Diagnostic Value of Holter Monitoring QT Interval Combined with Treadmill Exercise Test for Multivessel Coronary Artery Disease in Patients with Coronary Heart Disease

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Abstract: Objective: To investigate the diagnostic value of Holter monitoring QT interval combined with treadmill exercise test (TET) in patients with multivessel coronary artery disease in coronary heart disease. Methods: A total of 230 patients with coronary artery disease treated at our hospital between July 2023 and December 2024 were enrolled. Patients were grouped based on coronary angiography results as the gold standard: 100 cases in the multivessel disease group and 130 cases in the non-multivessel disease group. We compared QT interval and TET-related indicators between the two groups and analyzed the diagnostic efficacy of single QT interval detection, single TET detection, and combined detection for detecting multivessel coronary artery disease. Results: Both QT interval and TET-related indicators were significantly higher in the multivessel group than in the non-multivessel group (P<0.05). The diagnostic performance metrics (sensitivity, specificity, accuracy) of combined detection significantly outperformed single-method detection (P<0.05). Conclusion: Combining Holter ECG QT interval monitoring with exercise stress testing (EST) significantly enhances diagnostic efficacy for multi-vessel coronary artery disease in CHD patients. This noninvasive, convenient approach warrants clinical implementation.

***Keywords*:** Holter monitoring; QT interval; exercise stress test; coronary heart disease; multivessel coronary artery disease

1. Introduction

Coronary heart disease remains a leading cause of morbidity and mortality worldwide. Multivessel coronary artery disease, as a severe subtype, significantly increases the risk of myocardial infarction and sudden cardiac death[1,2]. Accurate early diagnosis of multivessel coronary artery disease is clinically significant for developing individualized treatment plans and improving long-term patient outcomes. Coronary angiography remains the gold standard for diagnosing coronary artery lesions, clearly revealing the location, severity, and extent of vascular stenosis. However, this invasive procedure carries potential risks such as puncture bleeding and vascular injury, and its high cost limits its application for routine screening in large populations[3].

Holter monitoring enables 24-hour continuous ECG surveillance, effectively capturing intermittent myocardial ischemia and ventricular repolarization abnormalities during rest. The QT interval, as a core indicator reflecting ventricular repolarization, shows a close correlation with the severity of coronary artery disease [4]. Exercise stress testing induces myocardial ischemia through graded exercise loads, providing a direct assessment of coronary reserve function. Related indicators further reflect the extent and distribution of myocardial ischemia [5].

Single diagnostic methods have clear limitations: Holter monitoring lacks sufficient sensitivity for detecting stress-induced myocardial ischemia, while exercise stress testing is prone to result bias influenced by patient fitness levels and autonomic nervous system function. In recent years, multimodal combined detection has emerged as a research focus in cardiovascular disease diagnosis, though its value in diagnosing multivessel coronary artery disease requires further validation. Therefore, this study selected patients with coronary artery disease to investigate the diagnostic efficacy of combining Holter monitoring QT interval with exercise stress testing for multivessel coronary artery disease, aiming to provide clinicians with a noninvasive, efficient diagnostic approach.

2. Materials and Methods

2.1 Study Population

A total of 230 patients with coronary heart disease were enrolled in this study, all of whom received treatment at our hospital between July 2023 and December 2024. Groups were stratified based on coronary angiography results as the gold standard: 100 patients in the multivessel disease group and 130 patients in the non-multivessel disease group. Comparisons of general characteristics between groups showed no significant differences (P > 0.05), as shown in Table 1.

Table 1. Comparison of General Characteristics Between Groups

Item		Multivessel Disease Group (n=100)	Non-Multivessel Disease Group (n=130)	t/X^2 Value	P Value
Gender (%)	Male	58 (58.00)	74 (56.92)	0.027	0.870
	Female	42 (42.00)	56 (43.08)		
Mean Age (years)		63.79±7.82	62.13±8.69	0.596	0.552
BMI (kg/m^2)		23.57±3.24	23.49±3.18	0.188	0.851
Systolic Blood Pressure (mmHg)		134.28±15.61	136.87±14.56	1.296	0.196
Diastolic Blood Pressure (mmHg)		75.83±8.15	76.23±7.94	0.374	0.708
Comorbidities (%)	Hypertension	65 (65.00)	98 (75.38)	2.952	0.086
	Diabetes	35 (35.00)	32 (24.62)		
Smoking history (%)		46 (46.00)	62 (47.69)	0.065	0.799
Alcohol consumption history (%)		71 (71.00)	97 (74.62)	0.375	0.540

2.2 Inclusion and Exclusion Criteria

Inclusion Criteria: (1) Patients presenting with symptoms such as chest tightness, chest pain, or palpitations with a high clinical suspicion of coronary artery disease; (2) All patients completed Holter monitoring, TET, and coronary angiography within one week of each other; (3) Patients were conscious and able to cooperate with the study; (4) Patients signed an informed consent form.

Exclusion Criteria: (1) Patients with acute myocardial infarction, severe arrhythmia, heart failure, or cardiomyopathy; (2) Patients experiencing hypertensive crisis, severe hepatic or renal insufficiency, or electrolyte imbalance; (3) Patients unable to tolerate Holter monitoring or TET; (4) Patients with prior history of coronary intervention or bypass graft surgery; (5) Patients who withdrew from the study.

2.3 Examination Methods

(1) Holter Monitoring: Continuous 24-hour monitoring was performed using a Mortara H12+ Holter monitor with a sampling frequency of 1000 Hz. Prior to monitoring, patients were instructed on device wear precautions and advised to maintain routine activities while avoiding strenuous exercise and intense emotional fluctuations. They were also directed to record the timing of any discomfort such as chest tightness or pain during the monitoring period. After monitoring, data were imported into the dedicated analysis system for automated processing. Two senior ECG physicians performed manual blinded corrections, focusing on measuring the QT interval—the duration from the onset of the QRS complex to the end of the T wave. Select clear, interference-free cardiac cycles from the 12 leads. Measure the QT interval for three consecutive cycles per lead and calculate the average. The final QT interval result for the patient is the mean of these lead averages.

(2) Exercise Treadmill Test: Employing the DMS300/BTR01 exercise treadmill device, a graded exercise stress test was conducted using the Bruce protocol. Baseline resting 12-lead ECG and blood pressure readings were recorded prior to exercise. Continuous monitoring of ECG waveform changes and blood pressure fluctuations occurred during exercise, with data recorded every 3 minutes. Recording intervals were shortened if abnormal indicators emerged. Exercise termination criteria: - Reaching target heart rate (Target HR = 220 - actual age) - Development of typical angina symptoms - ST-segment depression ≥0.2 mV (horizontal or downsloping) or elevation ≥0.1 mV - Significant blood pressure increase (systolic >210 mmHg) or decrease (≥20 mmHg below baseline) - Severe arrhythmia or patient intolerance to exercise. Following the test, continue monitoring the patient's ECG and blood pressure until baseline recovery. Calculate the T wave peak-to-end interval (Tpe), microvolt-level T wave alternans (MTWA), and ST/heart rate (HR) index. The ST/HR index formula is: (peak exercise ST segment depression value - baseline ST segment depression value) / (peak exercise HR - baseline HR).

(3) Coronary angiography: Using the Judkins technique, contrast agent was injected into the coronary arteries via the femoral or radial artery access. Multi-angle images were captured using a digital subtraction angiography system. Two experienced cardiologists independently interpreted the results, assessing stenosis severity using the Gensini scoring system. Stenosis ≥50% was defined as significant disease. Multivessel disease was defined as ≥50% stenosis in two or more major coronary artery branches: left anterior descending artery, left circumflex artery, and right coronary artery.

2.4 Statistical Methods

Data were analyzed using SPSS 26.0 software. Count data were recorded as counts and percentages and analyzed using the chi-square test. Continuous data were recorded as means and standard deviations and analyzed using the t-test. A P value

< 0.05 was considered statistically significant.

3. Results

3.1 Comparison of Holter ECG QT Interval and TET-Related Indicators Between Groups

The QT interval and all TET indicators were significantly higher in the multivessel disease group than in the non-multivessel disease group (P < 0.05). See Table 2.

Table 2. Comparison of Holter ECG QT Interval and TET-Related Indicators Between Groups

Group	n	QT Interval (ms)	Tpe (ms)	MTWA (μV)	ST/HR Index[μV/ (beat·min)]
Multiple Lesion Group	100	442.36±48.35	108.57±12.39	66.53±8.15	4.71±0.63
Non-Multiple Lesion Group	130	405.89±49.23	85.76±13.15	56.71±6.10	3.68±0.64
tValue		5.613	13.371	10.452	12.182
PValue		0.000	0.000	0.000	0.000

3.2 Comparison of Diagnostic Efficacy for Multivessel Coronary Artery Disease Among Different Testing Methods

The diagnostic efficacy of combined QT interval monitoring with TET during ambulatory ECG monitoring was superior to that of single testing methods. P<0.05. See Table 3.

Table 3. Comparison of Diagnostic Efficacy for Multivessel Coronary Artery Disease Among Different Testing Methods

Test Method	Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
QT Interval Single Test	74.00	76.90	75.70	71.30	79.20
TET Single Test	79.00	81.50	80.40	77.50	82.80
Combined Test	87.00	92.30	90.00	88.90	91.00

4. Discussion

Early and precise identification of multivessel coronary artery disease is crucial for improving patient outcomes. While coronary angiography serves as the gold standard for diagnosis, clearly revealing the location and severity of vascular stenosis, its invasive nature and high examination costs make it difficult to implement as a routine screening tool in primary care settings [6]. Our findings reveal that both electrocardiographic indicators and exercise stress test parameters in the multivessel disease group differ significantly from those in the non-multivessel disease group. This phenomenon stems from the fact that multivessel coronary stenosis induces persistent myocardial hypoperfusion and hypoxia, leading to reduced stability of myocardial electrical activity. This, in turn, prolongs ventricular repolarization and exacerbates myocardial ischemia during exercise stress.

Holter monitoring enables 24-hour continuous ECG surveillance, effectively capturing intermittent myocardial ischemia and ventricular repolarization abnormalities during rest and daily activities. Its core indicators provide direct reflection of myocardial electrophysiological alterations[7]. Exercise stress testing induces myocardial ischemia through graded exercise loads, assessing coronary reserve function, with related indicators further revealing the extent and severity of myocardial ischemia[8]. However, each method has distinct limitations: Holter monitoring exhibits poor sensitivity for detecting occult myocardial ischemia during exercise, while exercise stress testing results are susceptible to patient fitness levels and autonomic nervous system function, leading to potential bias. Neither method alone can fully meet the demands of precise clinical diagnosis[9].

This study confirms that the diagnostic efficacy of combining Holter ECG parameters with exercise stress testing significantly surpasses that of either method alone. This superiority stems from the complementary nature of the two techniques, which assess coronary artery lesions from distinct perspectives, forming a synergistic diagnostic system. This conclusion aligns with multiple published studies in recent years. Some research indicates that the diagnostic concordance rate of noninvasive ECG combined with stress testing is significantly higher than that of single tests, offering advantages of operational convenience and low cost, making it more suitable for large-scale population screening[10,11]. Other studies suggest that the combined testing approach can effectively reduce both missed diagnosis and misdiagnosis rates, providing reliable evidence for formulating individualized treatment plans in clinical practice[12].

This study has certain limitations. All samples were sourced from a single center, and the retrospective nature of the study may introduce selection bias. Additionally, the impact of varying lesion severity on diagnostic efficacy was not thoroughly analyzed. Future prospective, multicenter studies with larger samples are needed to further validate the clinical value of combined detection approaches. Additionally, incorporating more ECG indicators to construct diagnostic models could enhance diagnostic accuracy and specificity, providing richer theoretical foundations and practical guidance for noninvasive diagnosis of multivessel coronary artery disease.

5. Conclusion

This study confirms that the combination of Holter ECG QT interval monitoring and exercise stress testing significantly outperforms single-modality approaches in diagnosing multi-vessel coronary artery disease in patients with coronary heart disease. This combined strategy achieves complementary technical advantages, effectively enhancing diagnostic sensitivity and specificity while reducing rates of missed and misdiagnosis. Additionally, its noninvasive, convenient, and cost-effective characteristics make it suitable for promotion across all levels of medical institutions, particularly primary care settings. It provides reliable evidence for early screening and disease assessment of multi-vessel coronary artery disease in CHD, demonstrating high clinical application value.

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