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Original Research Article

Clinical and echocardiographic features of patients with single-chamber and dual-chamber pacemakers

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ABSTRACT

Background: The abnormalities in cardiac action potential generation and propagation may emerge at various levels in the electrical conduction system of heart, initiating from the sinoatrial node to the purkinje fibers which depolarize the ventricles. Thus, decline in this internal cardiac automaticity or propagation integrity, requires prompt use of pacemaker to initiate the cardiomyocytes to the baseline through excitation-contraction coupling. The aim of this study is to identify clinical and echocardiographic features of patients with single-chamber and dual-chamber pacemakers.
Methods: This retrospective study consist of 85 patients admitted to the Grodno Regional Clinical Cardiological Center (Belarus) for pacemaker implantation over a period of 2 years, from January 2024 to December 2025. The patients were divided into 2 groups according to the type of pacemaker implanted. Group 1 included 42 patients with single-chamber pacemakers, while Group 2 included 43 patients with dual-chamber pacemakers.
Results: This study consisted of 85 patients divided into single-chamber (SR, n=42) and dual-chamber (DR, n=43) pacemaker groups. The SR group was older (median 77 vs. 71.8 years, p=0.01). Sick sinus syndrome and second-degree AV block were more frequent in DR (60.4% and 27.9%, p<0.01), while third-degree AV block and persistent atrial fibrillation was prevalent in SR (57.1% and 80.9%, p<0.001). ESR and AST were lower, and RBC counts borderline higher in DR (p≤0.05). SR showed larger atrial diameters and more pleural effusion (p<0.01); ventricular function was similar.
Conclusions: This study explored the significant differences among patients with single-chamber and dual-chamber pacemakers in clinical, rhythm, laboratory, and echocardiographic parameters.

Keywords: Pacemaker, Single-chamber, Dual-chamber, Echocardiographic features, Clinical features

INTRODUCTION

The abnormalities in cardiac action potential and propagation may emerge at several levels in electrical conduction system of heart, arising out of sinoatrial node to the purkinje fibers which excites ventricles. When this cardiac automatism or propagation integrity declines, an external input is essential to prompt cardiomyocytes to the baseline through the excitation-contraction coupling, and the pacemakers facilitate this external input. Therefore, the pacemaker implantation is crucial for a beneficial therapy, mainly for patients with sick-sinus syndrome and atrio-ventricular abnormalities.[1,2] The pacemaker is a cardiac device, which utilizes low-energy electrical impulses to control the heart rate and rhythm. Currently, the following types of pacemaker implants such as single-chamber (SC), double-chamber (DC), biventricular, leadless are available. Single-chamber pacemakers detect and pace in atrium or ventricle, particularly in chamber. While dual-chamber pacemakers' coordinate pacing in both the atrium and ventricles. Therefore, examining the clinical and echocardiographic features of patients with these implants

are vital for patient management and long-term outcomes. The echocardiographic features provide an insightful observation into hemodynamic impact of pacing and potential complications following it. Therefore, in this study we will explore the clinical and echocardiographic features of patients with single-chamber and dual-chamber pacemakers. The surgical indications of single-chamber pacemaker include symptomatic bradycardias, 3rd degree AV block, sinus node syndrome and chronic atrial fibrillation with bradycardia and surgical indications of dual-chamber pacemaker includes restoring physiological AV synchrony in symptomatic sinus node dysfunction patients and 3rd degree AV block.[3,4]

Furthermore, current literature shows gaps in knowledge regarding SC and DC pacemakers mainly on long-term outcomes in association to patients' mortality and reduced hospitalization, despite the superior physiological pacing of DC pacemakers.[5] The potential differences for clinical implication of SR and DR are patient's hemodynamical stability, incidence of atrial fibrillation, risk of heart failure and stroke. The DC pacing patients were significantly more hemodynamically stable than SC patients, since DC pacing prevents pacemaker syndrome, a disorder of hypotension, syncope and fatigue resulting from AV synchrony in SC pacing by managing atrial and ventricular contractions.

In addition, DC pacing was clinically effective in reducing the incidence of atrial fibrillation than ventricular SC pacing. Evidence suggested that DC pacing was significantly better in long-term outcomes with declined risk of developing stroke and heart failure.[6] Thus, the primary aim of this study is to examine the clinical and echocardiographic features of patients with single-chamber and dual-chamber pacemakers to enhance the understanding of long-term outcomes of SC and DC pacemakers and improve patient mortality.

METHODS

This single-center retrospective study consisted of 85 patients checked into the Grodno Regional Clinical Cardiological Center (Belarus) for pacemaker implantation over a period of 2 years, from January 2024 to December 2025. The most common indications for dual-chamber pacemaker implantation were sinus node dysfunction and high-grade AV block; for single-chamber pacemaker implantation, brady-systolic form of permanent AF was indicated. Indications were formulated according to the Guidelines for implantation of cardiac pacemakers of the American College of Cardiology, the American Heart Association, and the Heart Rhythm Society.

The patients were divided into 2 groups according to the type of pacemaker implanted. Group 1 included 42 patients with single-chamber pacemakers, while Group 2 included 43 patients with dual-chamber pacemakers. Exclusion criteria from the study were: acute coronary syndrome, myocarditis, pericarditis, pulmonary embolism, valvular pathology of the heart requiring surgical correction, prosthetic heart valves, oncological diseases and severe concomitant extracardiac pathology. All patients underwent clinical, laboratory, and instrumental studies, including transthoracic echocardiography. The echocardiography was conducted on Phillips iE33 device with a multi-frequency sensor (frequency 2.5-5.0 MHz). The examination was conducted with the patient in the Sim's position to the researcher or on the supine position. The study protocol consisted of the following indicators: LA and right atrium (RA) diameter in 2-chamber and 4-chamber mode, end-systolic diameter and end-diastolic diameter (mm) of the left ventricle (LV), LVEF; assessment of the state of the valvular apparatus of the heart, degree of regurgitation on the valves.

The statistical analysis was performed using the STATISTICA 12.0 software package with a preliminary check for normal distribution using a distribution histogram. Quantitative data, the distribution of which was not normal, were given as a median, 25% and 75% quartiles. Since most of the quantitative characteristics did not align with the normal distribution law, non-parametric methods were applied for comparison. The Mann-Whitney test was utilized to assess differences in quantitative traits among two independent groups. At a significance level of P less than 0.05, it was considered that the studied indicator in the compared groups had statistically significant differences. The study was performed according to Good Clinical Practice standards and the principles of the Declaration of Helsinki. The informed consent was collected from all participants prior to inclusion in the study.

RESULTS

Patient demographics and clinical characteristics

This study consisted of 85 patients categorized into 42 patients in the single-chamber pacemaker group (SR Group) and 43 patients in the dual-chamber pacemaker group (DR Group). Female gender representation was similar between groups (42.8% in SR vs. 39.5% in DR, P=0.82). Patients in SR Group were significantly older, with a median age of 77 years (72; 84) compared to 71.8 years (65.6; 79.5) in DR Group (p=0.01). Body mass index (BMI) and prevalence of overweight and obesity lacked the statistical difference among both groups.

The prevalence of hypertension was high and comparable in both groups (~90%). Stable angina was more common in DR Group (30.2%) than SR Group (16.6%), although not statistically significant (p=0.20). Prior myocardial infarction was more frequent in SC Group (23.8%) compared to DR Group (9.3%), approaching statistical significance (p=0.08). Diabetes mellitus and heart failure severity (NYHA class) were similar between groups (Table 1).

Table 1: Clinical characteristics of patients.

Parameter	Group SR (n=42)	Group DR (n=43)	P
Female gender, N (%)	18 (42.8%)	17 (39.5%)	0.82
Age, years	77 (72; 84)	71.8 (65.6; 79.5)	0.01
Body mass index, kg/m²	30 (28; 32.9)	31 (28.1; 32.5)	0.53
Overweight, N (%)			
Obesity, N (%)	14 (33.3%)	17 (39.5%)	0.65
Hypertension, N (%)	38 (90.4%)	39 (90.6%)	1
Stable angina, N (%)	7 (16.6%)	13 (30.2%)	0.20
Previous MI, N (%)	10 (23.8%)	4 (9.3%)	0.08
Diabetes mellitus, N (%)	6 (14.2%)	6 (13.9%)	1
Heart failure NYHA class	2.4 (2; 3)	2.1 (2; 3)	0.23

Note: MI – myocardial infarction; NYHA – New York Heart Association.

Rhythm and conduction disturbances

There were significant differences observed in rhythm and conduction disturbances among both groups (Table 2). Sick sinus syndrome was present primarily in DR Group (60.4%, p<0.001), while absent in SR Group. Second-degree AV block was more frequent in DR Group (27.9%) than in Group SR (4.7%, p=0.006). Conversely, third-degree AV block was significantly more common in SR Group (57.1%) compared to DR Group (20.9%, p<0.001). Paroxysmal atrial fibrillation (AF) occurred more often in Group DR (39.5%) than Group SR (11.9%, p=0.0057), whereas persistent AF was more prevalent in SR Group (80.9%) versus DR Group (9.3%, p<0.001). The incidence of atrial flutter, left bundle branch block (LBBB), right bundle branch block (RBBB), and left anterior hemiblock were comparable between groups. Minimal heart rate, maximal pause duration, and incidence of presyncope and syncope did not statistically significant.

Laboratory findings

The laboratory parameters revealed few significant differences (Table 3). RBC counts were marginally elevated in DR Group (4.6 (4.4; 5) ×10^12/L) compared to SR Group (4.4 (3.9;5)×10^12/L), reaching borderline significance (p=0.05). Erythrocyte sedimentation rate (ESR) was significantly lower in DR Group (10.5 (5;14.2) mm/h) than in SR Group (14.9 (7.2; 19.7) mm/h, p=0.04). Aspartate aminotransferase (AST) levels were also lower in DR Group (19.3 (15; 23.4) IU/L) compared to SR Group (25.4 (20;27.7) IU/L, p=0.04). Other laboratory parameters, including hemoglobin, white blood cell count, platelets, urea, creatinine, estimated glomerular filtration rate (eGFR), total cholesterol, glucose, alanine aminotransferase (ALT), sodium, potassium, and NT-proBNP levels, lacked statistically meaningful difference among both groups.

Table 2: Characteristics of rhythm and conduction disturbances in the studied groups of patients.

Parameter	Group SR (n=42)	Group DR (n=43)	P
Sick sinus syndrome, N (%)	0 (0%)	26 (60.4%)	<0.001
Av-block 2-degree, N (%)	2 (4.7%)	12 (27.9%)	0.006
Av-block 3-degree, N (%)	24 (57.1%)	9 (20.9%)	<0.001
Paroxysmal AF, N (%)	5 (11.9%)	17 (39.5%)	0.0057
Persistent AF, N (%)	34 (80.9%)	4 (9.3%)	<0.001
Atrial flutter, N (%)	7 (16.6%)	8 (18.6%)	1
LBBB, N (%)	3 (7.1%)	5 (11.6%)	0.71
RBBB, N (%)	6 (14.2%)	8 (18.6%)	0.77
Left anterior hemiblock, N (%)	4 (9.5%)	4 (9.3%)	1
Minimal heart rate, B.P.M.	30.7 (27;35)	32.8 (27.7;39)	0.38
Maximal pause duration, sec	4128.9 (2668;4337.2)	3945.4 (2495.5;4910)	0.77
Presyncope, N (%)	21 (50%)	26 (60.4%)	0.38
Syncope, N (%)	20 (47.6%)	16 (37.2%)	0.38

Note: AV – atrioventricular; AF – atrial fibrillation; LBBB – left bundle branch block; RBBB – right bundle branch block.

Echocardiographic parameters

Significant differences were noticed in the atrial dimensions (Table 4). LA diameter measured medial to lateral was greater in Group SR (48.1 mm (43;50) compared to Group DR (40.8 mm (38;43.2), p<0.001). Similarly, the LA diameter (front to back) was larger in Group SR (64.2 mm (58;68.5) than Group DR (56.7 mm (54;60),p=0.001). RA diameters, both medial to lateral and front to back, were significantly higher in Group SR (44.1 mm (40;46) and 61 mm (54.5;67.5), respectively) compared to Group DR (38.3 mm (35.7;40), p<0.001 and

52.6 mm (48;56), p<0.001, respectively). LV dimensions and volumes (end-systolic diameter, end-diastolic diameter, end-systolic volume, end-diastolic volume) were numerically elevated in Group SR but was statistically insignificant. Left ventricular ejection fraction (LVEF) tended to be higher in Group DR (59.6% (56.7;63)) than Group SR (55.4% [51.5; 61.5], p=0.09).

Ventricular wall thickness, right ventricular diameter, and contractility index were similar between both groups. Pleural effusion was significantly more prevalent in Group SR (30.9%) in comparison to Group DR (4.6%, p=0.0016), while pericardial effusion rates showed no significant difference.

Table 4: Echocardiographic parameters of patients (ME (25%;75%)).

Parameter	Group SR (n=42)	Group DR (n=43)	P
LA diameter (medial to lateral), mm	48.1 (43;50)	40.8 (38;43.2)	<0.001
LA diameter (front to back), mm	64.2 (58;68.5)	56.7 (54;60)	0.001036
RA diameter (medial to lateral), mm	44.1 (40;46)	38.3 (35.7;40)	<0.001
RA diameter (front to back), mm	61 (54.5;67.5)	52.6 (48;56)	<0.001
LV ESD, mm	39.1 (31.5;44.5)	34 (31;36.2)	0.07
LV EDD, mm	53.3 (47.5;57.5)	50.3 (47;54)	0.23
LV ESV, ml	66.8 (40;78.5)	48.1 (37;56)	0.08
LV EDV, ml	142.8 (102.5;165)	118.8 (101.7;138.5)	0.14
LVEF, %	55.4 (51.5;61.5)	59.6 (56.7;63)	0.09
Septal thickness (systolic), mm	17.4 (15;19.5)	16.7 (16;18)	0.31
Septal thickness (diastolic), mm	13.5 (11;15)	12.8 (11.7;14)	0.25
Posterior wall thickness (systolic), mm	16.1 (15;17.5)	16.1 (15;17)	0.82
Posterior wall thickness (diastolic), mm	11.8 (11;13)	11.5 (10;13)	0.44
Right ventricle diameter, mm	27.7 (24.5;30)	26.1 (25.9;29)	0.14
Contractility index	1.1 (1;1.2)	1 (1;1)	0.35
Pleural effusion, n (%)	13 (30.9%)	2 (4.6%)	0.0016
Pericardial effusion, n (%)	6 (14.2%)	3 (6.9%)	0.31

Note: LA – left atrium; RA – right atrium; LV – left ventricle; ESD – end-systolic diameter; EDD – end-diastolic diameter; ESV – end-systolic volume; EDV – end-diastolic volume; LVEF – left ventricular ejection fraction

DISCUSSION

This retrospective study explored the clinical, rhythm, laboratory, and echocardiographic characteristics of patients with single-chamber (SR Group) and dual-chamber (DR Group) pacemakers, showing significant differences that align with and expand upon existing global findings. According to the global context, older age was noticed in the SR group reflecting the trends observed in several international cohorts, where advanced age often associates with more severe conduction system disease requiring ventricular pacing.[7] The higher prevalence of prior myocardial infarction in this group is compatible with studies connecting ischemic heart disease to advanced AV block needing single-chamber pacing.[8] The marked rhythm disturbances between groups follow more established clinical indications globally. The sole presence of sick sinus syndrome in the dual-chamber group corresponds to guidelines recommending atrial-based pacing to maintain AV synchrony in sinoatrial node dysfunction.[9]

On the contrary, the predominance of third-degree AV block in the single-chamber group supports the use of ventricular pacing in complete heart block, a finding validated by large registries.[10] The differential prevalence of paroxysmal versus persistent AF among both groups reflects atrial remodeling patterns depicted in past echocardiographic and electrophysiological studies.[11]

Furthermore, the laboratory findings of lower reinforce the significance of personalized pacemaker selection based on underlying conduction disorders and atrial pathology. Dual-chamber pacemakers appear to be more superior for patients with sick sinus syndrome and paroxysmal AF, potentially maintaining the AV synchrony and thereby reducing atrial remodeling. Single-chamber devices remain relevant for advanced AV block with persistent AF and noticeable atrial enlargement. Comprehensive echocardiographic evaluation is vital for risk stratification and management, especially given the correlation of pleural effusion with adverse outcomes.

Study limitations

The functional limitation of this study is the limited sample size, from a single hospital. Additionally, other important factors that may play a role in these findings, including genetic polymorphisms and treatment characteristics, were not assessed. Nonetheless, our results must be interpreted with caution and larger studies with higher patient numbers should be carried out to confirm our findings.

Future recommendations

Prospective, multicenter studies with large-scale cohorts are crucial to validate these findings and assess the impact of pacemaker type on long-term outcomes, including the heart failure progression and the potential of arrhythmia.

Investigations into device programming optimization and inflammatory marker regulation could further supplement for personalized pacing strategies.

CONCLUSION

This study explored the significant differences among patients with single-chamber and dual-chamber pacemakers in clinical, rhythm, laboratory, and echocardiographic parameters. Single-chamber patients were older, and presented with more persistent atrial fibrillation, advanced AV block, larger atrial sizes, and higher rates of pleural effusion.

Dual-chamber patients predominantly presented with sick sinus syndrome and paroxysmal form of atrial fibrillation, with lower inflammation markers and better atrial dimensions. These findings highlight the need for personalized pacemaker selection and comprehensive echocardiographic evaluation to improve patient management. Further research is necessary to confirm these results and assess long-term outcomes.

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