Iranian Heart Journal; 2025; 26 (3)

Original Article

Atrial High-Rate Episodes and Their Association With Interatrial Block in Dual-Chamber Pacemaker Recipients

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ABSTRACT

Background: In the era of cardiac pacing, atrial lead placement has enabled continuous monitoring of atrial electrical activity, including atrial high-rate episodes (AHRE). Once considered an incidental finding, AHRE has now emerged as a significant risk factor for thromboembolic events.

Methods: This study involved 250 patients who visited the pacemaker interrogation clinic for routine follow-up after dual-chamber pacemaker implantation. ECG analysis assessed P-wave morphology and duration as predictors of interatrial block (IAB). Further, atrial lead interrogation was performed to detect AHRE.

Results: Among the 250 patients studied, 65 exhibited IAB: 54 had partial IAB, while 11 presented with complete IAB. The mean P-wave duration was 104.04 ± 15.92 milliseconds (range: 80–140 ms). P-wave morphology in lead II was upright in 239 patients (95.6%) and bimodal in 11 patients. Per ESC guidelines, AHRE was defined as lasting > 5 minutes. Forty-five patients developed AHRE, with a median duration of 7 minutes (range: 5–30 min) and a mean rate of 187.53 ± 23.59 beats per minute (range:110–231 bpm). A strong association was observed between P-wave duration and AHRE incidence. Of the 45 patients with AHRE, 33 (73.3%) had partial IAB, 6 (13.3%) had complete IAB, and 6 (13.3%) displayed normal P-wave morphology and duration.

Conclusions: The detection of AHRE via dual-chamber pacemakers showed a significant association with IAB. Both IAB and AHRE were strongly linked to older age and comorbidities, including diabetes, hypertension, and ischemic heart disease. ***(Iranian Heart Journal 2025; 26(3): 69-78)***

KEYWORDS: Thromboembolism, Arrythmia, Atrial fibrillation

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Received: February 4, 2025 **Accepted:** May 20, 2025

Remarkable progress in cardiac implantable electronic devices (CIEDs) has transformed cardiac care in recent decades, extending beyond basic pacing to comprehensive arrhythmia management. These devices now provide continuous, real-time rhythm monitoring, playing a crucial role in detecting subclinical

arrhythmias, particularly atrial fibrillation (AF) and atrial high-rate episodes (AHRE). [1] AHRE is universally characterized by atrial rates exceeding 175 beats per minute for 5 to 6 minutes in patients without documented clinical AF. This duration threshold was established to reduce false-positive detection from artifacts or lead-related noise. [2]

The clinical impact of AHRE is substantial, given both its high prevalence and its association with increased AF risk and subsequent thromboembolic events. While the thrombotic risk of AHRE remains lower than that of overt AF, its detection during device interrogation warrants clinical attention. [2-4]

The concept of interatrial block (IAB) was first introduced in the early 1970s and was originally classified into partial and advanced forms. Partial IAB occurs when electrical conduction between the right and left atria is delayed but still follows the normal path through the interatrial septum. In contrast, advanced (or complete) IAB is characterized by complete failure of the right atrial impulse to propagate through the interatrial septum, resulting in caudocranial activation of the left atrium. Both forms of IAB can be detected on surface ECG through characteristic changes in P-wave morphology and duration. [5,6]

Research has demonstrated that advanced IAB correlates with various supraventricular arrhythmias, particularly AF. Whereas partial IAB exerts minimal hemodynamic consequences, the advanced form, characterized by P-wave durations exceeding 150 milliseconds, shows significant clinical implications. This advanced form is associated with pronounced hemodynamic alterations, increased risk of AF, elevated thromboembolic potential, and higher mortality rates. [7-10]

This study investigated the association between AHRE and IAB in patients with dual-chamber pacemakers or other implantable cardiac devices.

PATIENTS

This cross-sectional observational study was conducted from July 2023 through February 2024 at the permanent pacemaker interrogation outpatient clinic of Ain Shams University Hospitals. The study included 250 patients with implanted dual-chamber cardiac devices, all of whom were enrolled at least 6 months post-implantation. Device implantation followed the most recent European Society of Cardiology pacing guidelines. [11]

Inclusion Criteria

Eligible participants included patients who (1) received dual-chamber pacemaker implantation for atrioventricular (AV) block management, (2) had devices capable of atrial arrhythmia detection and recording, and (3) provided informed consent.

Exclusion criteria

Patients were excluded if they (1) declined participation, (2) had pre-existing clinical AF, (3) presented with other clinical supraventricular arrhythmias, (4) exhibited post-implantation lead-related sensing/pacing abnormalities, or (5) were taking antiarrhythmic medications.

METHODS

The study utilized quota sampling, enrolling all eligible patients meeting the inclusion criteria until reaching the target sample size. Participants underwent a comprehensive evaluation, including (1) detailed clinical history collection encompassing demographic data, risk factors, and comorbidities; (2) device programming to detect and characterize AHRE, including their frequency, rate, and duration. AHRE was defined according to current standards

as asymptomatic atrial tachyarrhythmias detected by implantable devices with atrial sensing capabilities, which provide continuous monitoring and ECG recordings. The European Society of Cardiology 2020 Guidelines specifically define AHREs as atrial tachyarrhythmias with rates ≥175 beats per minute lasting ≥ 5 minutes. [11] All participants received 12-lead ECGs with focused analysis of P-wave characteristics. IAB was classified as partial (P-wave duration ≥ 120 ms), intermittent (transient appearance/disappearance), or advanced (P-wave duration ≥ 120 ms with biphasic morphology in inferior leads II, III, and aVF). [7]

The study received approval from the cardiology department council and the hospital's ethics committee, and it was carried out in accordance with institutional guidelines.

Statistical Analysis: Data were collected, coded, reviewed, and entered into the Statistical Package for Social Science (IBM SPSS), version 20. Qualitative data were presented as numbers and percentages, while quantitative data with a parametric distribution were summarized using means, standard deviations, and ranges. The chi-square test was employed to compare 2 groups with qualitative data. For comparisons between 2 groups with quantitative data and a parametric distribution, the independent *t*-test was utilized. Multivariate logistic regression analysis was conducted to identify predictors of the no-reflow phenomenon among the studied patients. The confidence interval was set at 95%, and the accepted margin of error was 5%. Thus, the *P*-value was considered significant as follows: $P > 0.05$: non-significant, $P < 0.05$: significant, and $P < 0.01$: highly significant.

RESULTS

The mean age of the study population was 64.67 ± 11.35 years, ranging from 18 to 88 years. Females comprised 54.2% of the population under study. The most common risk factor was diabetes mellitus, which affected 158 patients (63.2%), followed by hypertension in 134 patients (53.6%) and ischemic heart disease in 46 patients (18.4%). Complete AV dissociation was the sole indication for pacing in this population.
During device programming of the study cohort, comprehensive lead measurements were obtained. Concerning ventricular parameters, 142 patients lacked intrinsic rhythm, while the remaining 108 demonstrated intrinsic R waves with a mean amplitude of 9.25 ± 2.55 mV (range: 4.8–18 mV). Ventricular pacing thresholds averaged 0.93 ± 0.36 mV at 0.4 millisecond pulse width (range: 0.25–2.5 mV), with mean impedance measuring 618.44 ± 115.14 Ω (range: 316–891 Ω).
Atrial measurements revealed mean P-wave amplitudes of 3.78 ± 1.23 mV (range: 0.5–5 mV). Atrial pacing thresholds averaged 0.88 ± 0.41 mV at 0.4 milliseconds (range: 0.25–2.5 mV), with a mean impedance of 380.96 ± 96.47 Ω (range: 214–850 Ω).

Incidence of IAB and its subtypes

Among the 250 study participants, 65 (26%) exhibited IAB. Partial IAB was identified in 54 patients (21.6%), while complete IAB was observed in 11 cases (4.4%). The mean P-wave duration across all patients measured 104.04 ± 15.92 ms (range: 80–140 ms). P-wave morphology analysis in lead II demonstrated upright patterns in 239 patients (95.6%) and bimodal configurations in 11 patients (4.4%).

Table 1. The ECG data of the studied population

ECG		No. = 250
P-wave duration, ms	Mean ± SD	104.04 ± 15.92 ms

	Range	80 – 140 ms
Interatrial block	Normal	185 (74.0%)
	Interatrial block	65 (26.0%)
Interatrial block degree	Normal	185 (74.0%)
	Partial interatrial block	54 (21.6%)
	Complete interatrial block	11 (4.4%)
P-wave morphology	Upright	239 (95.6%)
	Bimodal	11 (4.4%)

Further analysis of the group with IAB (65 patients) revealed that 54 of these individuals had partial IAB, with a mean age of 69.80 ± 12.27 years. The prevalence of partial IAB was higher among males, as well as in diabetic and hypertensive individuals. Complete IAB was observed in 11 patients, also with a mean age of 69.80 ± 12.27 years. This subgroup exhibited a higher percentage of female patients and a greater incidence of diabetes mellitus and hypertension. Notably, all subjects in this group had documented coronary artery disease.

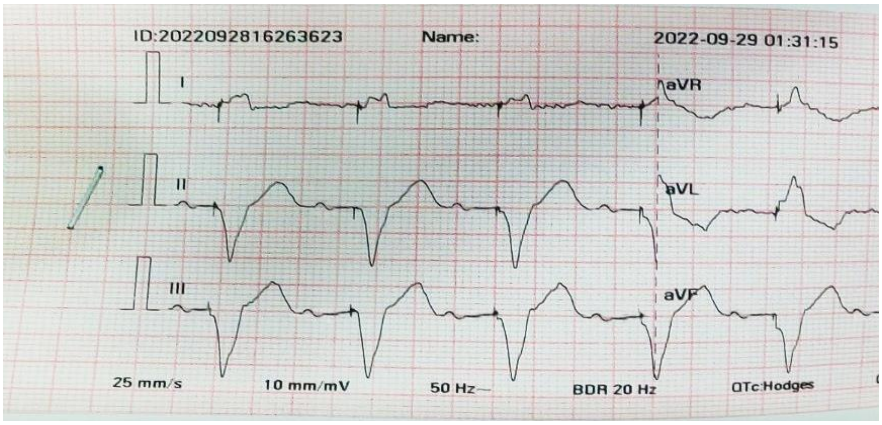

Figure 1. The ECG shows complete interatrial block.

Table 2. The demographic data of the studied patients with interatrial block

		Interatrial Block Degree			Test value	*P*-value	Sig.
		Normal	Partial Interatrial Block	Complete Interatrial Block			
		No. = 185	No. = 54	No. = 11			
Age, y	Mean ± SD	62.94 ± 10.38	69.80 ± 12.27	68.73 ± 14.44	8.908•	0.000	HS
	Range	24 – 87	18 – 88	30 – 81			
Sex	Female	102 (55.1%)	21 (38.9%)	8 (72.7%)	6.329*	0.042	S
	Male	83 (44.9%)	33 (61.1%)	3 (27.3%)			
Diabetes mellitus	No	79 (42.7%)	10 (18.5%)	3 (27.3%)	10.961*	0.004	HS
	Yes	106 (57.3%)	44 (81.5%)	8 (72.7%)			
Hypertension	No	99 (53.5%)	14 (25.9%)	3 (27.3%)	14.484	*0.010	S
	Yes	86 (46.5%)	40 (74.1%)	8 (72.7%)			
Ischemic heart disease	No	159 (85.9%)	34 (63.0%)	0 (0.0%)	17.300	*0.000	HS
	Yes	26 (14.1%)	20 (37.0%)	11 (100.0%)			
	Complete heart block	185 (100.0%)	54 (100.0%)	11 (100.0%)			

P-value > 0.05: nonsignificant (NS); *P*-value < 0.05: significant (S); *P*-value < 0.01: highly significant (HS)
*The chi-square test
• One-way ANOVA

Table 3. Ventricular lead measurements in patients with partial and complete interatrial block

Ventricular Lead		Interatrial Block Degree			Test value•	*P*-value	Sig.
		Normal	Partial Interatrial Block	Complete Interatrial Block			
		No. = 185	No. = 54	No. = 11			
R wave	Mean ± SD	9.09 ± 2.57 mv	10.08 ± 2.42 mv	11.50 ± 0.71 mv	1.609	0.205	NS
	Range	4.8 – 18 mv	5.8 – 12 mv	11 – 12 mv			
Pacing threshold	Mean ± SD	0.94 ± 0.38 MV at 0.4 ms	0.90 ± 0.28 MV at 0.4 ms	0.86 ± 0.36 MV at 0.4 ms	0.565	0.569	NS
	Range	0.25 – 2.5 MV at 0.4 ms	0.5 – 1.8 MV at 0.4 ms	0.5 – 1.5 MV at 0.4 ms			
Impedance	Mean ± SD	624.72 ± 114.37Ω	611.85 ± 111.70Ω	545.00 ± 128.00Ω	2.636	0.074	NS
	Range	316 – 891Ω	330 – 852Ω	410 – 740Ω			

P-value > 0.05: nonsignificant (NS); *P*-value < 0.05: significant (S); *P*-value < 0.01: highly significant (HS)

Table 4. Atrial lead measurements in patients with partial and complete interatrial block

Atrial Lead		Interatrial Block Degree			Test value•	*P*-value	Sig.
		Normal	Partial Interatrial Block	Complete Interatrial Block			
		No. = 185	No. = 54	No. = 11			
P wave	Mean ± SD	3.72 ± 1.22 MV	3.91 ± 1.29 MV	4.25 ± 0.93 MV	1.277	0.281	NS
	Range	0.5 – 5 MV	0.8 – 5 MV	2.8 – 5 MV			
Pacing threshold	Mean ± SD	0.90 ± 0.39 MV at 0.4 ms	0.90 ± 0.49 MV at 0.4 ms	0.65 ± 0.20 MV at 0.4 ms	1.962	0.143	NS
	Range	0.25 – 2.5 MV at 0.4 ms	0.5 – 2.5 MV at 0.4 ms	0.5 – 1 MV at 0.4 ms			
Impedance	Mean ± SD	372.85 ± 92.50 Ω	398.76 ± 108.53 Ω	430.00 ± 79.17 Ω	3.043	0.049	S
	Range	214 – 799 Ω	234 – 850 Ω	310 – 550 Ω			

P-value > 0.05: nonsignificant (NS); *P*-value < 0.05: significant (S); *P*-value < 0.01: highly significant (HS)

AHRE

According to the ESC guidelines, the duration of AHRE should exceed 5 minutes. Forty-five patients developed AHRE, with a median duration of 7 minutes, ranging from 5 to 30 minutes, and a mean rate of 187.53 ± 23.59 beats per minute. The demographic data of the studied group that developed AHRE indicated an older age group, with a mean age of 71.18 ± 11.59 years and a range of 18 to 88 years. The prevalence of AHRE was higher in males, with 35 patients classified as diabetic (77.8%), 37 as hypertensive (82.2%), and 15 suffering from ischemic heart disease (33.3%).

Table 5. Atrial high-rate episode data of the studied patients

Atrial high-rate episodes		No. = 250
Type	No	172 (68.8%)
	Atrial tachycardia	70 (28.0%)
	AF	8 (3.2%)
Atrial high-rate episodes	No	33 (42.3%)
	Yes	45 (57.7%)
Duration, min	Median (IQR)	7 (6 – 9) min
	Range	5 – 30 min
Frequency per month	Median (IQR)	6 (3 - 10)
	Range	1 – 25

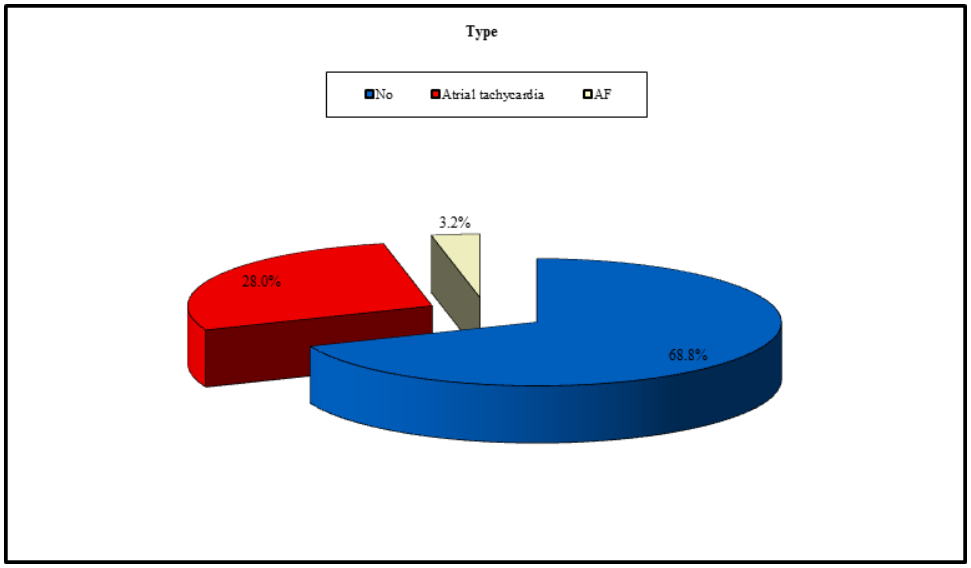

Figure 2. The image illustrates the forms of atrial high-rate episodes.

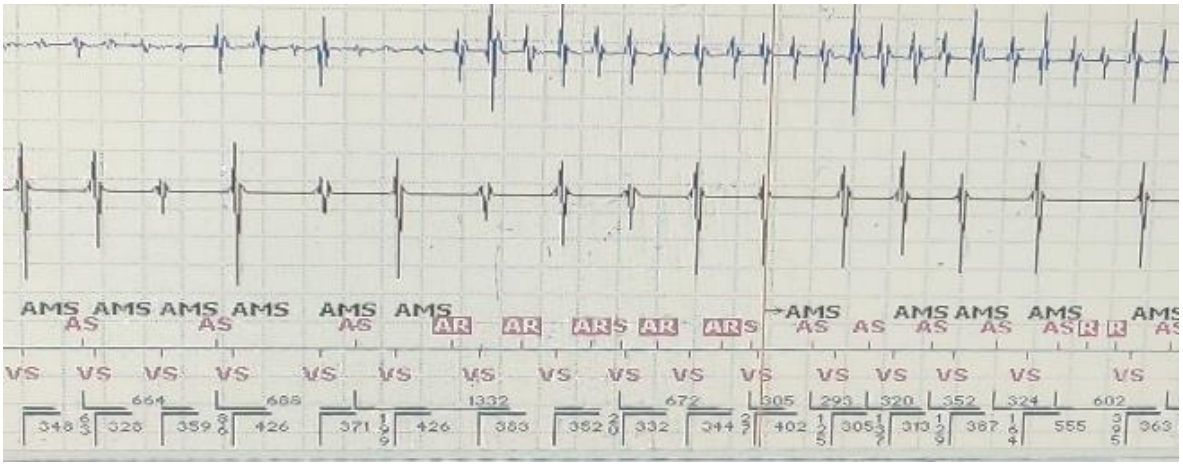

Figure 3. The image showcases atrial high-rate episodes during pacemaker interrogation.

Table 6. Demographic characteristics among the patients with atrial high-rate episodes

		Atrial High-Rate Episodes		Test value	*P*-value	Sig.
		No	Yes			
		No. = 205	No. = 45			
Age, y	Mean ± SD	63.24 ± 10.81	71.18 ± 11.59	-4.401•	0.000	HS
	Range	24 – 87	18 – 88			
Sex	Female	113 (55.1%)	18 (40.0%)	3.383*	0.066	NS
	Male	92 (44.9%)	27 (60.0%)			
Diabetes mellitus	No	82 (40.0%)	10 (22.2%)	5.014*	0.025	S
	Yes	123 (60.0%)	35 (77.8%)			
Hypertension	No	108 (52.7%)	8 (17.8%)	18.077*	0.000	HS
	Yes	97 (47.3%)	37 (82.2%)			
Ischemic heart disease	No	174 (84.9%)	30 (66.7%)	8.151*	0.004	HS
	Yes	31 (15.1%)	15 (33.3%)			
	Yes	205 (100.0%)	45 (100.0%)			

P-value > 0.05: nonsignificant (NS); *P*-value < 0.05: significant (S); *P*-value < 0.01: highly significant (HS)

A strong relationship existed between the P-wave duration and the incidence of AHRE. Among the 45 patients who developed AHRE, 33 had partial IAB (73.3%), 6 had complete IAB (13.3%), and 6 patients exhibited normal P wave morphology and duration (13.3%).

Table 7. ECG findings in patients with and without atrial high-rate episodes

ECG		Atrial High-Rate Episodes		Test value	*P*-value	Sig.
		No	Yes			
		No. = 205	No. = 45			
P-wave Duration, ms	Mean ± SD	99.29 ± 12.42 ms	125.67 ± 11.66 ms	-13.037•	0.000	HS
	Range	80 – 140 ms	90 – 140 ms			
Interatrial block	Normal	179 (87.3%)	6 (13.3%)	104.977*	0.000	HS
	Interatrial block	26 (12.7%)	39 (86.7%)			
Interatrial block degree	Normal	179 (87.3%)	6 (13.3%)	105.244*	0.000	HS
	Partial interatrial block	21 (10.2%)	33 (73.3%)			
	Complete interatrial block	5 (2.4%)	6 (13.3%)			
- wave Morphology	Upright	200 (97.6%)	39 (86.7%)	10.412*	0.001	HS
	Bimodal	5 (2.4%)	6 (13.3%)			

P-value > 0.05: nonsignificant (NS); *P*-value < 0.05: significant (S); *P*-value < 0.01: highly significant (HS)
*The chi-square test
• The independent *t*-test

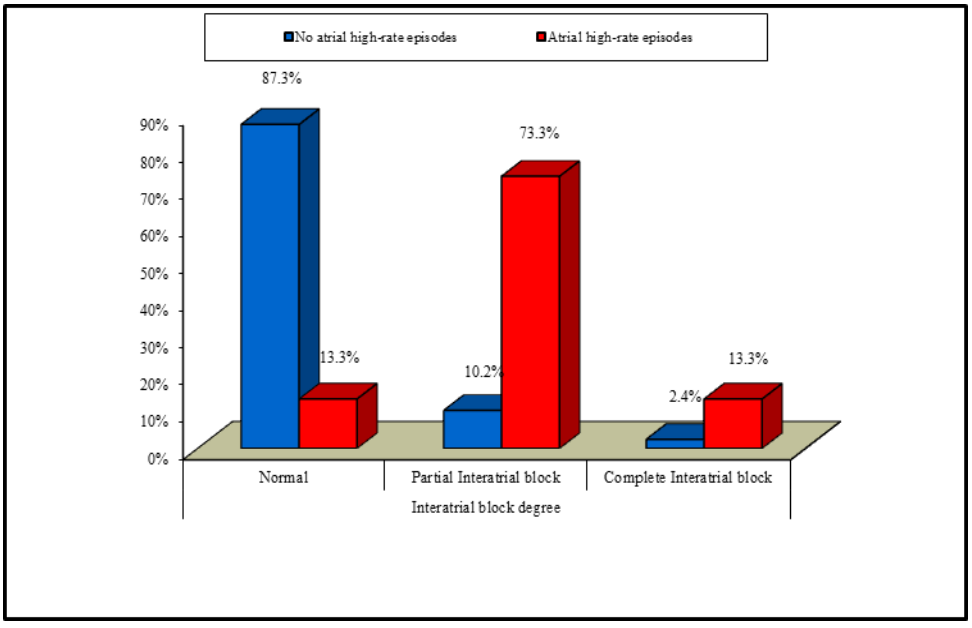

Figure 4. The image illustrates the degree of interatrial block in patients with and without recorded atrial high-rate episodes.

DISCUSSION

AHRE has garnered significant attention due to its established association with atrial arrhythmias, particularly AF, and the consequent elevated risk of thromboembolic and cerebrovascular events. Numerous studies have investigated the relationship between IAB and AHRE development. The characteristic ECG alterations observed in IAB correlate with disrupted atrial mechanics and abnormal interatrial

conduction, predisposing patients to various atrial tachyarrhythmias. [12, 13]

The integration of atrial leads in permanent pacemakers has revolutionized continuous AHRE monitoring during routine device interrogations. This advancement has led to increased detection of AF episodes and, consequently, more frequent implementation of thromboembolic prevention strategies. [14]

In our study, among the 250 patients examined, 54 had partial IAB (21.6%), while 11 patients had complete IAB (4.4%). This finding is consistent with the research conducted by Tekkesin et al., [15] who assessed 367 patients who received dual-chamber pacemakers for sinoatrial nodal disease. Pre-implantation ECGs were analyzed to detect IAB, and routine interrogation was performed 6 months after implantation. Patients were categorized into 2 groups based on the presence or absence of AHRE. IAB was identified in 115 patients (32.4%) of the total study population, with 29% having partial IAB and 3% having advanced IAB.

In a study by Ariyarajah et al. [5] involving 404 patients, 182 exhibited IAB (45%; mean age 64.32 ± 19.27 y; males 51.6%), while 222 served as controls. The analysis revealed significant associations between IAB and several cardiovascular risk factors: coronary artery disease (OR, 3.150, 95% CI, 2.05 to 4.83, r = 0.3; P < 0.001), hypertension (OR, 2.918, 95% CI, 1.85 to 4.60, r = 0.2; P < 0.001), diabetes mellitus (OR, 2.542, 95% CI, 1.62 to 3.97, r = 0.1; P< 0.001), and hypercholesterolemia (OR, 1.823, 95% CI, 1.22 to 2.74, r = 0.2; P = 0.004). These findings support our study results, which identified 65 patients with IAB. Among these, 54 had partial IAB (mean age 69.80 ± 12.27 y), showing male predominance (61.1%) with frequent comorbidities: diabetes mellitus (81.5%), hypertension (74.1%), and ischemic heart disease (37%, n=20). The 11 complete IAB cases (mean age 69.80 ± 12.27 y) demonstrated female predominance (72.2%) with similar comorbidities: diabetes mellitus (72.7%), hypertension (72.7%), and universal ischemic heart disease prevalence (100%). [5]

Our analysis focused specifically on hypertension, diabetes mellitus, and ischemic heart disease, all showing statistically significant associations with IAB presence. [5]

Forty-five patients developed AHRE, with a median duration of 7 minutes (range: 5–30 min) and a mean heart rate of 187.53 ± 23.59 beats per minute (range: 110–231 bpm). In our cohort, these patients with AHRE (mean age: 71.18 ± 11.59 y; range: 18–88 y) showed a male predominance (60%) and a high prevalence of comorbidities: diabetes mellitus (77.8%), hypertension (82.2%), and ischemic heart disease (33.3%).

These risk factors demonstrated strong associations with both AHRE and IAB, chiming with findings from a study by Rubio Campal et al. [16] involving 380 patients. Their investigation defined AHRE as atrial rates ≥ 225 beats per minute lasting ≥ 5 minutes. Among their 125 patients with AHRE, 80% had hypertension, and 32% showed structural heart disease.

Our findings revealed a strong correlation between the P-wave duration and the incidence of AHRE. Among the 45 patients who developed AHRE, 33 had partial IAB (73.3%), 6 had complete IAB (13.3%), and 6 patients exhibited normal P-wave morphology and duration (13.3%). These results are concordant with the research conducted by Çinier et al., [9] who assessed 388 patients with cardiac implantable electronic devices due to sick sinus syndrome, advanced AV block, and various types of conduction diseases associated with syncope. Devices were regularly interrogated to identify AHRE during the follow-up period, and AHRE was detected in 33% of patients. The mean P-wave duration was 123 ± 23 milliseconds, significantly longer in patients with AHRE. IAB was observed in 39% of patients: 32% with partial IAB and 7% with advanced IAB.

Limitations

The present study has 2 principal limitations: (1) its single-center design with a relatively small sample size, and (2) the need for a longer follow-up duration to strengthen the clinical correlations.

CONCLUSIONS

The results of the current study showed that dual-chamber pacemaker-detected AHRE was significantly associated with IAB. Both IAB and AHRE demonstrated strong correlations with advanced age and comorbidities, particularly diabetes mellitus, hypertension, and ischemic heart disease.

Declarations

Ethical Approval and Consent to Participate

The Research Ethics Committee of the Faculty of Medicine at Ain Shams University reviewed and approved the study from an ethical standpoint. The committee is organized and operates in accordance with the guidelines of the International Council for Harmonisation (ICH) Anesthesiology, the Islamic Organization for Medical Sciences (IOMS), the United States Office for Human Research Protections, and the United States Code of Federal Regulations, functioning under Federal Wide Assurance No. FWA 000017585. The REC does not disclose the names of its members, following the university and REC standard operating procedures. Patient data were presented only after obtaining informed written consent, and the research procedures were explained to the participants, ensuring the protection of their privacy and confidentiality.

Consent to Publication

Not applicable.

Availability of Data and Materials

All data, including angiogram films and stored echocardiographic loops, are accessible to the authors and are maintained in the Cath Lab and echocardiography records at Ain Shams University.

Conflict of Interest

All authors declare that there are no conflicts of interest.

Funding

This study was not funded. The cohort examined was recruited from a pool of patients referred to the cardiology department, catheterization laboratory, and echocardiography unit at Ain Shams University.

Authors' Contributions

All authors have read and approved the final manuscript. Individual contributions are as follows:

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Acknowledgments
Not applicable

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