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ARTICLE

Factors Affecting the Occurrence of Arrhythmias Following Pacemaker Implantation

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Abstract

Aims/Background Pacemakers are essential devices for patients with cardiac rhythm abnormalities. However, the occurrence of arrhythmias after pacemaker implantation remains a clinical challenge. This study aimed to identify and analyze the factors that influence the occurrence of arrhythmias following pacemaker implantation to improve patient outcomes.

Methods Clinical data of patients who received pacemaker implantation treatment in the Affiliated Hospital of Chengdu University from January 2021 to December 2022 were retrospectively analyzed. A total of 137 patients were followed up for 12 months and then divided into two groups based on the occurrence of arrhythmias post-implantation: the occurrence group (n = 40) and the non-occurrence group (n = 97). General data, including gender, age, cardiac function indexes, and preoperative anxiety, were collected and compared. Binary logistic regression was used to analyze the influencing factors of arrhythmia occurrence, while Spearman correlation analysis was employed to examine the correlation between cardiac function indexes and arrhythmia occurrence.

Results Significant differences were found in age, history of hypertension, preoperative anxiety score, preoperative depression score, preoperative left ventricular end-diastolic diameter (LVEDD), and preoperative left ventricular ejection fraction (LVEF) between the two groups ($p < 0.05$). There was a positive correlation between arrhythmias occurrence and preoperative LVEDD and LVEF (r = 0.270, 0.329; $p < 0.01$). Age, history of hypertension, preoperative anxiety score, preoperative depression score, preoperative LVEDD, and preoperative LVEF were identified as risk factors for arrhythmias (odds ratio [OR]) = 2.507, 2.479, 3.012, 2.432, 3.614, 4.525; all $p < 0.05$).

Conclusion Age, history of hypertension, preoperative anxiety score, preoperative depression score, preoperative LVEF, and preoperative LVEDD are important influencing factors for arrhythmias occurrence, which are correlated with preoperative cardiac function indexes. Thus, preoperative observation utilizing these factors can provide a reference for screening high-risk groups.

Key words: pacemaker; arrhythmia; cardiac function; influencing factors

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Introduction

With the development of science and technology and the continuous advancement of medical technology, pacemakers have gradually attracted clinical attention and become widely used, especially in the treatment of patients with heart disease (Zhang et al, 2023; Wang et al, 2023). A pacemaker refers to a complete pacing system, consisting of pacing electrode leads, pacemakers, and programmers. The pacemaker and pacing electrode leads are implanted into the patient's body to deliver small electrical pulses to the heart in order to stimulate to heartbeat. It is

currently one of the most effective methods for treating patients with arrhythmias and other heart diseases (Hemelsoet et al, 2021; Todd, 2022; Waldmann et al, 2021). A growing understanding of the arrhythmia mechanisms and the advancements in pacing engineering have facilitated the rapid development of cardiac pacing therapy, which is widely and adopted due to its high efficacy (Kreimer et al, 2022; Liu and Yuan, 2021b; Su and Wu, 2021).

Nevertheless, some patients may experience adverse outcomes after pacemaker implantation treatment. Various factors can affect the treatment outcome after pacemaker implantation, leading to the occurrence of arrhythmias. Patients may experience impulses, reentrant conduction, atrial arrhythmias, and even death, which pose a serious threat to patient recovery and safety (Alhuarrat et al, 2023; Kawakami et al, 2023; Liu et al, 2021a). Actively analyzing the relevant factors influencing the occurrence of arrhythmias, screening high-risk patients for arrhythmias, and implementing effective interventions are of great value in improving patient outcomes. Previous studies have shown that the preoperative cardiac function of patients is associated with the occurrence of arrhythmias, with abnormal cardiac function heightening the risk of arrhythmias (Bhardwaj et al, 2022; Umesh Pai et al, 2022; Vinogradova and Lakatta, 2021). It is believed that many factors contribute to the occurrence of arrhythmias, such as hypertension, negative emotions, and age, but no studies have clearly indicated the correlation between preoperative cardiac indicators and the occurrence of arrhythmias following pacemaker implantation (Gjermeni et al, 2021). In light of this knowledge gap, this retrospective study analyzed the association between cardiac function-related factors and the occurrence of arrhythmias following pacemaker implantation in patients who had received pacemaker treatment, thereby providing a theoretical reference for the clinical screening of high-risk patients.

Methods

General Information

A retrospective analysis was conducted on the clinical data of 137 patients who received pacemaker implantation therapy in the Affiliated Hospital of Chengdu University from January 2021 to December 2022. These patients include those showing heart failure, sick sinus syndrome, complete atrioventricular block, etc. (Toogood, 2007). The decision to implant a pacemaker should be based on a comprehensive, multifactorial evaluation of the patient's symptoms by a professional physician. This study was approved by the Medical Ethics Committee of the Affiliated Hospital of Chengdu University (approval number: PJ2024-039-02), and was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki; informed consent was obtained from the patients.

Only patients meeting the following criteria were included in this study: (1) aged >18 years; (2) receiving their first pacemaker implantation, such as fainting, dizziness, blurred consciousness, fatigue, low exercise tolerance, drug toxicity, etc.; (3) meeting the relevant criteria outlined in the 2014 European Society of Cardiology guidelines (Özdemir and European Society of Cardiology, 2014), presenting

with symptoms such as dyspnea and arrhythmia, and being diagnosed with primary heart disease including atrial fibrillation, ventricular fibrillation, bradycardia, or other cardiac rhythm abnormalities through imaging tests such as echocardiography; (4) having complete clinical data, and (5) not participating in any other clinical studies.

The exclusion criteria of this study are as follows: (1) patients with concomitant thyroid disease; (2) patients with contraindications to pacemaker implantation; (3) patients who underwent pacemaker replacement during the study period; (4) patients with severe liver, kidney, or other organ dysfunction; (5) patients with severe mental illness or cognitive dysfunction; and (6) patients lost to follow-up after treatment.

Experimental Design

Treatment Methods

Pacemaker implantation therapy was performed in all patients, with permanent pacemakers implanted via the left subclavian vein. The decision to implant a single-chamber or dual-chamber pacemaker is based on the individual patient's condition, with the choice depending on whether atrioventricular synchrony is desired. Single-chamber pacemakers are implanted in either the right atrium or right ventricle of the heart through a lead wire for cardiac monitoring and pacing, with the electrode located in either the right atrium or right ventricle. The implantation of dual-chamber pacemakers involves the placement of two lead wires in the patient's heart, with electrodes located in both the right atrium and right ventricle, followed by monitoring of cardiac activity in the right atrium and right ventricle.

Data Collection

This study was a retrospective analysis. Patient data, including general information (gender, drinking history, age, education level, body mass index, smoking history, family history of the disease, marital status) and clinical data (history of coronary heart disease, history of hypertension, diabetes, preoperative anxiety score, preoperative depression score, and preoperative cardiac function indicators, such as left ventricular end-diastolic diameter (LVEDD), left ventricular ejection fraction (LVEF)), were collected through the hospital medical record system. Patients underwent echocardiography before treatment to assess cardiac function indicators.

Relevant Definitions

(1) Diagnostic criteria for arrhythmia after pacemaker implantation therapy: During the 12-month follow-up visit, the diagnosis of arrhythmia can be confirmed based on the occurrence of atrial tachycardia, atrial flutter, or atrial fibrillation recorded on patient's surface electrocardiogram, 24-hour Holter monitoring, or pacemaker telemetry recordings $\geq$1 time (Xu et al, 2021).

(2) Coronary heart disease: Patients are diagnosed with coronary heart disease if they meet one of the following conditions: (i) a history of angina pectoris with significant ST-T changes on surface electrocardiogram, 24-hour Holter monitoring, or

exercise stress test; (ii) coronary angiography showing ≥50% stenosis of coronary arteries; and (iii) a clear history of myocardial infarction.

(3) Diagnostic criteria of hypertension: Hypertension is defined as systolic blood pressure >140 mmHg and diastolic blood pressure >90 mmHg, according to the diagnostic criteria in the "Chinese Guidelines for the Prevention and Treatment of Hypertension" (Song et al, 2023).

(4) Diagnostic criteria of diabetes: The diagnosis of diabetes is confirmed based on the presence of symptoms such as polyuria, polydipsia, polyphagia, and weight loss, as well as fasting blood glucose ≥7.0 mmol/L and random blood glucose ≥11.1 mmol/L, according to the diagnostic criteria in the "2022 Chinese Clinical Guidelines for the Prevention and Treatment of Type 2 Diabetes in the Elderly" (Chinese Elderly Type 2 Diabetes Prevention and Treatment of Clinical Guidelines Writing Group et al, 2022).

(5) Self-Rating Anxiety Scale (SAS): Each of the 20 items in the SAS scores 5 points. The total score is 100, with higher scores indicating more severe anxiety: a score <50 indicates no anxiety while ≥50 indicates anxiety (Guo and Huang, 2021).

(6) Self-Rating Depression Scale (SDS): Each of the 20 items in the SDS scores 5 points. The total score is 100, with higher scores indicating more severe depression: a score <50 indicates no depression and ≥50 indicates depression (Dong et al, 2021).

(7) According to the World Health Organization's age classification, individuals aged 60 and above are considered elderly; therefore, in the present study, the sample was divided into two age groups based on this criterion: ≥60 years old and <60 years old (Xiao et al, 2022).

(8) Based on the assessment of cardiac function, an LVEF ≥50% and an LVEDD ≤55 mm indicate normal cardiac function (Li et al, 2023).

Statistical Analysis

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) Statistics for Windows version 27.0 (IBM Corp., Armonk, NY, USA). After conducting normality tests, we used the Kolmogorov-Smirnov test to assess whether the sample data obeyed the normal distribution. This nonparametric method compares the maximum difference (D value) between the sample distribution and theoretical normal distribution to determine if the data follows a normal distribution. If the D value is less than the critical value corresponding to the chosen significance level α, we accept that the data are normally distributed. Parametric statistical methods were then used for analyzing all the continuous data that passed normality tests. Normally distributed continuous data are expressed as mean ± standard deviation. These data were analyzed using *t*-tests in this study. Categorical data are expressed as counts and percentage, and were analyzed using chi-square tests. The $p < 0.05$ was considered statistically significant. Spearman correlation analysis was used to analyze the relationship between heart function indicators and the treatment effects of pacemaker implantation treatment. Logistic

regression analysis was used to analyze the factors influencing treatment effects in patients.

Based on the follow-up results recorded in the medical record system, patients were divided into the occurrence group and the non-occurrence group. In univariate analysis, general information, preoperative cardiac function, and anxiety levels of patients in both groups were analyzed and compared. In multivariate analysis, indicators with significant differences in the univariate analysis were included in the logistic regression model. Multivariate analysis was conducted on the prognosis and treatment effects of patients. In correlation analysis, the correlation between cardiac function indicators and the occurrence of arrhythmias after pacemaker implantation treatment was analyzed.

Results

Incidence of Arrhythmias Following Pacemaker Implantation

Based on the follow-up results recorded in the medical record system, among the 137 patients who received pacemaker implantation treatment, 40 patients experienced arrhythmias, accounting for 29.20% of the samples (40/137), and were assigned to the occurrence group. Ninety-seven patients who did not experience arrhythmias, accounting for 70.80% (97/137), were assigned to the non-occurrence group.

Univariate Analysis of Arrhythmias Following Pacemaker Implantation

There were significant differences in age, history of hypertension, preoperative anxiety scores, preoperative depression scores, preoperative LVEDD, and preoperative LVEF between the two groups ($p < 0.05$), as shown in Table 1.

Correlation Analysis of Cardiac Indicators and Occurrence of Arrhythmias

As shown in Table 2, there was a significant positive correlation between the occurrence of arrhythmias and both preoperative LVEDD ($r = 0.270$, $p = 0.001$) and preoperative LVEF ($r = 0.329$, $p < 0.001$). LVEDD, which reflects the end-diastolic diameter of the left ventricle, was found to be positively associated with a higher incidence of arrhythmias. A larger LVEDD indicates more pronounced ventricular dilation, which can lead to disturbances in electrical conduction and increase the risk of arrhythmias. Similarly, LVEF, an indicator of the heart's pumping efficiency, was inversely correlated with arrhythmia risk when it was reduced, suggesting that impaired cardiac function may lead to electrophysiological instability. These findings highlight the importance of preoperative cardiac function in predicting postoperative arrhythmia occurrence.

Univariate Analysis of Factors Influencing the Occurrence of Arrhythmias

As shown in Table 3, the occurrence of arrhythmias was assigned as the dependent variable (Y), whereas the age, history of hypertension, preoperative anxiety scores, preoperative depression scores, preoperative LVEDD, and preoperative LVEF were assigned as independent variables X1, X2, X3, X4, X5, and X6, respectively.

Table 1. Univariate analysis of arrhythmias following pacemaker implantation.

Indicator		Occurrence group (n = 40)	Non-occurrence group (n = 97)	χ^2/t	*p*-value
Gender (n, %)	Male	22 (55.00)	47 (48.45)	0.486	0.486
	Female	18 (45.00)	50 (51.55)		
Age (n, %)	<60 years old	17 (42.50)	63 (64.95)	5.874	0.015
	≥60 years old	23 (57.50)	34 (35.05)		
Body mass index (kg/m^2)		22.15 ± 2.11	22.18 ± 2.15	0.075	0.941
Education level (n, %)	High school and below	20 (50.00)	45 (46.39)	0.148	0.701
	College degree and above	20 (50.00)	52 (53.61)		
Smoking history (n, %)	Yes	15 (37.50)	40 (41.24)	0.165	0.685
	No	25 (62.50)	57 (58.76)		
Alcohol consumption history (n, %)	Yes	12 (30.00)	35 (36.08)	0.465	0.495
	No	28 (70.00)	62 (63.92)		
Family disease history (n, %)	Yes	10 (25.00)	19 (19.59)	0.497	0.481
	No	30 (75.00)	78 (80.41)		
Marital status (n, %)	Yes	28 (70.00)	65 (67.01)	0.116	0.733
	No	12 (30.00)	32 (32.99)		
History of coronary heart disease (n, %)	Yes	11 (27.50)	18 (18.56)	1.357	0.244
	No	29 (72.50)	79 (81.44)		
History of hypertension (n, %)	Yes	25 (62.50)	39 (40.21)	5.655	0.017
	No	15 (37.50)	58 (59.79)		
Diabetes mellitus (n, %)	Yes	13 (32.50)	29 (29.90)	0.090	0.764
	No	27 (67.50)	68 (70.10)		
Preoperative anxiety score (n, %)	<50 points	14 (35.00)	60 (61.86)	8.223	0.004
	≥50 points	26 (65.00)	37 (38.14)		
Preoperative depression score (n, %)	<50 points	14 (35.00)	55 (56.70)	5.335	0.021
	≥50 points	26 (65.00)	42 (43.30)		
Preoperative LVEDD (n, %)	≤55 mm	10 (25.00)	53 (54.64)	10.016	0.002
	>55 mm	30 (75.00)	44 (45.36)		
Preoperative LVEF (n, %)	≥50%	12 (30.00)	64 (65.98)	14.843	<0.001
	<50%	28 (70.00)	33 (34.02)		

Abbreviations: LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction.

Table 2. Correlation analysis of cardiac indicators and occurrence of arrhythmias.

Indicator	Occurrence of arrhythmias	
	r	*p*-value
Preoperative LVEDD	0.270	0.001
Preoperative LVEF	0.329	<0.001

Table 3. Univariate assignment of factors affecting the occurrence of arrhythmias detected after pacemaker implantation.

Variable symbol	Variable	Assignment method
Y	Occurrence of arrhythmias	0 = Not occurred, 1 = Occurred
X1	Age	0 = Less than 60 years old, 1 = 60 years old or above
X2	History of hypertension	0 = No, 1 = Yes
X3	Preoperative anxiety score	0 = <50 points, 1 = ≥50 points
X4	Preoperative depression score	0 = <50 points, 1 = ≥50 points
X5	Preoperative LVEDD	0 = ≤55 mm, 1 = >55 mm
X6	Preoperative LVEF	0 = ≥50%, 1 = <50%

Y, dependent variable; X, independent variable.

Logistic Regression Analysis of Factors Influencing the Occurrence of Arrhythmias

Logistic regression analysis revealed that age, history of hypertension, preoperative anxiety scores, preoperative depression scores, preoperative LVEDD, and preoperative LVEF were all risk factors for the occurrence of arrhythmias following pacemaker implantation (odds ratio [OR] = 2.507, 2.479, 3.012, 2.432, 3.614, and 4.525, respectively), as shown in Table 4.

Discussion

The present study found that 29.20% of patients experienced arrhythmia following pacemaker implantation. The occurrence of arrhythmias following pacemaker implantation is positively correlated with preoperative LVEDD and preoperative LVEF. Age, history of hypertension, preoperative anxiety score, preoperative depression score, preoperative LVEDD, and preoperative LVEF are all risk factors for the occurrence of arrhythmias following pacemaker implantation. This suggests that there is a correlation of arrhythmia occurrence following pacemaker implantation with preoperative LVEDD and LVEF. It is worth noting that there are multiple related factors playing interacting roles in this relationship. It is one of the urgent issues in clinical practice to screen high-risk groups for these related factors and take effective measures to prevent postoperative arrhythmia in patients.

Pacemakers are common medical devices used in the treatment of patients with cardiac rhythm abnormalities. They maintain normal cardiac rhythm by emitting electrical pulses and are used to treat conditions such as atrial fibrillation, ventricular fibrillation, and bradycardia. However, previous research has found that various factors that lead to the occurrence of arrhythmias, such as reentrant conduction and

Table 4. Logistic regression analysis of factors influencing the occurrence of arrhythmias received following pacemaker implantation.

Variable	β	SE	Wald χ^2	p-value	OR value	OR value 95% CI
Age	0.919	0.384	5.723	0.017	2.507	1.188–5.392
History of hypertension	0.908	0.387	5.509	0.019	2.479	1.162–5.289
Preoperative anxiety score	1.102	0.392	7.914	0.005	3.012	1.416–6.631
Preoperative depression score	0.889	0.391	5.209	0.023	2.432	1.147–5.329
Preoperative LVEDD	1.285	0.418	9.435	0.002	3.614	1.636–8.539
Preoperative LVEF	1.510	0.406	13.815	<0.001	4.525	2.083–10.334

CI, confidence interval; OR, odds ratio; SE, standard error.

atrial arrhythmias, can affect the treatment outcomes of patients after pacemaker implantation (Sagris et al, 2021). A study has suggested that cardiac function, negative emotions, and age are all factors associated with the occurrence of arrhythmias detected after pacemaker implantation (Polikandrioti, 2022). Therefore, it is necessary to pay comprehensive attention to patients who have received pacemaker treatment, analyze the factors influencing the occurrence of arrhythmias after treatment, and screen high-risk groups for relevant factors before treatment to effectively prevent postoperative arrhythmias. This is currently one of the key issues that needs to be addressed in clinical practice (van Weperen et al, 2021).

Our data analyses revealed that several factors can influence the occurrence of arrhythmias following pacemaker implantation. Age, history of hypertension, preoperative anxiety, and preoperative depression were identified in this study as risk factors for the occurrence of arrhythmias following pacemaker implantation. A previous study has shown that pacemakers have potential in the treatment of chronic heart disease, but are influenced by factors such as age and emotions, which are associated with the occurrence of arrhythmias (Rossi et al, 2023), aligning with the results of this study. Age is an important factor in the occurrence of arrhythmias after pacemaker implantation. A previous study has found that increasing age leads to changes in cardiac muscle and physiological systems, resulting in unstable cardiac electrical activity. The aging process often involves degenerative changes in the cardiac conduction system and results in an increased incidence of organic heart disease (Triposkiadis et al, 2022). Due to the low cognitive level and high sensory threshold in the elderly, diseases often go unnoticed and treatments are not administered in a timely manner, leading to a higher risk of arrhythmias. Nadarajah et al (2021) found that hypertension underlying the occurrence of arrhythmias in patients and is an important independent risk factor. Long-term uncontrolled hypertension can lead to structural and functional changes in the heart, increasing the risk of arrhythmias. It can also affect the cardiac electrophysiological activity, leading to blockage or abnormal excitation of the cardiac conduction system, increased atrial pressure, changes in myocardial fibre properties due to increased pressure load and uneven traction, changes in conduction and refractory periods, and instability of atrial myocardial potentials, resulting in an increased risk of arrhythmias (Nadarajah et al, 2021). Anxiety and depression can cause autonomic

nervous system dysfunction, sympathetic nervous system activation, and parasympathetic nervous system inhibition, leading to increased levels of adrenaline in the body. Stempien et al (2022) showed that stimulating adrenaline can directly affect the heart, and negative emotions can cause immune system imbalance and release of inflammatory factors, increasing the cardiac workload and the risk of arrhythmia. Separately, a positive correlation of arrhythmia occurrence following pacemaker implantation with preoperative LVEDD and preoperative LVEF was observed in this study. Preoperative LVEDD and LVEF were both risk factors for the occurrence of arrhythmias detected after pacemaker implantation, indicating a correlation between the occurrence of arrhythmias after treatment and preoperative cardiac function. LVEF and LVEDD are important indicators for assessing cardiac function, especially in the event of preoperative cardiac dysfunction in which the contractile and dilation functions of the heart are impaired (Stempien et al, 2022). In the presence of myocardial abnormalities, severe damage to myocardial tissue can lead to conduction disturbances, resulting in electrophysiological abnormalities and an increased risk of arrhythmias. A previous study has shown that pacemakers are common diagnostic and therapeutic devices for arrhythmias, maintaining normal cardiac rhythm by delivering electrical pulses (Monnet, 2023). However, in the event of preoperative cardiac dysfunction, the reduced pumping capacity of the heart can affect the effectiveness of the implanted pacemaker. Additionally, patients with cardiac dysfunction require more energy to maintain cardiac work, an act that affects the battery life of the pacemaker and increases the frequency of battery replacement, resulting in a higher risk of arrhythmias (Weinreb et al, 2024).

In the present study, we acknowledge that treating age as a categorical variable may limit our comprehensive understanding of the relationship between age and arrhythmogenesis. In statistical analyses, it is often recommended to consider age as a continuous variable in order to capture subtle variations and potentially nonlinear relationships with outcome variables. However, in accordance with existing clinical guidelines and research practices, and considering specific concerns regarding older age groups in clinical practice, we opted to analyze age using a classification based on a cut-off point of 60 years. While this categorization approach may simplify the relationship between age and study outcomes and facilitate rapid identification of older patients during clinical decision-making, it may obscure the potential impact of the entire range of ages on arrhythmogenesis. Additionally, categorizing age can reduce statistical power and increase errors due to binning. For future studies, we recommend analyzing age as a continuous variable for a more precise assessment of its effect on arrhythmogenesis. Furthermore, we suggest exploring possible nonlinear relationships between age and arrhythmia through more sophisticated statistical models that account for potential confounders.

Several limitations of this study should be acknowledged. Firstly, the findings of this study based on patients selected from a single center may limit their generalizability to other populations. Adding to this challenge is the small sample size used in this study. In addition, the unique characteristics of this institution may restrict the generalizability of the results obtained to other medical institutions with different backgrounds. Secondly, under the retrospective study design and framework,

we could not completely eliminate potential confounding factors and information bias, but information of subjects in both occurrence and non-occurrence groups were gathered as much as possible for the purposes of demonstrating their comparability. Future research can address these limitations by conducting large-sample, multicenter studies with more refined designs. Despite these limitations, this study provides substantial support for predicting the treatment outcomes of patients who had received pacemaker implantation treatment and provides a clinical theoretical basis for implementing relevant measures to improve treatment outcomes.

Conclusion

Multiple factors can influence the occurrence of arrhythmias following pacemaker implantation. This study focused on six main factors, namely age, history of hypertension, preoperative anxiety scores, preoperative depression scores, preoperative LVEF, and preoperative LVEDD. These indicators are independent factors that influence the occurrence of arrhythmias, and there is a significant correlation between cardiac function indicators and the treatment outcomes of patients implanted with pacemaker. Therefore, after pacemaker implantation, it is essential to closely monitor patients' cardiac function and implement relevant treatment measures in the case of cardiac dysfunction. Additionally, healthcare personnel should take into account emotions, age, and history of chronic diseases in patients while formulating treatments for them.

Key Points

- This study identified several key risk factors associated with the development of arrhythmias after pacemaker implantation, including age, history of hypertension, preoperative anxiety and depression scores, and cardiac function indicators such as left ventricular end-diastolic diameter (LVEDD) and left ventricular ejection fraction (LVEF).
- The findings highlight the importance of considering cardiac function and psychological status in preoperative assessment, which can help identify high-risk patient groups and potentially improve clinical treatment strategies.
- Our findings suggest that clinicians should consider patient-specific factors when developing treatment plans and adopt more aggressive monitoring and interventions for high-risk patients.
- This study provides directions for future research, including exploring other potential risk factors and evaluating the effectiveness of preventive interventions in reducing the occurrence of arrhythmias after pacemaker implantation.

Availability of Data and Materials

The datasets used during the current study are available from the corresponding author on reasonable request. Due to privacy restrictions, certain data are not publicly available, but de-identified data can be provided after approval from the authors.

Author Contributions

JJ conceived and designed the experiments, performed the experiments, and wrote the first draft of the manuscript. SH contributed to data analysis tools and performed the statistical analysis. MA participated in the collection of clinical data. XT helped with the interpretation of results. JJ supervised the project, secured funding, and provided administrative support. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Medical Ethics Committee of the Affiliated Hospital of Chengdu University (approval number: PJ2024-039-02), and was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki and informed consent obtained from the patient.

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Conflict of Interest

The authors declare no conflict of interest.

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