posteroseptal AV BTs. Their anatomic location adjacent to septal AV BTs make them easy to misinterpret as remnant AV BTs. This might result in unnecessary ablations and even AV nodal injury unless FV BT is properly considered. We suggest that a diagnostic maneuver for FV BTs should be performed when ventricular preexcitation persists after ablations of manifest AV BTs, especially in septal AV BTs.

Previous studies proposed ECG criteria for FV BTs. Sternick et al. reported that a narrower QRS width was the most important criterion for differentiating FV BTs from a septally located AV BTs [4]. Oh et al. reported that FV BTs have different characteristics from anteroseptal AV BTs in PR interval, S wave amplitude, and R wave width in V1 [8]. However, they were not properly applicable in this study (sensitivity; 23.5–86.4%), especially in patients with HCM (sensitivity of the ECG criteria was <40% except for QRS width). This was probably due to the effect of ventricular hypertrophy and abnormal intraventricular conduction in patients with HCM. In addition, FV BTs were occasionally associated with manifest AV BTs (13.6–28.6%) in this study and in previous studies [1,4]. When manifest AV BTs coexist with FV BTs, it is

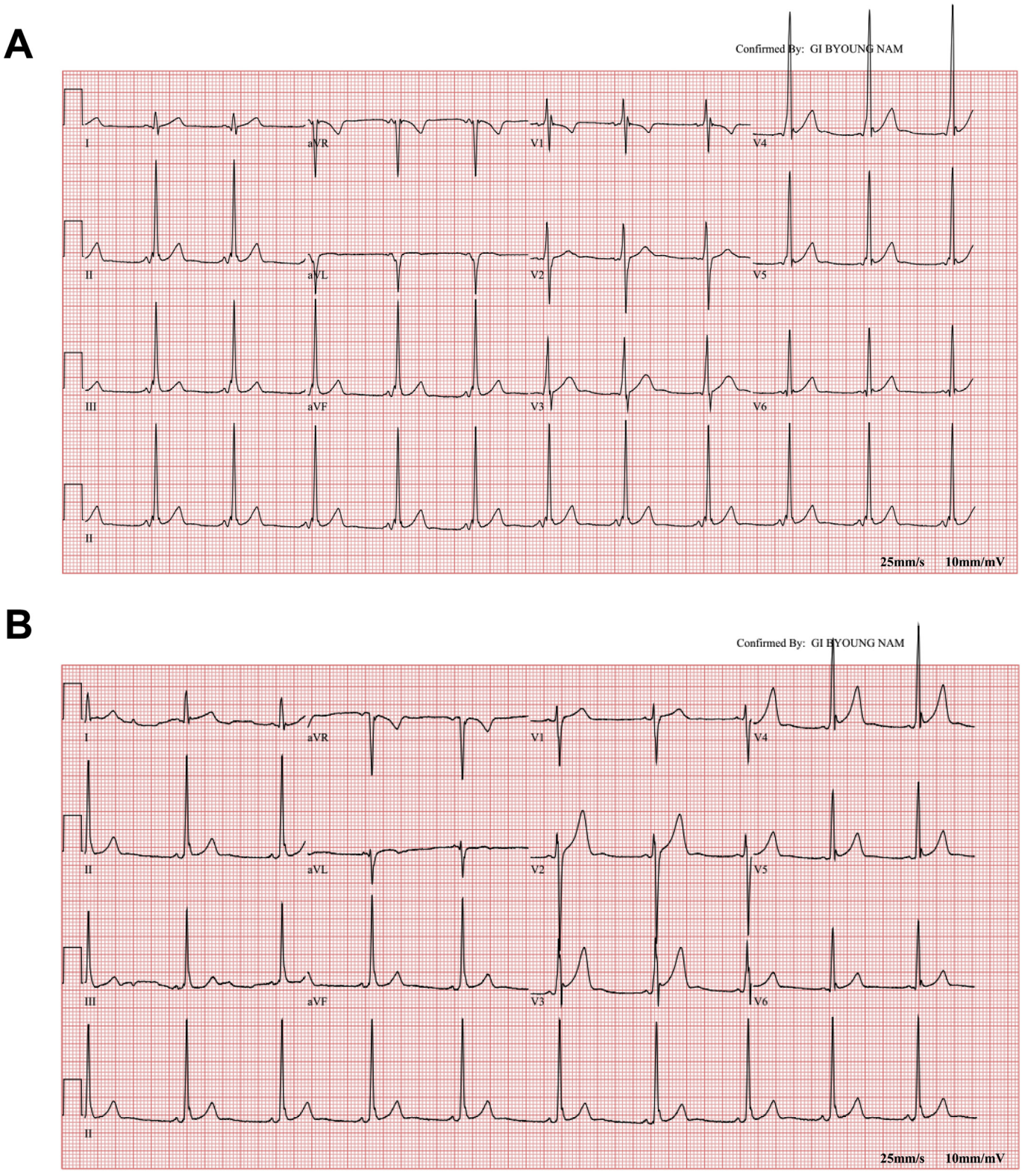

Fig. 4. Patient 11. Twelve lead ECG before (A) and after (B) the ablation of a manifest left lateral AV BT. Although the degree of the delta wave was decreased, the delta wave remained and its polarity was similar between before and after ablation. This finding was misinterpreted as the presence of a remnant AV BT and resulted in an unnecessary second electrophysiologic study. AV: atrioventricular; BT: bypass tract; ECG: electrocardiography.

impossible to diagnose FV BTs by ECG alone before AV BTs ablation. Furthermore, 6 patients in this study had very subtle preexcitation and we could not recognize the presence of FV BTs by ECG until the EP study had been performed. Therefore, EP study is a definitive and essential diagnostic test for the diagnosis of FV BTs.

A previous study reported the association between FV BTs and *PRKAG2* gene mutation [10]. FVBTs with *PRKAG2* mutation have distinct clinical, ECG, and EP characteristics. They have a wider QRS morphology, right bundle branch block, high incidence of HCM, sinus bradycardia, AF, AFL, and complete AV block, and a poorer prognosis [11,12]. Although

Table 2
Application of previously published ECG characteristics of fasciculoventricular bypass tract.

	Applicable/total case (sensitivity)
QRS width ≤ 120 ms	17/22 (77.3%)
PR interval > 110 ms	16/22 (72.7%)
Width of R wave in V1 < 35 ms	4/17[a] (23.5%)
Amplitude of S wave in V1 < 20 mm	19/22 (86.4%)

ECG: electrocardiography.
[a] QS pattern which is unmeasurable was observed in 5 patients.

some patients in the current study had the above characteristics, we could not ascertain whether they had *PRKAG2* mutation because we did not conduct a genetic analysis.

Although there were no data about the true prevalence of FV BTs, including in asymptomatic patients, we suggest that the true prevalence of FV BTs is more than we think. In clinical practice, FV BT is easily missed because the degree of ventricular preexcitation is very subtle as noted above. Furthermore, findings suggestive of FV BT such as short HV interval and fixed subtle preexcitation with decremental AV node conduction may be overlooked when tachycardia is not induced during EP study.

Limitations

This study has several limitations. First, the number of patients (n = 22) was too small to derive a definite conclusion. However, this is an inherent limitation of studies on FV BTs because of the paucity of FV BTs. Nonetheless, to our knowledge, this is the largest study on FV BTs confirmed by EP study. Although a previous study was conducted on 23 patients with FV BTs, the presence of FV BT was not confirmed by EP study [13]. Second, there might have been a selection bias as this study was conducted at a tertiary care hospital on symptomatic patients requiring EP study. It is plausible that patients with FV BTs in this study had more symptoms, concomitant arrhythmias, and cardiac diseases than general patients with FV BTs. However, these patients who require EP study are a major group requiring clinical attention because most general patients with FV BTs are asymptomatic and do not need clinical care.

Conclusions

FV BTs were frequently accompanied by AV BT or other arrhythmias and cardiac diseases. Although FV BTs played no role in reentrant tachycardia, FV BTs could cause misdiagnosis and inappropriate therapy, even unnecessary RF delivery, if not properly considered. ECG is limited for the diagnosis of FV BTs, and EP study with diagnostic maneuver for FV BTs is definitive and essential for differentiating FV BTs from AV BTs.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jelectrocard.2019.04.002.

Disclosure of conflict of interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

We thank Jin-Seok Jeong, Doo-Young Han, and Jong-Pil Yun for their support with the preparation of this manuscript.

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