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Article

Clinical Value of High-Channel 12-Lead Holter in Assisting Early Identification of Arrhythmias in High-Risk Populations

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Abstract

Aims/Background: Cardiac arrhythmias are common in high-risk populations, often presenting paroxysmally and asymptomatically, leading to missed diagnoses and increased cardiovascular risks. This study aimed to retrospectively analyze the clinical value of high-channel 12-lead Holter electrocardiogram (ECG) in the early identification of arrhythmias in high-risk populations and to provide a reference for cardiovascular risk prevention and control in these groups. **Methods**: Clinical data from 300 patients who met the criteria for high-risk populations and received diagnosis and treatment in Zibo Central Hospital from August 2023 to June 2024 were retrospectively collected. All patients underwent both routine 12-lead ECG examination and high-channel 12-lead Holter monitoring during the same period. The detection rates of atrial fibrillation, frequent ventricular premature beats ($\geq$30 beats/h), frequent atrial premature beats ($\geq$100 beats/24 h), and atrioventricular block were compared between the two modalities using appropriate statistical tests. Univariate logistic regression was performed to identify factors associated with positive arrhythmia detection. **Results**: The overall arrhythmia detection rate of the high-channel 12-lead Holter (35.0%) was significantly higher than that of the routine 12-lead ECG (20.0%) ($p < 0.001$). The Holter showed significant advantages in detecting atrial fibrillation (11.7% *vs* 6.0%, $p < 0.001$) and frequent ventricular premature beats (14.3% *vs* 7.7%, $p < 0.001$). Univariate logistic regression revealed that smoking history, drinking history, hypertension, coronary heart disease, heart failure, higher body mass index (BMI) and type 2 diabetes mellitus were significantly associated with positive arrhythmia detection by Holter (all $p < 0.001$). Similar patterns were observed for routine ECG, except for diabetes and BMI. **Conclusion**: In high-risk populations, the high-channel 12-lead Holter is highly valuable for screening paroxysmal and intermittent arrhythmias (especially atrial fibrillation and frequent ventricular premature beats). It can serve as an effective supplement to the routine ECG, providing a key basis for the early and accurate detection and intervention of arrhythmias in high-risk groups.

Keywords: ambulatory electrocardiography; cardiac arrhythmia; clinical factors; retrospective studies

1. Introduction

Arrhythmia is a common cardiovascular disorder characterized by abnormalities or disruptions in the normal electrical activation or contraction sequence of the heart. It is characterized by irregular heart rhythms, which can manifest as bradycardia (heart rate <60 beats/min) or tachycardia (heart rate >100 beats/min) [1]. Different types of arrhythmias exert varying impacts on patients: some have a favorable prognosis, while others may cause prominent palpitations, syncope, or even sudden cardiac death [2]. Additionally, the treatment costs for arrhythmias are substantial—for atrial fibrillation alone, the annual expenditure in the United States amounts to approximately 26 billion US dollars [3].

Currently, therapeutic and management strategies for arrhythmias include antiarrhythmic drugs, pacemakers, automated external defibrillators (AEDs), and radiofrequency ablation [4]. However, arrhythmias in high-risk populations (e.g., patients with hypertension, coronary heart disease, or the elderly) often occur paroxysmally and asymptomatically, making them highly prone to missed diagnosis via routine electrocardiogram (ECG). Therefore, early and accurate identification of such arrhythmias is crucial for improving patient prognosis [5].

Routine 12-lead ECG, with its short monitoring duration (only a few minutes), frequently fails to capture abnormal ECG signals, leading to missed diagnoses, delayed treatment, and increased risks of adverse cardiovascular events such as stroke and heart failure [6]. Although traditional Holter monitors enable 24-hour recording, their limited number of channels results in insufficient integrity and accuracy of signal acquisition, which cannot meet the needs of detecting early, subtle arrhythmias [7,8].

High-channel 12-lead Holter ECG represents an advanced form of dynamic cardiac monitoring. It integrates the continuous recording capability of traditional monitors with the comprehensive spatial information provided by standard 12-lead ECG. Through optimized channel design, it can continuously collect more comprehensive dynamic ECG data over 24 hours, theoretically improving the detection rate of early arrhythmias [9]. Compared with modern devices like adhesive patch monitors, Holter systems

offer superior multi-lead resolution for complex arrhythmias [10]. In this study, we retrospectively analyzed two types of ECG data from 300 high-risk individuals, compared the detection performance between the high-channel 12-lead Holter and routine 12-lead ECG, and further verified the clinical value of high-channel 12-lead Holter in the early identification of arrhythmias, aiming to provide practical evidence for cardiovascular management in high-risk populations.

2. Methods

2.1 Study Subjects

High-risk individuals who attended the Department of Cardiovascular Medicine and Department of Geriatrics in Zibo Central Hospital from August 2023 to June 2024 were retrospectively selected as study subjects. Case data were extracted from the hospital's electronic medical record system, ECG database, and clinical diagnosis and treatment records. After screening, a total of 300 eligible cases were finally included (Fig. 1). The inclusion and exclusion criteria of this study are as follows:

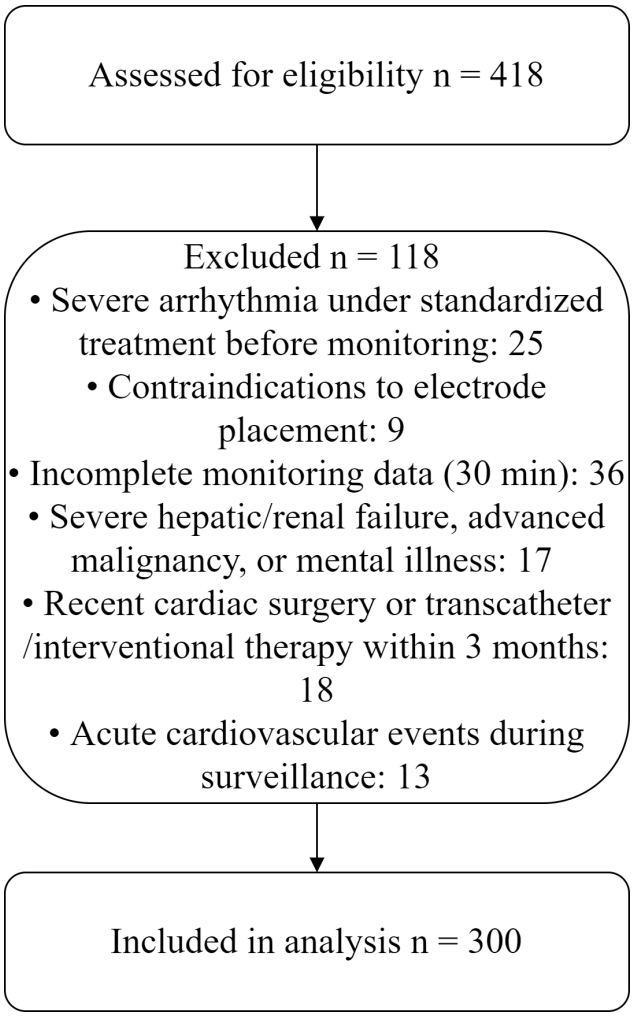

Fig. 1. Flowchart of patient selection.

2.1.1 Inclusion Criteria

(1) Meeting the definition of "high-risk population for arrhythmia" with at least one of the following risk factors: ① hypertension (systolic blood pressure $\geq$140 mmHg and/or diastolic blood pressure $\geq$90 mmHg, or a confirmed previous diagnosis of hypertension with regular use of antihypertensive drugs); ② coronary heart disease (coronary artery stenosis $\geq$50% confirmed by coronary angiography or coronary computed tomography angiography, or a previous history of acute myocardial infarction); ③ type 2 diabetes mellitus (fasting blood glucose $\geq$7.0 mmol/L, 2-hour postprandial blood glucose $\geq$11.1 mmol/L, or a confirmed previous diagnosis of diabetes mellitus with antidiabetic treatment); ④ heart failure (New York Heart Association [NYHA] functional class I–III, left ventricular ejection fraction $<$50% or ventricular remodeling confirmed by echocardiography); ⑤ age $\geq$65 years.

(2) Completion of both routine 12-lead ECG examination and high-channel 12-lead Holter monitoring within 1 week after enrollment.

(3) Complete medical records, including baseline demographic characteristics, diagnosis and treatment records of underlying diseases, and original reports and interpretation results of both ECG tests.

(4) Age $\geq$45 years.

2.1.2 Exclusion Criteria

(1) Confirmed diagnosis of severe arrhythmia with standardized treatment before monitoring.

(2) Contraindications to electrode placement.

(3) Incomplete ECG monitoring data (Holter monitoring duration $<$22 hours, or signal loss $>$30 minutes due to electrode detachment).

(4) Comorbidity with severe hepatic or renal failure, advanced malignant tumors, or mental disorders resulting in inability to cooperate with diagnosis, treatment, or follow-up.

(5) Recent cardiac surgery or transcatheter/interventional therapy within the past 3 months.

(6) Occurrence of acute cardiovascular events during surveillance.

2.2 Study Methods

2.2.1 Routine 12-Lead ECG Examination

A GE MAC 5500 12-lead ECG machine (General Electric Company, USA) was used. Before the examination, patients were instructed to lie quietly in the supine position for 5 minutes and to remove metal objects from the chest and abdomen. Limb leads (I, II, III, aVR, aVL, aVF) and precordial leads (V1–V6) were placed in accordance with international standards. The recording duration was adjusted flexibly based on patients' clinical symptoms: for asymptomatic patients, continuous ECG signals were recorded for 30 seconds at a paper speed of 25 mm/s and a gain of 10 mm/mV; for patients with suspected symptoms

such as palpitations and chest tightness, the recording duration was extended to 1–2 minutes, focusing on observing signal changes in leads II and V1.

The examination results were independently interpreted by 2 associate chief physicians with more than 5 years of experience in ECG interpretation, using a blinded method in which each was unaware of the other's findings or the patient's Holter results. Disagreements were resolved through discussion or consultation with a third senior physician. The core diagnostic criteria followed domestic authoritative consensus and ECG diagnostic principles [11,12], with a key focus on identifying the following arrhythmias:

• Atrial fibrillation: disappearance of P waves, replaced by f waves, and absolutely irregular RR intervals;

• Ventricular premature beats: prematurely appearing wide and deformed QRS complexes with complete compensatory pauses;

• Atrial premature beats: prematurely appearing ectopic P waves with incomplete compensatory pauses;

• Atrioventricular block: Grade I, PR interval $>$0.20 s; Grade II, gradual prolongation or sudden drop-out of PR interval; Grade III, complete atrioventricular dissociation.

2.2.2 High-Channel 12-Lead Holter Monitoring

A BeneHeart R12 high-channel 12-lead Holter recorder (Mindray, Shenzhen, China) was used, with the supporting analysis software BeneHeart Holter Analysis System (version 5.0, Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). Before monitoring, the patient's chest and abdominal skin were cleaned, and silver-chloride electrode pads were attached in accordance with the standard for the routine 12-lead ECG, ensuring the contact impedance between electrodes and skin was $<$5 kΩ. After connecting the recorder, patients were advised to conduct normal daily activities, avoiding strenuous exercise and exposure to strong magnetic fields, and to keep a detailed 24-hour activity diary, including activity type, symptom onset, and onset time.

After monitoring was completed, the recorder was connected to a computer to import 24-hour continuous ECG data (sampling frequency: 500 Hz; time resolution: 1 ms). The same 2 associate chief physicians performed offline analysis using a blinded method: after the automatic analysis software initially identified abnormal ECG events, the physicians independently checked the original waveforms one by one, corrected software misjudgments (e.g., excluding false positives caused by myoelectric interference and baseline drift), and finally confirmed the type of arrhythmia, episode frequency, duration, and correlation with symptoms. They were unaware of each other's interpretations or prior routine ECG results to minimize bias.

3. Data Collection

Two researchers independently extracted data from the electronic medical record system. The extracted content included: (1) baseline data (sex, age, body mass index [BMI], smoking history, drinking history, type of underlying disease); and (2) ECG test data (reports from the routine 12-lead ECG examination, including examination time, type of arrhythmia, and interpretation results, and from the high-channel 12-lead Holter monitoring, including monitoring time, type of arrhythmia, episode frequency, duration, and symptom correlation records). After extraction, the two researchers cross-checked the data. In case of discrepancies, the final results were confirmed by reviewing original test images (waveforms stored in the ECG machine and Holter analyzer) and consulting clinical physicians to ensure data accuracy.

3.1 Observation Indicators

The detection rates of target arrhythmias by the two test methods included:

① Atrial fibrillation (paroxysmal or persistent; duration $\geq$30 seconds during Holter monitoring or clear f waves recorded by ECG examination);

② Frequent ventricular premature beats ($\geq$30 beats/h during Holter monitoring or $\geq$3 beats/min on ECG examination);

③ Frequent atrial premature beats ($\geq$100 beats/24 h during Holter monitoring or $\geq$2 beats/min recorded on ECG examination);

④ Atrioventricular block (Grade I, II, or III, according to the above interpretation criteria).

3.2 Statistical Methods

Continuous variables were expressed as median (1st Quartile [Q_1], 3rd Quartile [Q_3]) if non-normally distributed (determined by Kolmogorov–Smirnov test), and categorical variables were expressed as frequency (n) and percentage (%). A paired design was adopted to compare the detection rates of arrhythmias (overall and by subtype: atrial fibrillation, frequent ventricular premature beats, frequent atrial premature beats, and atrioventricular block) between the two methods. Paired analyses were performed on the results of the routine 12-lead ECG examination and 24-hour Holter monitoring from each patient. Based on the overall and subtype-specific detection data, the number of cases with both positive, only routine ECG positive, only Holter positive, and both negative results were calculated. The McNemar test (paired chi-square test) was used to compare detection rate differences between the two methods; when the expected frequency was $<$5, the exact probability method based on the binomial distribution was applied. Univariate logistic regression analysis was performed to assess associations between baseline variables (e.g., age, sex, comorbidities) and positive arrhythmia detection. All analyses were conducted using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). The significance level was set at α = 0.05 (two-tailed), and a p-value $<$ 0.05 was considered statistically significant.

4. Results

4.1 Baseline Data

A total of 300 high-risk individuals with cardiovascular conditions were included in this study. Baseline characteristics showed that the study population was mainly elderly (median age: 67.00 years), with a body mass index (BMI) within the normal range (median: 23.60 kg/m^2). Participants commonly had multiple cardiovascular comorbidities, including coronary heart disease, hypertension, type 2 diabetes mellitus, and heart failure, as well as risk factors such as smoking and alcohol consumption. These subjects met the inclusion criteria for a high-risk cardiovascular population, providing a representative study cohort for the subsequent comparison of the efficacy between the two ECG detection methods (Table 1).

Table 1. Baseline characteristics of patients.

Variables	Total (n = 300)
Age (years), M (Q_1, Q_3)	67.00 (58.00, 76.00)
Body mass index (BMI) (kg/m^2), M (Q_1, Q_3)	23.60 (21.60, 25.40)
Sex, n (%)	
Male	168 (56.00)
Female	132 (44.00)
Smoking history, n (%)	104 (34.67)
Drinking history, n (%)	108 (36.00)
Hypertension, n (%)	126 (42.00)
Coronary heart disease, n (%)	84 (28.00)
Type 2 diabetes mellitus, n (%)	72 (24.00)
Heart failure, n (%)	48 (16.00)

Note: M, median; Q_1, 1st Quartile; Q_3, 3rd Quartile.

4.2 Comparison of Detection Results

According to Table 2, the total arrhythmia detection rate of the high-channel 12-lead Holter was significantly higher than that of the routine 12-lead ECG (35.0% *vs* 20.0%, $p < 0.001$). Subtype-specific analysis showed that the Holter also had significantly higher detection rates than the routine ECG in atrial fibrillation (11.7% *vs* 6.0%, $p < 0.001$) and frequent ventricular premature beats (14.3% *vs* 7.7%, $p < 0.001$). However, there were no statistically significant differences in the detection rates of frequent atrial premature beats (6.7% *vs* 4.7%, $p = 0.238$) or atrioventricular block (2.3% *vs* 1.7%, $p = 0.625$) between the two methods. These results suggest that the high-channel 12-lead Holter has clear advantages in detecting paroxysmal and intermittent arrhythmias and is particularly suitable for screening atrial fibrillation and frequent ventricular premature beats.

To further clarify the detection advantages of Holter monitoring for different arrhythmia subtypes, in-depth analyses were conducted on atrial fibrillation and frequent ventricular premature beat subtypes, and their specific detection distributions are shown in Tables 3,4.

As shown in Table 3, Holter monitoring detected a total of 35 cases of atrial fibrillation, among which 20 cases were Holter-positive only, while routine electrocardiography detected only 3 cases of "routine ECG-only positive" atrial fibrillation ($p < 0.001$). This result is highly consistent with the clinical characteristics of atrial fibrillation, namely its paroxysmal onset and short duration. Due to the limited detection time, routine electrocardiography is prone to miss transient episodes of atrial fibrillation, while Holter monitoring allows continuous 24-hour recording, capturing more intermittently occurring atrial fibrillation events and providing greater value for screening occult atrial fibrillation.

As shown in Table 4, Holter monitoring detected 43 cases of frequent ventricular premature beats, among which 25 were "Holter-only positive"—a number significantly higher than the 5 "routine ECG-only positive" cases identified by routine ECG ($p < 0.001$). The onset of ventricular premature beats is often associated with factors such as physical activity and emotional states, exhibiting marked dynamic variability. Holter monitoring can comprehensively record changes in ventricular premature beat load and onset patterns over 24 hours; whereas routine ECG only reflects the heart's electrical activity at a single moment, resulting in a higher rate of missed diagnosis for dynamic ventricular premature beats. This explains why Holter monitoring shows a distinct advantage in detecting the frequent ventricular premature beat subtype.

To explore the associations between baseline characteristics and positive arrhythmia detection using the two methods, univariate logistic regression was performed (Table 5). For routine ECG positive detection, significant predictors included smoking history ($p < 0.001$), indicating over a 10-fold increase in odds; drinking history ($p < 0.001$); hypertension ($p < 0.001$); coronary heart disease ($p < 0.001$); and heart failure ($p < 0.001$). Sex, age, BMI, and type 2 diabetes were not significant ($p > 0.05$). For Holter positive detection, similar factors were significant, with stronger associations for heart failure ($p < 0.001$) and additional significance for type 2 diabetes ($p < 0.001$) and BMI ($p < 0.001$), suggesting that extended monitoring may better capture arrhythmias linked to metabolic and chronic conditions. These findings highlight the associations between clinical factors and arrhythmia susceptibility and the enhanced sensitivity of Holter monitoring in identifying these clinically relevant patterns.

5. Discussion

This study employed a paired design to compare arrhythmia detection between the routine ECG and high-channel 12-lead Holter monitoring. The results showed that Holter monitoring was significantly superior to routine ECG in terms of the overall arrhythmia detection rate and

Table 2. Comparison of arrhythmia detection results between the routine 12-lead ECG and high-channel 12-lead Holter.

Indicator	Routine ECG positive, n (%)	Holter positive, n (%)	Both positive, n	Only routine ECG positive, n	Only Holter positive, n	χ^2	p
Total detection	60 (20.0%)	105 (35.0%)	45	15	60	25.81	<0.001
Atrial fibrillation	18 (6.0%)	35 (11.7%)	15	3	20	-	<0.001
Frequent ventricular premature beats	23 (7.7%)	43 (14.3%)	18	5	25	12.03	<0.001
Frequent atrial premature beats	14 (4.7%)	20 (6.7%)	8	6	12	-	0.238
Atrioventricular block	5 (1.7%)	7 (2.3%)	4	1	3	-	0.625

Note: χ^2, McNemar test; -, exact binomial test (when expected counts were <5); ECG, electrocardiogram.

Table 3. Detection of atrial fibrillation subtype (n).

	Holter - Atrial Fibrillation = Positive	Holter - Atrial Fibrillation = Negative	Total
Routine ECG - Atrial Fibrillation = Positive	15	3	18
Routine ECG - Atrial Fibrillation = Negative	20	262	282
Total	35	265	300

Table 4. Detection of frequent ventricular premature beat subtype (n).

	Holter - Frequent Ventricular Premature Beats = Positive	Holter - Frequent Ventricular Premature Beats = Negative	Total
Routine ECG - Frequent Ventricular Premature Beats = Positive	18	5	23
Routine ECG - Frequent Ventricular Premature Beats = Negative	25	252	277
Total	43	257	300

Table 5. Univariate logistic regression analysis of factors associated with arrhythmia detection.

Variables	Routine ECG Positive					Holter Positive				
	β	SE	Z	p	OR (95% CI)	β	SE	Z	p	OR (95% CI)
Sex										
Female					1.00 (Reference)					1.00 (Reference)
Male	–0.30	0.29	–1.04	0.296	0.74 (0.42~1.30)	0.01	0.24	0.05	0.961	1.01 (0.63~1.63)
Smoking history										
No					1.00 (Reference)					1.00 (Reference)
Yes	2.33	0.34	6.85	<0.001	10.31 (5.29~20.09)	1.59	0.26	6.05	<0.001	4.90 (2.93~8.20)
Drinking history										
No					1.00 (Reference)					1.00 (Reference)
Yes	1.62	0.31	5.25	<0.001	5.06 (2.76~9.27)	1.54	0.26	5.92	<0.001	4.67 (2.80~7.78)
Hypertension										
No					1.00 (Reference)					1.00 (Reference)
Yes	1.47	0.31	4.69	<0.001	4.33 (2.35~8.00)	1.81	0.27	6.80	<0.001	6.11 (3.63~10.30)
Coronary heart disease										
No					1.00 (Reference)					1.00 (Reference)
Yes	1.33	0.30	4.40	<0.001	3.77 (2.09~6.81)	1.17	0.27	4.38	<0.001	3.22 (1.91~5.44)
Type 2 diabetes mellitus										
No					1.00 (Reference)					1.00 (Reference)
Yes	–0.05	0.34	–0.14	0.892	0.96 (0.49~1.86)	1.54	0.29	5.38	<0.001	4.67 (2.66~8.18)
Heart failure										
No					1.00 (Reference)					1.00 (Reference)
Yes	2.03	0.34	5.90	<0.001	7.58 (3.87~14.85)	3.04	0.46	6.62	<0.001	21.00 (8.52~51.74)
Age	0.01	0.01	0.80	0.424	1.01 (0.98~1.04)	–0.01	0.01	–0.54	0.586	0.99 (0.97~1.02)
BMI	–0.03	0.04	–0.79	0.431	0.97 (0.90~1.05)	0.23	0.04	5.98	<0.001	1.26 (1.17~1.36)

OR, odds ratio; CI, confidence interval; SE, Standard Error.

the detection of atrial fibrillation and frequent ventricular premature beat subtypes, which is consistent with the findings of previous studies [10,13].

In the univariate logistic regression analyses, several clinical factors—especially smoking history, drinking history, hypertension, and heart failure—showed large odds ratios with relatively wide 95% confidence intervals, particularly for Holter-based detection. This pattern likely reflects the high-risk nature of our cohort (all patients met at least one high-risk criterion, and arrhythmia prevalence was high), which reduces the number of truly unexposed patients and can yield imprecise and apparently inflated estimates in univariate models, especially when outcomes are common. Age was not significantly associated with positive arrhythmia detection, which may seem inconsistent with clinical experience; however, our sample had a narrow age range (all $\geq$45 years; median 67 years) and strong correlations between age and comorbidities such as hypertension, coronary heart disease, diabetes, and heart failure. In this context, the per-year effect of age is likely attenuated, and the odds ratios for age were very close to 1.00, suggesting a relatively flat association within this already high-risk cohort. Taken together, these results should be regarded as exploratory associations rather than causal effects, and confirmation in larger, more heterogeneous populations with multivariable modelling is needed.

From the perspective of clinical significance, the advantages of high-channel 12-lead Holter monitoring stem from its core characteristics of "long-duration, dynamic monitoring". Clinically, approximately 1/3 of atrial fibrillation cases are "paroxysmal atrial fibrillation", and the duration of such episodes is often short (usually less than 24 hours). Due to the limited detection time, the missed diagnosis rate of routine ECG for paroxysmal atrial fibrillation can be as high as 30%–50% [14,15]. In this study, high-channel 12-lead Holter monitoring additionally detected 20 cases of "Holter-only positive" atrial fibrillation. This finding strongly indicates that it can effectively compensate for the shortcomings of routine ECG in screening paroxysmal atrial fibrillation, providing a more accurate screening approach for patients with unexplained stroke or obvious palpitations but normal routine ECG results. This facilitates earlier definitive diagnosis and timely targeted treatment for such patients.

For frequent ventricular premature beats, their onset is closely associated with multiple factors, such as myocardial ischemia and autonomic nervous tension, exhibiting a significant feature of "temporal heterogeneity"—for example, the number of ventricular premature beats increases during physical activity but decreases at rest [16]. This dynamic variability, combined with underlying mechanisms like electrolyte imbalances or sympathetic activation, highlights Holter monitoring's role in the quantitative assessment for interventions such as ablation [17]. By accurately assessing the load and characteristics of ventricular premature beats, clinicians can formulate more evidence-based treatment plans, avoiding over- or under-treatment.

While studies have demonstrated that adhesive patch-type electrocardiogram devices, by extending monitoring duration (e.g., to 72 hours), can significantly improve the detection rate of paroxysmal atrial fibrillation (PAF)—reportedly by 2.2 times compared to 24-hour Holter monitoring—their widespread clinical adoption must consider algorithm-enhanced accuracy and device cost [18,19]. The single-lead design of many patch monitors may compromise signal quality, necessitating complementary advances in artificial intelligence (AI)-assisted analysis to ensure diagnostic reliability [20]. Therefore, despite the advantages of patch devices in extended monitoring and patient comfort, Holter monitoring remains a more widely adopted and logistically feasible option in routine clinical practice, particularly suitable for short- to medium-term monitoring scenarios [21].

However, this study also has certain limitations. First, the sample size is relatively small (only 300 subjects were included), which may affect the statistical power for low-incidence subtypes (e.g., atrioventricular block) and make it difficult to fully demonstrate the differences between high-channel 12-lead Holter and routine ECG in these subtypes. Second, the study did not conduct stratified analysis based on the severity of arrhythmias (e.g., CHA_2DS_2-VASc score for atrial fibrillation, Lown classification for ventricular premature beats), which limited the ability to further explore the detection advantages of high-channel 12-lead Holter for high-risk arrhythmias. Future studies could expand the sample size and conduct subgroup analysis incorporating arrhythmia severity to more comprehensively evaluate the clinical value of high-channel 12-lead Holter, thereby providing stronger evidence for its broader clinical application.

6. Conclusion

The high-channel 12-lead Holter significantly outperforms the routine 12-lead ECG in detecting arrhythmias in high-risk populations, particularly paroxysmal atrial fibrillation and frequent ventricular premature beats. Owing to its long-duration, dynamic monitoring capability, the high-channel 12-lead Holter provides an effective supplement to routine ECG for early identification of clinically significant arrhythmias in high-risk individuals and may support more timely risk stratification and intervention. Future studies with larger cohorts and stratified analyses across arrhythmia subtypes and severity will help further refine patient selection and monitoring strategies.

Key Points

• This retrospective study demonstrates that the high-channel 12-lead Holter ECG significantly improves arrhythmia detection rates compared to the routine 12-lead

ECG in high-risk populations, particularly for atrial fibrillation and frequent ventricular premature beats.

• Baseline risk factors such as smoking, hypertension, and heart failure are strongly associated with positive detections in univariate logistic regression, highlighting the need for targeted screening.

• The advantages of Holter monitoring lie in its extended monitoring capability, which captures paroxysmal events missed by short-duration methods, providing clinical value for early intervention.

• Limitations include sample size and lack of severity stratification, underscoring the need for future research with larger cohorts and subgroup analyses.

• Overall, Holter monitoring serves as an effective supplement to routine ECG, offering evidence-based support for cardiovascular risk management in high-risk populations.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

LH and XHJ designed the research study. XHJ and LH performed the research. XHJ and LH analyzed the data. LH drafted this article. Both authors contributed to the important editorial changes in the manuscript. Both authors read and approved the final manuscript. Both 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 retrospective study was approved by the Ethics Committee of Zibo Central Hospital (approval number: 2025262). Case data were extracted from the hospital's electronic medical record system, ECG database, and clinical diagnosis and treatment records. The protocol was reviewed by the Ethics Committee of Zibo Central Hospital, which confirmed eligibility for consent waiver. The waiver was granted because (i) analyses were performed on existing records that had been anonymized before investigator access; (ii) the study involved no more than minimal risk; and (iii) participants' privacy was safeguarded through de-identification and secure data handling. The study was conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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