Journal of Clinical and Nursing Research, 2025, Volume 9, Issue 8
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Evaluating the Impact of Different Electrocardiogram Methods on Detecting Pacemaker Dysfunction and Cardiac Function Changes in Pacemaker Patients

Yan Li[1,2,3], Chun Zhou[4], Ying Li[1,2,3], Binlin Chen[1,2,3]

[1]The First College of Clinical Medical Science,China Three Gorges University,Yichang 443003,Hubei,China
[2]Electrocardiogram Diagnosis Department,Yichang Central People's Hospital,Yichang 443003,Hubei,China
[3]Hubei Provincial Clinical Research Center for Ischemic Cardiovascular Disease,Yichang 443003,Hubei,China
[4]Arrhythmia Department,The First Affiliated Hospital of Dalian Medical University,Dalian 116011,Liaoning,China

Abstract: *Objective*: To investigate the effect of 12-lead electrocardiogram and 24-hour dynamic electrocardiogram in detecting pacemaker dysfunction and changes in cardiac function indexes in patients with pacemaker implantation. *Methods*: A total of 136 patients with pacemaker implantation in the First Clinical Medical College of Three Gorges University, Institute of Cardiovascular Disease of Three Gorges University and Yicang Central People's Hospital from January 2023 to December 2024 were selected as the research objects. All patients received 12-lead electrocardiogram and 24-hour holter 3–14 days after implantation. *Results*: The overall detection rate of various types of pacemaker dysfunction by Holter was significantly higher than that by conventional ECG (27.21% vs. 5.15%, χ^2=24.402, $P < 0.001$). The overall arrhythmia detection rate of Holter was significantly higher than that of conventional electrocardiogram (57.35% vs. 10.29%, χ^2=67.277, $P < 0.001$). The time domain indexes of heart rate variability obtained by 24-hour continuous monitoring of Holter were significantly improved compared with those of conventional electrocardiogram ($P < 0.05$). *Conclusions*: Compared with 12-lead electrocardiogram, 24-hour holter monitoring can more accurately detect pacemaker dysfunction and arrhythmia in patients with pacemaker implantation, and provide more comprehensive data of heart rate variability, which is helpful for clinicians to better evaluate the cardiac function of patients and adjust treatment plans.

Keywords: Pacemaker implantation; Electrocardiogram; Abnormal pacemaker function; Cardiac arrhythmia; Heart rate variability

Online publication: August 19, 2025

1. Introduction

Pacemaker implantation is a key treatment to correct severe bradyarrhythmia and heart block, and its postoperative management directly affects the quality of life and long-term prognosis of patients. With the popularization of implantation technology and the upgrading of device functions, the requirements for monitoring the working state of pacemakers are increasingly refined, especially the timely identification of intermittent dysfunction and potential imbalance of cardiac electrical activity [1]. As a basic screening tool, routine 12-lead electrocardiogram is widely used in clinical practice because of its convenient operation and instant results, but its short recording time may lead to missed diagnosis of paroxysmal abnormalities [2]. While a 24-hour Holter provides a more complete perspective to capture incidental events by continuously monitoring cardiac electrophysiological activity, but its cost and efficiency limitations also need to be weighed [3]. At present, there is no unified standard for the joint evaluation of pacemaker dysfunction, such as sensing threshold drift, pacing signal loss, and secondary arrhythmia in clinical practice. If such abnormalities are not detected in time, they may lead to decreased cardiac output or even syncope in pacing-dependent patients. Based on this, this study selected 136 patients with pacemaker implantation to systematically compare the detection efficiency of routine electrocardiogram and dynamic electrocardiogram in different types of dysfunction, spontaneous conduction arrhythmia, and heart rate variability, in order to provide scientific support for optimizing the postoperative monitoring scheme and improving the risk early warning ability.

2. Materials and methods

2.1. General information

A total of 136 patients with pacemaker implantation who were admitted to the First Clinical Medical College of China Three Gorges University, Institute of Cardiovascular Disease of China Three Gorges University and Yicang Central People's Hospital from January 2023 to December 2024 were selected as the research objects. All patients completed the standardized follow-up, including 79 males (58.09%) and 57 females (41.91%). The average age was 65.38 ± 8.74 years (range, 48–82 years). There were 62 cases (45.59%) with single-chamber pacemaker and 74 cases (54.41%) with dual-chamber pacemaker. Fifty-eight cases (42.65%) had atrioventricular block, 71 cases (52.21%) had sick sinus syndrome, and 7 cases (5.15%) had congenital heart disease. There were 89 cases (65.44%) of hypertension, 47 cases (34.56%) of type 2 diabetes, and 62 cases (45.59%) of coronary heart disease.

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

(1) Meeting the indications for permanent pacemaker implantation in 2021 ESC Guidelines for Cardiac Pacing and Cardiac Resynchronization Therapy [4].
(2) Regular follow-up ≥ 6 months.
(3) Complete clinical data, including preoperative cardiac function evaluation, pacemaker parameter records, and follow-up data.
(4) Signed informed consent and volunteered to participate in the study.

2.2.2. Exclusion criteria

(1) Acute myocardial infarction, uncontrolled heart failure or malignant arrhythmia.
(2) Severe electrolyte disturbance.
(3) Complicated with tumor, severe liver and kidney dysfunction or active infection.
(4) Mental disorder or physical activity limitation.

(5) Pacemaker implantation time less than 3 months or postoperative infection and other complications.

2.3. Methods

2.3.1. Routine 12-lead ECG

All patients underwent each 12-lead ECG assessment from 3 to 14 days after surgery. The resting state ECG activity was recorded by Japan Optoelectronic ECG-9130P synchronous ECG acquisition device combined with ECGLAB-A-A wired ECG workstation (Meigao Medical). The patient was placed in the supine position, guided to maintain calm breathing, the limb leads were adhered to the international standard position (RA/LA/RL/LL), and the chest leads (V1-V6) were strictly positioned along the intercostal space. The acquisition parameters were set as gain 10 mm/mV and paper speed 25 mm/s, and the electrophysiological signals were continuously monitored for 60 seconds. The effective map was defined as noise amplitude < 0.1 mV. Daily data were baseline calibrated and noise filtered by LabChart 10.0 software to eliminate the artifacts of electromyography and respiratory motion.

2.3.2. 24-hour ambulatory electrocardiogram

The 12-channel Holter monitoring system of DMS was used for 24 hours continuous multilead electrophysiological signal acquisition from 3 to 14 days after operation. Technical points: (1) Stop β-blockers and class I/III antiarrhythmic drugs 72 hours before the examination; (2) The electrodes were placed according to Einthoven triangle and the anatomical marks of chest leads, and anti-allergic conductive cream was used to reduce skin impedance; (3) During the acquisition period, symptom events (such as palpitations and syncope) and exercise intensity levels were marked in real time through the human-computer interaction module. The raw data were processed by BioxWin analysis system: the wavelet transform algorithm was used to eliminate the high-frequency interference, the R wave recognition threshold was set as 0.5 mV, and the ST segment offset was quantified based on 80 ms after J point. The standard of valid data was that the false error rate was less than 5% and the continuous recording time was more than 22 hours; those who did not meet the standard needed to be reexamined within 48 hours.

2.4. Observation indicators

2.4.1. Abnormal pacemaker function

The specific detection content included: (1) Abnormal pacing function, such as pacing signal failed to effectively drive myocardial depolarization; (2) Ventricular and atrial oversensing, that is, excessive sensing of unexpected signals; (3) Ventricular and atrial poor sensing, that is, insufficient perception of normal signals; And (4) Pacing syndrome, which may be characterized by a range of uncomfortable symptoms such as dizziness and fatigue.

2.4.2. Cardiac function

(1) Arrhythmia: The types of arrhythmia included: premature ventricular beats, which are early contractions originating in the ventricles; atrial premature beats, or early atrial contractions; atrial tachycardia, characterized by a rapid atrial rhythm; sinus pause, a temporary cessation of impulse generation by the sinus node; pacemaker-mediated tachycardia, a form of tachycardia involving pacemaker activity; ventricular spontaneous rhythm, a rhythm originating spontaneously from the ventricles; pacemaker frequency unburst, referring to abnormal acceleration of the pacemaker's pacing rate; and atrioventricular block, a disruption in electrical conduction between the atria and ventricles. The total detection rate of

arrhythmias was calculated.

(2) Time domain of heart rate variability: It includes the standard deviation of all RR intervals (SDNN) within 24 hours, which reflects the overall degree of heart rate variability. The root mean square difference of successive normal R-R intervals (r-MSDD) within 24 hours was used to reflect the short-term variability of heart rate. The standard deviation of normal R-R interval (SDANN-index) for the whole continuous 5 minutes was used to evaluate the short-term stability of heart rate. The standard deviation of the mean R-R interval (SDANN) in every 5 minutes can reflect the long-term variation of heart rate.

2.5. Statistical methods

All the collected data were input into SPSS26.0 software for statistical analysis. The counting data were recorded as the number of cases and percentage (n(%)), analyzed by χ^2 test and other methods, and the measurement data were recorded as the mean and standard deviation ($\bar{x} \pm s$), analyzed by t test, and $P < 0.05$ was considered statistically significant.

3. Results

3.1. Comparison of abnormal pacemaker function

The results showed that the overall detection rate of various types of pacemaker dysfunction by Holter was significantly higher than that by conventional electrocardiogram (27.21% vs. 5.15%, χ^2=24.402, $P < 0.001$), as shown in **Table 1**.

Table 1. Comparison of pacemaker dysfunction [n (%)]

Group of groups	Routine electrocardiogram	Dynamic electrocardiogram	X^2	P
Number of cases	136	136		
The pacing function was abnormal	0(0.00)	7(5.15)	/	/
Ventricular and atrial oversensing	5(3.68)	17(12.50)	/	/
Poor sensing of the ventricle and atrium	2(1.47)	13(9.56)	/	/
The pacing syndrome	0(0.00)	0(0.00)	/	/
Sum up	7(5.15)	37(27.21)	24.402	0.000

3.2. Comparison of arrhythmia

The results showed that the overall arrhythmia detection rate of Holter was significantly higher than that of conventional electrocardiogram (57.35% vs. 10.29%, χ^2=67.277, $P < 0.001$), as shown in **Table 2**.

3.3. Time domain comparison of heart rate variability

The results showed that the time domain indexes of heart rate variability obtained by 24-hour continuous monitoring of Holter were significantly improved compared with those of conventional electrocardiogram ($P < 0.05$), as shown in **Table 3**.

Table 2. Comparison of arrhythmia [n (%)]

Group of groups	Routine electrocardiogram	Dynamic electrocardiogram	X^2	*P*
Number of cases	136	136		
Atrial tachycardia was present	0(0.00)	3(2.21)	/	/
Premature ventricular contractions	6(4.41)	27(19.85)	/	/
Atrial premature beats	7(5.15)	15(11.03)	/	/
Sinus pauses	0(0.00)	8(5.88)	/	/
Ventricular spontaneous rhythm	0(0.00)	6(4.41)	/	/
The pacemaker is running at a high rate	0(0.00)	7(5.15)	/	/
Pacemaker-mediated tachycardia	0(0.00)	5(3.68)	/	/
Atrioventricular block	1(0.74)	7(5.15)	/	/
Sum up	14(10.29)	78(57.35)	67.277	0.000

Table 3. Time-domain comparison of heart rate variability ($\bar{x} \pm s$)

Group of groups	Routine electrocardiogram	Dynamic electrocardiogram	*T*	*P*
Number of cases	136	136		
SDNN	98.62 ± 20.74	142.35 ± 28.58	14.778	0.000
SDANN-index	85.27 ± 18.96	121.73 ± 24.35	13.778	0.000
SDANN	122.18 ± 9.56	53.62 ± 12.47	50.884	0.000
r-MSDD	21.47 ± 6.84	38.95 ± 10.28	16.509	0.000

4. Discussion

The core goal of postoperative monitoring of cardiac pacemaker is to detect device dysfunction and secondary arrhythmia in time, so as to prevent hemodynamic disorders and malignant cardiovascular events. Recent studies have pointed out that the incidence of pacemaker dysfunction such as insufficient sensing and pacing threshold drift in the early stage of implantation is 5–15%, but it is easy to be missed by traditional examination methods due to concealed clinical manifestations [5].

This study found that the overall detection rate of pacemaker dysfunction by Holter was 27.21%, which was significantly higher than that by conventional ECG (5.15%). This difference was highly consistent with the previous research results of Li *et al.* [6]. Taking poor ventricular sensing as an example, the detection rate of dynamic electrocardiogram (9.56%) was higher than that of conventional electrocardiogram (1.47%), and its mechanism was closely related to the dynamic change of the impedance of the lead-myocardial interface. In the early postoperative period, electrode micro-dislocation or local myocardial edema can lead to the fluctuation of sensing threshold, which is easily triggered when the patient's position changes or respiratory movement. Conventional electrocardiogram is difficult to capture such time-discrete events because the single sampling time is less than 10 seconds. He *et al.* pointed out that postural changes can cause electrode contact impedance to fluctuate by 30%–50%, leading to intermittent sensing abnormalities. The long-term characteristics of Holter can just cover such physiological dynamic changes, thus significantly improving the detection sensitivity [7].

In addition, the detection rate of ventricular and atrial oversensing Holter (12.50%) was much higher than that of conventional electrocardiogram (3.68%). The mechanism involved the complexity of atrioventricular pacing timing. By continuously recording atrioventricular interval changes, Holter can identify the false trigger caused by atrial electrode missensing electromyogram signal or T wave, while conventional electrocardiogram is isolated due to sampling fragments. Such temporal dependency exceptions are difficult to resolve.

The advantage of Holter monitoring with respect to arrhythmia detection is the complete capture of sequence-dependent events. The detection rate of pacemaker-mediated tachycardia (PMT) in Holter monitoring (3.68%) was significantly higher than that in conventional monitoring (0%). The mechanism of PMT is closely related to the triggering conditions of PMT: PMT is often induced by premature atrial contraction through the reverse atrioventricular pathway. Holter can clearly show the coupling relationship between the reverse P wave and ventricular pacing signal after premature atrial contraction by continuously tracking the atrioventricular conduction sequence. Li *et al.* also confirmed that the detection rate of Holter in the diagnosis of PMT was 2.7%, which was significantly better than that of conventional 12-lead ECG [8]. In addition, the difference in detection of atrial premature beats (11.03% on Holter vs. 5.15% on conventional electrocardiogram) suggests that pacemaker implantation may cause mechanical stretch or an inflammatory response of the atrial muscle. Dynamic monitoring can early identify such electrical remodeling tendency and provide a basis for anticoagulation therapy. Heart rate variability analysis further revealed the essential differences between the two methods. The mean SDNN of the Holter group was higher than that of the conventional group, and the difference was due to the complete coverage of the circadian rhythm of the autonomic nerve by Holter data. The circadian fluctuation of HRV, such as increased vagal tone at night, can reflect the autonomic nervous regulation ability of the heart, while the conventional ECG can only reflect the transient state at the detection time, which may mask the true degree of autonomic nervous imbalance.

5. Conclusion

In conclusion, compared with 12-lead electrocardiogram, 24-hour holter monitoring can more accurately detect pacemaker dysfunction and arrhythmia in patients with pacemaker implantation, and provide more comprehensive heart rate variability data, which is helpful for clinicians to better evaluate the cardiac function of patients and adjust the treatment plan.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Zhu W, 2021, Current Status and Thinking of Cardiac Rehabilitation After Cardiac Pacemaker Implantation. General Nursing, 19(09): 1175–1181.

[2] The Effect of Conventional 12-Lead Electrocardiogram and 24-Hour Dynamic Electrocardiogram in the Diagnosis of Arrhythmia in Patients With Pacemaker Implantation, 2023, Cardiovascular Disease With Traditional Chinese and Western Electronic Journal, 2023(7): 97–99.

[3] Liu P, Fan N, 2024, Pacemaker Implantation in Patients With the Clinical Significance of the Application of 24 h

Dynamic ECG Examination. Journal of Practical Electrocardiology Journal, 2024(02): 118–121.
[4] Li XB, Chen Q, 2021, Interpretation of the Update of 2021 ESC Cardiac Pacing and Cardiac Resynchronization Therapy Guidelines. Journal of Clinical Electrocardiography, 30(06): 401–408.
[5] Zhang L, 2024, Risk Factors and Prognosis Analysis of AHRE After Dual Chamber Pacemaker Implantation, thesis, Hebei University.
[6] Li RQ, 2023, The Value of Conventional 12-Lead Electrocardiogram and 24-Hour Dynamic Electrocardiogram in Diagnosing Pacing Dysfunction and Arrhythmia After Pacemaker Implantation. Chinese Community Physicians, 39(27): 92–94.
[7] He J, Zhang L, Zheng X, 2024, Electrocardiogram and Electrocardiogram Characteristics of Micra AV Leadless Pacemaker. Electrocardiogram and Circulation, 43(06): 613–617+621.
[8] Li HL, Li QN, Zhou LJ, 2025, Comparative Study on the Value of 12-Lead Electrocardiogram and 24-Hour Dynamic Electrocardiogram in Patients With Pacemaker Implantation. Practical Medical Journal, 32(02): 145–148.