Comparative analysis of ischemic changes in electrocardiogram and coronary angiography results
A retrospective study

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Abstract
To improve the correct diagnosis rate of coronary heart disease and to explore the guiding value of electrocardiogram (ECG) ST-T ischemic changes in the clinical diagnosis of coronary heart disease.

A retrospective analysis was conducted on a total of 310 cases who underwent a conventional 12-lead ECG, 12-lead dynamic ECG (DECG, Holter) with ST-T ischemic changes, and then coronary angiography (CA) within 1 week in Qingdao Starr Heart Hospital from June 2015 to April 2020 in the study. Ischemic ST-T changes were evaluated using conventional diagnostic criteria, and Judkins diagnostic criteria were used in CA. The sensitivity and specificity of ECG were analyzed.

The specificity of ST-T changes in conventional ECG for the diagnosis of coronary heart disease is 33.7% and the sensitivity is 66.0%. The specificity of ST-T changes in Holter in the diagnosis of coronary heart disease is 55.6% and the sensitivity is 32.2%. The sensitivity of conventional ECG for the diagnosis of coronary heart disease is better than Holter, but its specificity is inferior to Holter. The negative likelihood ratios of the 2 ECGs for the diagnosis of coronary heart disease were 1.0 and 1.22, both >0.1, and the positive likelihood ratios were 0.99 and 0.73, both <10. The positive results of ST-T in conventional ECG were 128 males (65.7%), 77 females (66.9%), \((P<.05)\), 148 cases (74.7%) in the group \(\geq 60\) years old, and 75 cases in the group less than 60 years (67%), \((P>.05)\). The positive results of ST-T change of DECG were 135 males (69.2%), 69 females (60.0%), \((P<.05)\), 152 cases (78.7%) in the group \(\geq 60\) years, and 83 cases (70.9%) in the group less than 60 years, \((P>.05)\). Coronary heart disease-related factors: symptoms, hypertension, diabetes, cancer, family history, smoking history as independent variables, and a binary multivariate logistic regression analysis was performed.

The sensitivity of DECG in the diagnosis of myocardial ischemia in women and the elderly was slightly higher than that in men and young cases. ST-T ischemic changes in ECG are more significant for the diagnosis of coronary heart disease in male patients. Smoking, hypertension, diabetes, and family history are all high-risk factors for coronary heart disease.

Abbreviations: CA = coronary angiography, CECG = conventional 12-lead electrocardiogram, CHD = coronary atherosclerotic heart disease, ECG = electrocardiogram, DECG = dynamic 12-lead electrocardiogram, NLR = negative likelihood ratio, OR = odds ratio, PLR = positive likelihood ratio, ROC = receiver operating characteristic.

Keywords: coronary angiography, electrocardiogram, ischemic change

1. Introduction
Coronary atherosclerotic heart disease (CHD), also known as ischemic heart disease, is myocardial ischemia, hypoxia, or necrosis caused by stenosis or occlusion of stenosis. The incidence of CHD has increased with the rapid development of social and economic living standards and the prolongation of life expectancy.\(^{[1,2]}\) CHD has become one of the major diseases threatening human health. Coronary angiography (CA), which can be used to observe the stenosis of coronary vessels and the degree of lesions and accurately guide the assessment of prognosis, has become the gold standard for the diagnosis of CHD. However, it needs hospitalization as well as its related in-hospital complications.

Timely diagnosis can effectively prevent cardiovascular diseases and reduce cardiac events. Electrocardiogram (ECG), as a noninvasive tool, remains a clinically simple, easy, rapid diagnostic method, and its ST-T ischemic change has an important value in the diagnosis of CHD.\(^{[3–7]}\) Initial ECG has been used to assess more than 75% of patients with angina.\(^{[8]}\)

However, it was shown that the ECG has limited accuracy in the diagnostic workup of CAD.\(^{[9,10]}\) Fesmire et al presented that
the initial conventional 12-lead ECG (CECG) had a sensitivity of only 55.4% in patients ultimately diagnosed with the acute coronary syndrome. Similarly, Rude et al. showed that less than 50% of those diagnosed with acute myocardial infarction demonstrated ST-segment changes on their initial ECG. Even more, a 43% sensitivity was found for CECG by Edenbrand et al.

In this work, it is aimed to address the diagnostic value of the ECG for the detection of significant CHD in different age and gender in comparison with conventional invasive CA.

2. Information and methods

2.1. General information

From June 2015 to April 2020, 310 patients with episodes of chest pain and chest tightness were selected for treatment. Patients with CHD and angina pectoris were hospitalized. There were 195 males and 115 females (menopausal history ≥5 years), with an average age of 62.8 ± 9.4, of which 159 had hypertension, 124 had diabetes, 96 had both hypertension and diabetes, and 21 had persistent atrial fibrillation, 7 cases were cancer postoperative (colon cancer, rectal cancer, and breast cancer), 52 cases of 2 generations of immediate family members with a clear history of coronary heart disease (see Table 1 for details).

2.2. Methods and diagnostic criteria

Medical records were reviewed to identify cases. By consulting medical records, we selected 310 patients who had ST-T ischemic changes in CECG and or 12-lead Holter ECG and underwent CA within 1 week and retrospectively analyzed ECG and coronary arteries. Two diagnostic methods for coronary heart disease by angiography, to study the sensitivity and specificity of ST-T ischemic changes of ECG to CA stenosis ≥50%, to guide clinical diagnosis and treatment in time. The authors had no access to information that could identify individual participants during or after data collection.

2.2.1. ECG diagnostic criteria for CHD. Dynamic 12-lead electrocardiogram (DECG) diagnostic criteria: The ST segment exhibits horizontal or hypotonic depression ≥0.1 mv (1.0mm), sustained ≥1.0 min, and the interval between 2 episodes is ≥5.0 min. The normal ST segment downward measurement point is 80ms after the J point and automatically becomes 50ms after the J point when the heart rate is >120/min.

CECG diagnostic criteria:

- **T-wave changes:**
  - Subendocardial ischemia exhibits a symmetric, erect, and towering T wave consistent with the direction of the QRS main wave.
  - Subcardiac or transmural myocardial ischemia exhibits a symmetric deep T wave.

- **ST-segment changes:**
  - Subendocardium: Horizontal or downward oblique depression ≥0.1 mv has a diagnostic value. The J-point ST segment moves down by ≥2mm 80ms after the J point. Subepicardial or transmural myocardial ischemia: manifested as ST-segment elevation at the onset of symptoms, diagnostic criteria: ST-segment elevation ≥1 mm in 2 or more limb leads, or 2 or more chest leads joint ST segment elevation ≥2 mm

2.2.2. Criteria for diagnosis of CHD by CA. CA was performed using the Judkins method for selective multi-position projection of the left and right coronary arteries, with coronary artery stenosis ≥50% as positive. The degree of stenosis is defined as mild when stenosis is 50%–74%, moderate when it is 75%–90%, and severe when it is >90%.

2.3. Statistical analysis

In this paper, GPower3.1 statistical software was used to analyze the variance of the sample size, and the test power (1 – β) ≥0.8 is effective. The experimental data obtained in this work were analyzed with IBM SPSS Statistics 22.0 statistical software. Measurement data were expressed as means. A t test was conducted, count data were expressed in percentage, and a χ² test was performed. Test level α was 0.05, and differences were statistically significant at P < .05. The sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio were defined as follows:

- Sensitivity = true positive/(true positive + false negative) × 100%.
- Specificity = true negative/(true negative + false positive) × 100%.
- Positive likelihood ratio (PLR) = sensitivity/(1 – specificity).
- Negative likelihood ratio (NLR) = (1 – sensitivity)/specificity.

In addition, with coronary heart disease as the dependent variable and coronary heart disease-related factors: symptoms, hypertension, diabetes, cancer, family history, and smoking history as independent variables, a binary multivariate logistic regression analysis was performed.

3. Ethics statement

The Qingdao Sttarr Heart Hospital Ethics Review Committee provided ethics approval for this study (ER19-0008). Given that this study was conducted using strictly anonymized laboratory and administrative databases, informed consent was not required. This study complies with the Chinese law on the protection of privacy.

4. Results

Table 2 shows that the positive results of ST-T changes in CECG were observed in 128 males (65.7%) and 77 females (66.9%). No statistically significant differences in ischemic ST-T changes...
between CECG and gender difference ($P > .05$) were observed. A total of 135 male cases (69.2%) and 69 female cases (60.0%) were positive for ST-T change in DECG. The difference between ST-T ischemic change in DECG and gender was statistically significant ($P < .01$). A statistically significant difference between CA and gender difference ($P < .05$) was observed.

Table 3 shows that 148 cases (74.7%) in the group of patients aged over 60 years and 75 cases (67.0%) in the group of young patients were positive for ST-T changes in CECG, and the statistical difference between ST-T ischemic changes and age difference in CECG was significant ($P < .01$). A total of 152 cases (78.7%) in the group of patients aged over 60 years and 83 cases (70.9%) in the <60 years old group had positive results for ST-T changes in DECG. The statistical difference between the ischemic ST-T changes in DECG and age difference was significant ($P < .05$). No significant differences between CA and age difference ($P > .05$) were observed.

Table 4 shows that smoking, hypertension, diabetes, and family history are all independent risk factors for coronary heart disease (OR $> 1$).

As shown in Table 5 and Figure 1, the sensitivity of CECG diagnosis in CHD was better than that of DECG, and the specificity of CECG was inferior to that of DECG. The negative likelihood ratios of the 2 ECGs for the diagnosis of coronary heart disease were 1.0 and 1.22, both $> 0.1$, and the positive likelihood ratios were 0.99 and 0.73, both $< 10$.

5. Discussion
It is found that ST-T ischemic changes in ECG have a certain value for the clinical diagnosis of coronary heart disease, but the possibility of excluding or diagnosing coronary heart disease is still not significant. ST-T ischemic changes in ECG were more significant in diagnosing CHD in male patients. Smoking,
hypertension, diabetes, and family history are all high-risk risk factors for coronary heart disease.

Diagnosis of coronary heart disease based on ST-T ischemic changes in ordinary ECG has gender differences between men and women. The main reason could be that some of the female patients selected in the study are premenopausal or menopausal <5 years, which increases the level of endogenous estrogen in women. The protective effect reduces the incidence of coronary heart disease in female patients. Endogenous female estrogen directly expands the coronary vascular smooth muscle function and regulates the role of low- and high-density lipoprotein in vivo.\cite{14} It was also found that the microvascular difference between the genders make an important role. An NHLBI WISE\cite{15} study showed that approximately half of the coronary angiograms reveal microvascular dysfunction in women with non-obstructive CHD. Han et al\cite{16} found that atherosclerosis and epicardial vascular endothelial dysfunction are highly pronounced in male patients, and female microangiopathy is conventional. The results of the ARIC study\cite{17} showed that the degree of retinal artery stenosis is positively correlated with the incidence of CHD in women. The absence of this relationship in men suggests that microvascular disease is more important in the pathogenesis of CHD in women than in men.

DECG can effectively record the changes in ECG activity in the whole-day exercise state and the resting state and can thus be widely used in clinical practice. However, CHD diagnosis based on ischemic ST-T changes using DECG showed significant gender differences (female 54.5%, male 28.6%) in this study. Several female patients with false-positive ST-T changes may be associated with autonomic dysfunction, menopausal syndrome, X syndrome, and other related factors.\cite{18} Further observation and research are needed to determine whether the position of electrode placement is likely to change with the change in body position and activity, thereby causing a change in artifacts.

The comparison of the sensitivity and specificity of ST-T ischemic changes of ordinary ECG and Holter ECG for the diagnosis of coronary heart disease shows that the sensitivity of ordinary ECG in diagnosing coronary heart disease is better than that of Holter and the specificity is inferior to Holter. The differences between the sensitivity and specificity of CECG and DECG may be attributed to the inclusion of the CECG of the selected patients in ECG at the onset of the symptoms. DECG is often obtained after drug treatment, at which point the frequency of symptomatic episodes has decreased or seizures may no longer occur. The NLRs of the 2 ECGs for CHD diagnosis were very close, and the PLRs were 0.18 and 0.14, respectively. The

|                | Positive | Negative | Total | Specificity % | Sensitivity % | PLR   | NLR   |
|----------------|----------|----------|-------|--------------|--------------|-------|-------|
| CECG Positive  | 142      | 63       | 205   | 33.7%        | 66.0%        | 0.99  | 1.0   |
| Negative       | 73       | 32       | 105   |              |              |       |       |
| DECG Positive  | 97       | 77       | 174   | 36.3%        | 51.3%        | 0.81  | 1.34  |
| Negative       | 92       | 44       | 136   |              |              |       |       |

CA = coronary angiography, CHD = coronary atherosclerotic heart disease, DECG = dynamic 12-lead electrocardiogram, ECG = electrocardiogram, NLR = negative likelihood ratio, PLR = positive likelihood ratio.

Figure 1. ROC curve of data fitting. ROC = receiver operating characteristic.
5.1. Limitations

This work is based on small sample size. Thus, its conclusion may have limited generalizability.

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Author contributions

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