Journal of Electrocardiology 54 (2019) 54–60

Contents lists available at ScienceDirect

Journal of Electrocardiology

journal homepage: www.jecgonline.com

Frequency and characteristics of exercise-induced second-degree atrioventricular block in patients undergoing stress testing

Amanda R. Bonikowske *, Ahmad Barout [1], Sonia Fortin-Gamero, Maria Irene Barillas Lara, Suraj Kapa, Thomas G. Allison

Department of Cardiovascular Medicine, Mayo Clinic, Rochester, MN, United States of America

ARTICLE INFO

Keywords:
Arrhythmia
Exercise
Exercise intolerance
Exercise testing
Pacemaker
Second-degree AV block

ABSTRACT

Background: Spontaneous second-degree atrioventricular block induced by exercise (Ex2AVB) is rare, but it can cause profound exercise intolerance.

Objective: We sought to determine the frequency of Ex2AVB in our exercise testing practice and to describe characteristics of patients with Ex2AVB. We hypothesized that the number of patients would be small, but they would require invasive treatment.

Methods: We reviewed the Mayo Clinic Integrated Stress Center database for nonimaging tests performed from 2006 through 2010. All exercise tests coded as "second-degree atrioventricular block" were captured and reviewed. Tests were excluded if results showed evidence of second-degree atrioventricular block at rest.

Results: From 40,715 tests performed, definite Ex2AVB was found in only 19 patients (0.05%; 5 women and 14 men). Ex2AVB occurred as a Mobitz type II block in 4 patients and as a Mobitz type I block in 15. In 3 patients, Ex2AVB occurred only in recovery. Ex2AVB was intermittent in 11 patients and persistent in 8. Mean peak heart rate was higher with intermittent Ex2AVB than with persistent Ex2AVB (126 ± 39 vs 88 ± 28 bpm, $P < .01$), as was mean functional aerobic capacity (87% ± 20% vs 59% ± 14%, $P < .01$). Seven patients with persistent Ex2AVB received a permanent pacemaker; 1 underwent pacemaker adjustment.

Conclusion: Ex2AVB is uncommon but can cause exercise intolerance that requires pacemaker implantation. Structural or ischemic heart disease and resting conduction abnormalities are common findings in patients with Ex2AVB. Intervention is seldom required for intermittent Ex2AVB.

Introduction

Exercise-induced second-degree atrioventricular block (Ex2AVB) is uncommon in the general population [1]. The frequency is higher in older, long-term endurance athletes (up to 8%) [2,3]. Depending on the level of the block, Ex2AVB can be an important limiting factor in the ability of a patient or an athlete to perform and may require placement of a permanent pacemaker (PPM) [4,5]. The largest study to date has included 14 patients in a case series [1].

Exercise, atropine, and other vagolytic maneuvers physiologically increase the sinus rate and decrease the refractory period of the atrioventricular (AV) node, thereby allowing 1:1 AV conduction without any blockade [1,6]. The pathophysiologic basis of a second-degree AV block (AVB) can be disease of the conduction system generally below the level of the AV node, which then affects the refractory period of that particular part of the conduction system [7,8]. The disease is usually located in the bundle of His or at the level of the bundle branches. Without a concomitant decrease in the refractory period at the distal part of the conduction system, second-degree AVB is likely to occur [9]. One theory for explaining the cause of disease at the end of the conduction system in endurance athletes is myocardial remodeling and myocardial fibrosis in the left atrium, the right atrium, and the right ventricle [10,11]. Benign resting second-degree AVB is generally due to increased vagal tone (e.g., from endurance training), and it usually disappears with an increased heart rate (HR) (e.g., with exercise) [6].

We sought to provide a clearer picture of the frequency and characteristics of Ex2AVB by describing the patient population presenting with Ex2AVB documented in a large exercise-testing database. We hypothesized that the number of patients would be small, but, when induced by exercise, Ex2AVB would generally require invasive treatment such as PPM implantation.

Abbreviations: AHD, arrhythmogenic heart disease; AV, atrioventricular; AVB, atrioventricular block; CAD, coronary artery disease; EP, electrophysiologic; Ex2AVB, exercise-induced second-degree atrioventricular block; FAC, functional aerobic capacity; HR, heart rate; LBBB, left bundle branch block; PPM, permanent pacemaker; RBBB, right bundle branch block; SHD, structural heart disease.

* Corresponding author at: Department of Cardiovascular Medicine, Mayo Clinic, 200 First St SW, Rochester, MN 55905, United States of America.

E-mail address: bonikowske.amanda@mayo.edu (A.R. Bonikowske).

[1] Dr. Barout is now with UMass Memorial Medical Center, Worcester, Massachusetts.

https://doi.org/10.1016/j.jelectrocard.2019.03.009
0022-0736/

Methods

We retrospectively reviewed the Mayo Clinic Integrated Stress Center database for nonimaging tests performed from January 2006 through December 2010. All exercise test results coded as *second-degree AVB* were captured and reviewed through the electronic health record. The exercise testing protocol was the Bruce protocol or the Mayo protocol [12,13]. The Mayo exercise stress test protocol includes 2-minute stages beginning at 2 mph and 0% incline and increasing by 2 metabolic equivalent tasks at each stage. This protocol allows for smooth, linear increases in HR and oxygen consumption per unit time and is well tolerated by elderly patients and by patients with or without heart disease. The study was approved by the Mayo Clinic Institutional Review Board.

Study variables included resting and peak HR, HR reserve, percentage of predicted peak HR, functional aerobic capacity (FAC), and the absence or presence of other cardiac diseases (ischemic, congenital, or structural). FAC was estimated with calculations based on age, sex, and baseline fitness level [14,15]. Ex2AVB was described as *intermittent* if it began during exercise or recovery and resolved, and as *persistent* if it occurred during exercise or recovery and continued throughout electrocardiographic monitoring. Continuous variables were summarized as mean ± SD; discrete variables, as number (percentage of sample).

Tests were excluded if results showed evidence of second-degree AVB at rest, if Ex2AVB occurred during atrial flutter or pacemaker Wenckebach, or if nonconducted premature atrial complexes could not be distinguished from Ex2AVB.

From the chart review, we also determined whether a finding of Ex2AVB (or other mechanism producing chronotropic incompetence) was expected by the referring clinician from the patient's history and presentation of symptoms. The institution followed the published guidelines for decisions on device therapy that were current on the date of patient service.

Results

During the study period, 40,715 patients underwent nonimaging exercise stress tests. Baseline characteristics of the 40,715 patients included the following: mean ± SD age, 53.7 ± 14.7 years (range, 5–96 years); 14,268 (35%) were female; mean ± SD body mass index, 28.5 ± 5.6; 3787 (9.3%) had diabetes mellitus type 1 or 2; and 3106 (7.6%) were current smokers. Baseline cardiovascular status of the whole cohort (40,715 patients) is summarized in Fig. 1. Of the entire cohort, 6540 patients (16.1%) had structural heart disease (SHD); 6671 (16.4%) had arrhythmogenic heart disease (AHD); and 5738 (14.1%) had coronary artery disease (CAD). SHD included congenital and valvular heart disease, hypertrophic cardiomyopathy, and other nonischemic cardiomyopathy. AHD included nonspecified cardiac arrhythmia (309), atrial fibrillation or flutter (3307), complete heart block (64), second-degree heart block (24), long QT syndrome (446), sinoatrial node dysfunction (20), ventricular arrhythmia (884), supraventricular tachycardia (339), Wolff-Parkinson-White syndrome (102), left bundle branch block (LBBB) (276), right bundle branch block (RBBB) (452), and implantable cardioverter-defibrillator or PPM (3321).

Definite Ex2AVB was found in only 19 patients (0.05%; 5 women and 14 men). One female patient underwent 2 tests during the study period; results from both tests showed Ex2AVB. Baseline characteristics and exercise response variables for the 19 patients with Ex2AVB are summarized in Tables 1 and 2 and Fig. 2.

Most of the 40,715 patients in the active cohort did not have known heart disease and less than half had underlying cardiovascular disease. Ex2AVB was present only among patients with underlying cardiovascular disease. The most frequently identified heart diseases in our 19 study patients were SHD, CAD, and AHD.

Upon reviewing the preexercise test cardiac referral notes for our 19 patients, we found that Ex2AVB was an unexpected finding in 6 patients and an expected finding in 13.

At rest, 5 patients had normal sinus rhythm; 8, first-degree AVB; 4, sinus bradycardia; 3, RBBB; 2, LBBB; and 1, ST-segment abnormality. Two were paced.

None of the tests demonstrated ischemic electrocardiographic changes. Ex2AVB presented as Mobitz type II block in 4 patients and as Mobitz type I in 15.

In 8 patients, Ex2AVB occurred only in the exercise phase; in 2, only in the active recovery phase (defined as the first 3 min of recovery); and in 1, only in the cooldown phase (defined as minutes 3–6 of recovery). In 8 patients, Ex2AVB occurred in >1 phase.

Peak exercise HR (in beats per minute) was higher in intermittent Ex2AVB than in persistent Ex2AVB even though the difference was not statistically significant (109 ± 44 vs 88 ± 28, $P = .22$), but FAC was significantly higher in the intermittent group (80% ± 26% vs 57% ± 12%, $P = .02$). As shown in Fig. 3, HR at peak exercise was similar to HR at rest because of Ex2AVB.

Following exercise testing, 7 patients with Ex2AVB received a PPM; the indications were chronotropic insufficiency in 1 patient, complete

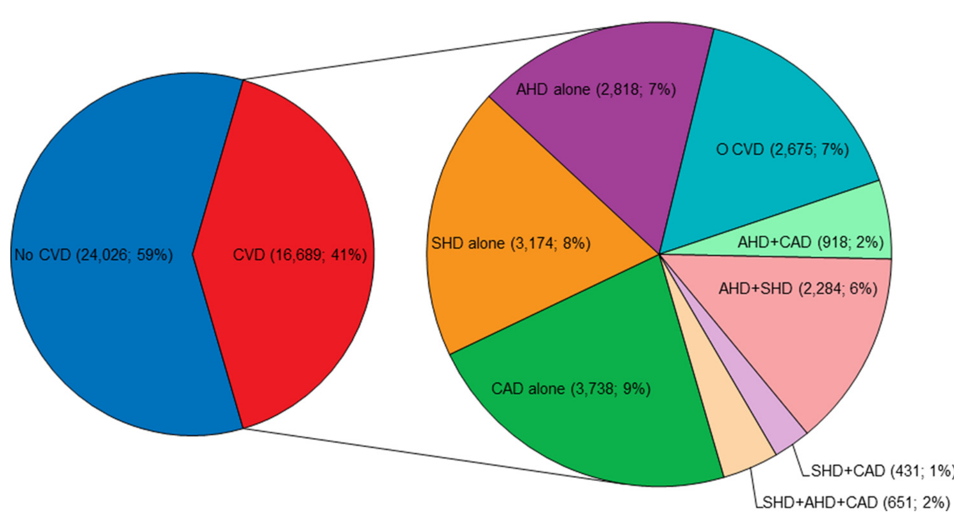

Fig. 1. Baseline cardiovascular status for the cohort (40,715 patients). AHD indicates arrhythmogenic heart disease; CAD, coronary artery disease; CVD, cardiovascular disease; O, other type of; SHD, structural heart disease.

Table 1
Baseline, ECG, and exercise data for patients (n = 19).

Variable	Value[a]
Baseline characteristic	
°Age, y	62 ± 17.1
°Female	5 (26)
°β-Blocker use	5 (26)
°ACEI/ARB use	4 (21)
°Statin use	7 (37)
°CAD	8 (42)
°PCI	1 (5)
°CABG	4 (21)
°OSA	4 (21)
°Obesity	4 (21)
°HOCM	1 (5)
°Congenital	7 (37)
°Past smoker	5 (26)
°AFIB	5 (26)
°Diabetes mellitus	0
°Myocardial infarction	2 (11)
°Hypertension	9 (47)
ECG at rest	
°HR, bpm	65 ± 13
°PR, ms	211 ± 53
°QRS, ms	119 ± 35
°QTc, ms	442 ± 28
Exercise variable	
°Exercise time, min	6.44 ± 2.00
°FAC, %	70.80 ± 23.11
°Peak HR, bpm	100 ± 38
°HR reserve, %	25 ± 34.4
°Mobitz type II block	4 (21)
°Mobitz type I block	15 (79)
°Negative chronotropic	7 (37)
°HRR, bpm	1.4 ± 25
°Angina during exercise	3 (16)
°SOB as reason to stop	10 (53)
°Fatigue as reason to stop	11 (58)
Outcome	
°Deceased	3 (16)
°Pacemaker afterward	7 (37)
ECG during block	
°HR, bpm	97.35 ± 26.37
°QRS, ms	164 ± 26
°QTc, ms	460 ± 64

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; AFIB, atrial fibrillation; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass graft surgery; CAD, coronary artery disease; ECG, electrocardiogram; FAC, functional aerobic capacity; HOCM, hypertrophic obstructive cardiomyopathy; HR, heart rate; HRR, heart rate recovery; OSA, obstructive sleep apnea; PCI, percutaneous coronary intervention; QTc, corrected QT interval; SOB, shortness of breath.

[a] Continuous data are presented as mean ± SD; categorical data as number of patients (percentage of sample).

heart block in 2, Ex2AVB in 3, and Ex2AVB and LBBB in 1. Another patient underwent adjustment of a PPM/automatic implantable cardioverter-defibrillator. One patient underwent pulmonary vein isolation ablation for atrial fibrillation, and 1 underwent cardioversion for concomitant atrial fibrillation. One patient with adult degenerative valve disease underwent aortic valve replacement. Six patients did not receive any intervention. Three patients died over 6 ± 1.4 years of follow-up: The cause was ventricular arrhythmia in 1 patient at age 40 years (5 years after the discovery of Ex2AVB); cancer in 1; and unknown in 1 at age 84 years (7 years after the diagnosis of Ex2AVB).

Discussion

Summary of findings

After reviewing a large database from the Integrated Stress Center at Mayo Clinic with 40,715 patients, we identified 19 patients (0.05%) who presented with Ex2AVB. Our findings confirmed that, despite Ex2AVB being uncommon, a small group of patients do have Ex2AVB with associated clinical symptoms such as dyspnea and syncope. Additionally, 7 of those 19 (37%) in our cohort who had Ex2AVB also received a PPM after the exercise test. Ex2AVB can be persistent or intermittent, and the patients in our cohort who presented with persistent Ex2AVB were older, were more likely to have underlying heart disease, and were more likely to receive additional therapy after the exercise test.

First-degree AVB occurred at rest in 7 of our 19 patients; apparently, this is a novel finding because we did not find any mention of an association between first-degree AVB and Ex2AVB in previous studies. However, first-degree AVB has been shown to be positively associated with an increased risk of other arrhythmias, such as atrial fibrillation, and is common in patients with CAD and chronic heart failure (prevalence >50%) [16].

Another previously unreported finding from our case series is the occurrence of Ex2AVB in the recovery period of the exercise test. The underlying cause of the phenomenon is unknown, but it may be related to disease in the conduction system. We do not think that Ex2AVB is related to or associated with ischemic changes because none of our patients showed ischemic ST-segment changes or signs and symptoms related to ischemia.

Seven patients did not receive a pacemaker: 5 of them had intermittent Ex2AVB, with only 1 having it occur outside recovery (in the resting and exercise period), and 2 had persistent Ex2AVB (beginning during exercise and persisting into recovery). Upon review of the patients' records after the stress test, the patients and the providers had broad discussions based on shared decision making. For these patients, a pacemaker was not pursued because the patients were asymptomatic and were not chronotropically incompetent. Therapy for 1 patient with persistent Ex2AVB that occurred at peak exercise included a dose modification of the antiarrhythmic medication (a calcium antagonist) and an ablation for atrial fibrillation (pulmonary vein isolation). After follow-up Holter monitoring results were discussed, a shared decision was made not to pursue any further intervention.

Comparison with previous studies

Our study, the largest case series of patients with Ex2AVB to date, was slightly larger than the 14-patient Juntendo University study published in 1996 [1]. That study did not specify the total number of tests reviewed, so the prevalence of Ex2AVB in that cohort is unknown. In addition, unlike that study, our study did not have the results of electrophysiologic (EP) studies for each patient, and therefore we could not report the anatomical location of the block (i.e., proximal or distal to the bundle of His) [1].

Other published findings on Ex2AVB are largely single case reports. According to the review by Zehender et al. [3], Ex2AVB is an unusual finding among athletes, but those authors did not mention the rate or incidence of Ex2AVB in the general population (it can be higher among older patients and among patients who present with underlying heart disease).

Mechanisms of Ex2AVB

Exercise testing can be helpful for identifying the level of the AVB because an infranodal (infra-Hisian) block generally resolves with increased sympathetic input, while those farther down the conduction system will not. EP studies (EP mapping) can be performed to localize the exact anatomy if necessary; however, patients who meet guidelines for device therapy generally do not undergo EP mapping. In this case series, EP studies were not routinely performed because most of the patients had a clear indication for a pacemaker without a need for further testing. But it has been shown that the AV node usually depends

Table 2
Baseline characteristics and exercise response variables for 19 patients with Ex2AVB.

Patient	Sex	Age, y	Protocol[a]	BB	Baseline ECG	Ex time, min	FAC, %	Mobitz type	Occurrence of Ex2AVB				Baseline PM	PM after Ex
									Duration	Phase	QRS, ms	QTc, ms		
1	M	77	Mayo	No	1 AVB	9.6	112.5	I	Int	AR	80	469	No	No
2	M	62	Mayo	Yes	1 AVB, RBBB, LAFB	9.2	90.7	I	Int	AR	120	471	No	No
3	M	53	Bruce	No	Sinus brady	5.5	54.1	I	Int	Ex	100	482	No	Yes
4	M	83	Bruce	No	NSR	6.0	87.3	I	Int	Ex	80	496	No	No
5	M	75	Mayo	Yes	Paced, 1 AVB	8.7	99.4	I	Int	Ex	160	372	Yes	…
6	M	79	Mayo	No	Sinus brady, 1 AVB, RBBB	6.7	80.6	I	Int	CD	120	433	No	No
7	M	33	Bruce	No	1 AVB, LAE	9.0	72.8	I	Per	Ex	80	614	Yes	…
8	M	35	Bruce	No	Sinus brady, RBBB	7.2	53.9	I	Per	Ex	160	589	No	Yes
9	M	73	Mayo	No	1 AVB	6.0	66.9	I	Per	Ex + AR	80	478	No	No
10	M	69	Bruce	No	NSR	4.4	52.3	I	Per	Ex + AR	80	405	No	Yes
11	M	59	Mayo	No	Sinus brady, LBBB	3.7	35.2	II	Per	Ex	120	383	No	Yes
12	M	62	Mayo	Yes	NSR/T-wave inversion	5.4	53	II	Per	Ex	80	436	No	Yes
13	F	66	Bruce	No	NSR	7.1	106	I	Int	Ex + AR + CD	100	516	No	Yes
14	F	36	Mayo	No	Int ventricular paced	4.7	43.5	I	Int	Ex + AR + CD	160	360	Yes	…
15	F	77	Mayo	No	NSR	4.1	61.7	I	Int	Ex	70	462	No	No
16	F	65	Mayo	Yes	1 AVB	4.2	53.8	I	Per	Ex + AR	80	458	No	No
17	F	81	Mayo	No	NSR	6.3	101.6	II	Int	Ex + CD	80	402	Yes	…
18	M	72	Mayo	Yes	1 AVB	3.7	40.7	II	Int	Ex + CD	100	447	Yes	…
19	M	45	Mayo	No	LBBB and atrial flutter	8.4	69	I	Per	Ex + AR	160	465	Yes	…

Abbreviations: AR, active recovery; BB, β-blockade; brady, bradycardia; CD, cooldown; ECG, electrocardiographic; Ex, exercise; Ex2AVB, exercise-induced second-degree atrioventricular block; FAC, functional aerobic capacity; Int, intermittent; LAE, left atrial enlargement; LAFB, left anterior fascicular block; LBBB, left bundle branch block; NSR, normal sinus rhythm; 1 AVB, first-degree atrioventricular block; Per, persistent; PM, pacemaker; QTc, corrected QT interval; RBBB, right bundle branch block.

[a] The Mayo exercise protocol includes 2-minute stages beginning at 2 mph and 0% incline and increasing by 2 metabolic equivalent tasks at each stage. This protocol allows for smooth, linear increases in heart rate and oxygen consumption and is well tolerated by elderly patients and by others with or without heart disease.

on the autonomic system to function, so a block at this level can improve or resolve when the sympathetic tone increases during exercise, while parasympathetic tone decreases at the same time, resulting in an increased atrial rate [7]. The conduction system distal to the AV node (His-Purkinje fibers) is less sensitive to autonomic modulation, so a block below the AV node would not be expected to decrease or otherwise change with exercise [7].

Exercise testing is an effective means for evaluating symptoms suggestive of Ex2AVB. Mobitz type I blocks generally resolve with exercise because the block is often at the level of the AV node and therefore will respond to vagolytic maneuvers such as exercise (which is often the result in athletes). In contrast, Mobitz type II blocks generally worsen with exercise because the block is more distal in the conduction system. However, in EP studies Mobitz type I lesions have been identified

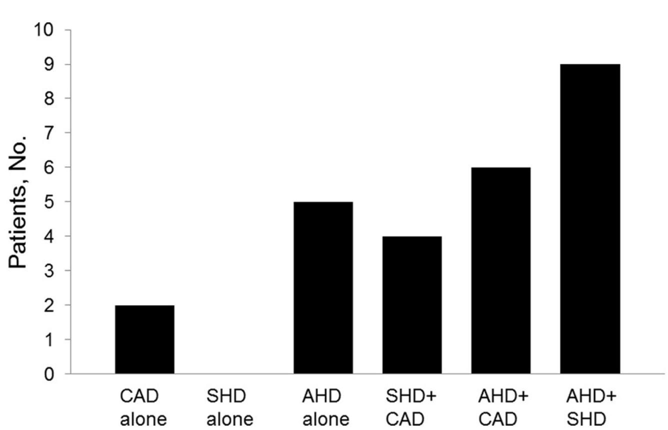

Fig. 2. Distribution of type of cardiovascular disease among 19 patients. AHD indicates arrhythmogenic heart disease; CAD, coronary artery disease; SHD, structural heart disease.

below the AV node; therefore, careful evaluation is required for any exercise-induced AVB. The sudden decrease in HR with Ex2AVB often causes symptoms, and the risk of rapid progression to third-degree AVB is common and suggests considerable conduction system disease, indicating the need for a PPM even when the patient is asymptomatic [1,17].

Therapeutic implications

The necessity of therapy for patients with Ex2AVB is better known now. Ex2AVB is a class I indication for PPM implantation as are third-degree AVB and second-degree AVB during exercise at any anatomical level without evidence of myocardial ischemia [18]. Additionally, patients who undergo ablation of the AV junction may require PPM [18]. In our study, all the patients with Mobitz type II block either had a PPM or received a PPM after they showed evidence of Ex2AVB. This is in accordance with the guidelines as we would expect. The patients with Mobitz type I block were more likely to be asymptomatic, not chronotropically incompetent, and they had a higher exercise capacity. Even though Ex2AVB is a class I indication for PPM implantation, we found that shared decision making in combination with results of clinical testing does not always lead to device implantation.

Limitations

A limitation of the present study is the lack of EP studies for all patients; additionally, the majority of our patients had underlying CAD or SHD or congenital heart disease that may have predisposed them to development of Ex2AVB. In addition, we found that in some of our patients, Ex2AVB developed during recovery, but the reason is not well understood and should be a subject for future studies.

Conclusion

Although Ex2AVB is uncommon, patients with Ex2AVB have limited exercise capacity. Our study results showed that Ex2AVB is more likely to be present in patients with congenital heart disease, AHD, or underlying CAD. The block generally occurs below the AV node (proximal or distal to the bundle of His or infra-Hisian). Exercise-induced AV block may require an EP study to determine the level of the block and the

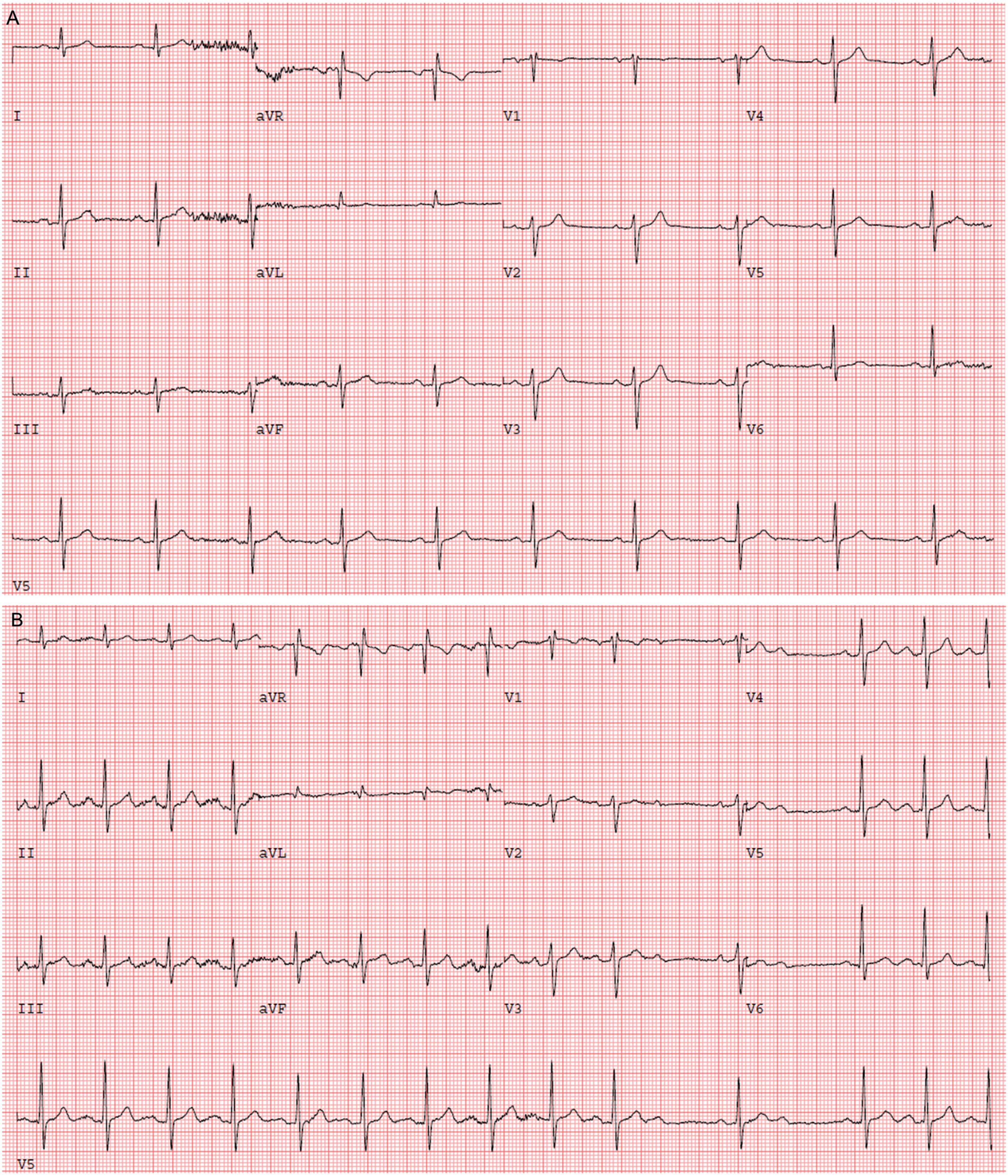

Fig. 3. Electrocardiographic tracings from a patient (patient 3 in Table 2) with progression of exercise-induced second-degree atrioventricular block. A, At rest (heart rate [HR], 59 beats per minute [bpm]). B, At stage 2 (3:50 min; HR, 87 bpm). C, At stage 2 (5:01 min; HR, 65 bpm with 2:1 conduction). D, At peak exercise (5:30 min; HR, 60 bpm).

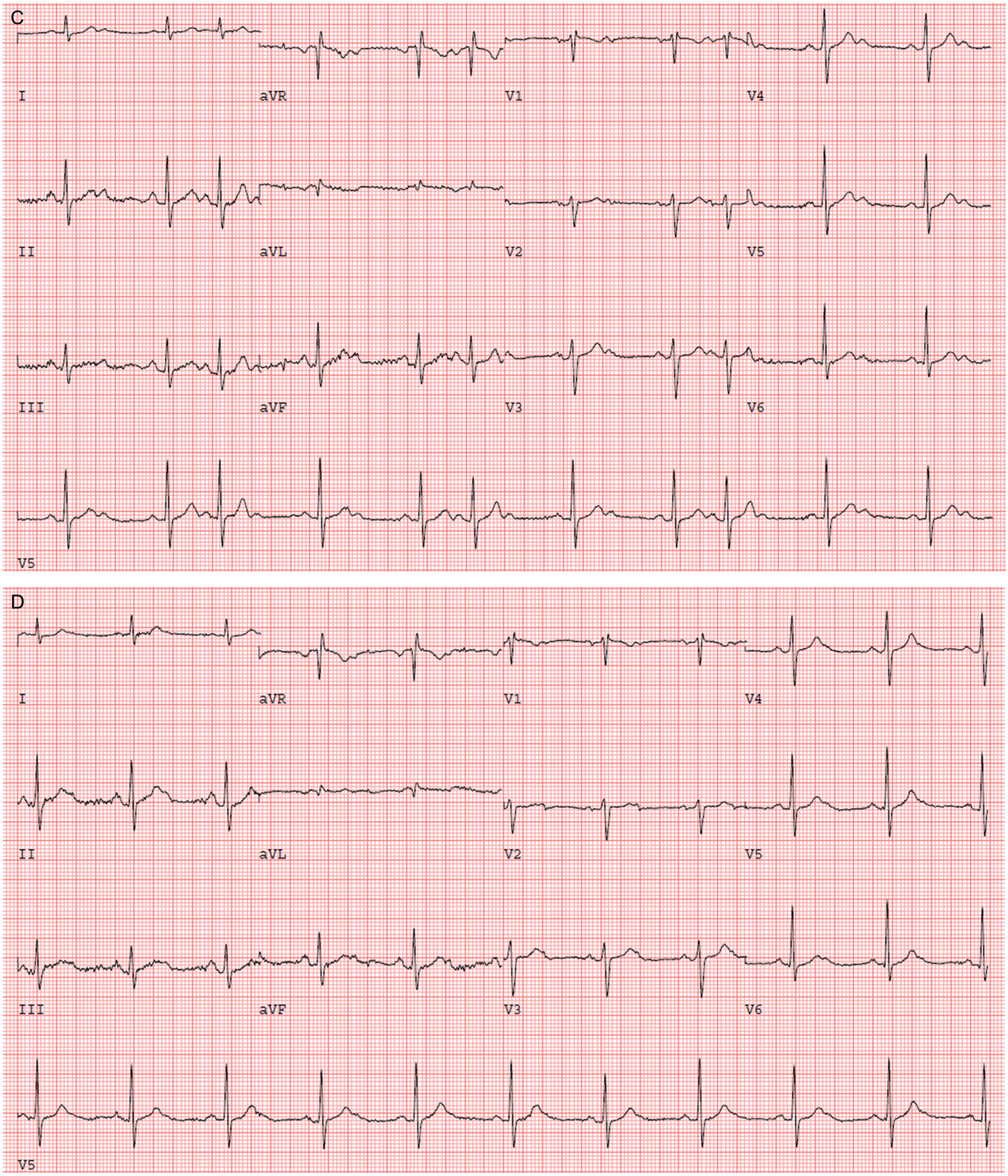

Fig. 3 (*continued*).

need for a PPM. Exercise testing is a noninvasive and effective method for evaluating the presence of second-degree AVB and associated symptoms.

Conflict of interest

None.

Role of the funding source

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

References

[1] Sumiyoshi M, Nakata Y, Yasuda M, et al. Clinical and electrophysiologic features of exercise-induced atrioventricular block. Am Heart J 1996;132(6):1277–81.
[2] Viitasalo MT, Kala R, Eisalo A. Ambulatory electrocardiographic recording in endurance athletes. Br Heart J 1982;47(3):213–20.
[3] Zehender M, Meinertz T, Keul J, Just H. ECG variants and cardiac arrhythmias in athletes: clinical relevance and prognostic importance. Am Heart J 1990;119(6):1378–91.
[4] Tuohy S, Saliba W, Pai M, Tchou P. Catheter ablation as a treatment of atrioventricular block. Heart Rhythm 2018;15(1):90–6.
[5] Epstein AE, Dimarco JP, Ellenbogen KA, et al. ACC/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities. Heart Rhythm 2008;5(6):e1–62.
[6] Bakst A, Goldberg B, Schamroth L. Significance of exercise-induced second degree atrioventricular block. Br Heart J 1975;37(9):984–6.
[7] Woelfel AK, Simpson Jr RJ, Gettes LS, Foster JR. Exercise-induced distal atrioventricular block. J Am Coll Cardiol 1983;2(3):578–81.
[8] Yuzuki Y, Horie M, Makita T, Watanuki M, Takahashi A, Sasayama S. Exercise-induced second-degree atrioventricular block. Jpn Circ J 1997;61(3):268–71.
[9] Watanabe Y, Dreifus LS. Second degree atrioventricular block. Cardiovasc Res 1967;1(2):150–8.
[10] Doutreleau S, Pistea C, Lonsdorfer E, Charloux A. Exercise-induced second-degree atrioventricular block in endurance athletes. Med Sci Sports Exerc 2013;45(3):411–4.
[11] La Gerche A, Burns AT, Mooney DJ, et al. Exercise-induced right ventricular dysfunction and structural remodelling in endurance athletes. Eur Heart J 2012;33(8):998–1006.
[12] Gibbons RJ, Balady GJ, Bricker JT, et al. ACC/AHA 2002 guideline update for exercise testing: summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). J Am Coll Cardiol 2002;40(8):1531–40.
[13] Gibbons RJ, Balady GJ, Beasley JW, et al. ACC/AHA guidelines for exercise testing. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). J Am Coll Cardiol 1997;30(1):260–311.
[14] Bruce RA, Cooper MN, Gey GO, Fisher LD, Peterson DR. Variations in responses to maximal exercise in health and in cardiovascular disease. Angiology 1973;24(11):691–702.
[15] Mansukhani MP, Allison TG, Lopez-Jimenez F, Somers VK, Caples SM. Functional aerobic capacity in patients with sleep-disordered breathing. Am J Cardiol 2013;111(11):1650–4.
[16] Nikolaidou T, Ghosh JM, Clark AL. Outcomes related to first-degree atrioventricular block and therapeutic implications in patients with heart failure. JACC Clin Electrophysiol 2016;2(2):181–92.
[17] Park MY, Shin WS, Shim BJ, et al. Exercise-induced intranodal atrioventricular block. Korean Circ J 2012;42(10):698–701.
[18] Epstein AE, JP DiMarco, Ellenbogen KA, et al. 2012 ACCF/AHA/HRS focused update incorporated into the ACCF/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. Circulation 2013;127(3):e283–352.