Meta-Analysis of Observational Studies in Epidemiology

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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 Sttarr 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 ≥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 ≥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

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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,[11] Similarly, Rude et al[12] 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.[13]

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 (1.0 mm), sustained ≥1.0 min, and the interval between 2 episodes is ≥5.0 min. The normal ST segment downward measurement point is 80 ms after the J point and automatically becomes 50 ms 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 ≥2 mm 80 ms 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%.

Table 1

Gender, age, and risk factor composition of 310 patients undergoing coronary angiography.

Risk factors	Cases (%)	Gender: Male	Gender: Female	Average age
High blood pressure	159 (51.2)	78	81	57.8
diabetes	124 (40)	67	57	63.2
Hypertension+diabetes	96 (30.9)	41	55	55.7
Persistent atrial fibrillation	21 (6.7)	2	19	67.1
After cancer surgery				
Colon cancer	2 (0.6)	2	0	59.4
Rectal cancer	2 (0.6)	2	0	62.1
Breast cancer	3 (0.9)	0	3	59.3
CHD family history	52 (16.7)	35	17	43.6
Smoking history (≥10 years)	79 (25.4)	78	1	67.9
No	27 (8.7)	16	11	47.4

CHD = coronary atherosclerotic heart disease.

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 $(1-\beta) \geq 0.8$ 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 χ^2 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

Table 2

ECG ST-T ischemic changes and CA in patients of different genders.

Diagnosis method	Male (195) (Number %)		Female (115) (Number %)		Total (310) (Number %)		*T*	*P*
CECG							4.13	.026
Positive	128	65.7	77	66.9	205	66.1		
Negative	67	34.3	38	33.1	105	33.9		
DECG							4.93	.016
Positive	123	65.1	51	42.1	174	56.1		
Negative	66	34.9	70	57.9	136	43.9		
CA							6.29	.008
Positive	102	52.3	67	58.3	169	54.5		
Negative	93	47.7	48	41.7	141	45.5		

Electrocardiogram positive: ST or T or ST and T show ischemic changes.
Electrocardiogram negative: ST or T or ST and T do not show ischemic changes.
CA=coronary angiography, CECG=conventional 12-lead electrocardiogram, DECG=dynamic 12-lead electrocardiogram, ECG=electrocardiogram.

Table 3

ECG ST-T ischemic changes and CA in patients of different ages.

Diagnosis method	≥60 years old (Number %)		<60 years old (Number %)		In total (310) (Number %)		χ^2	*P*
CECG							2.88	.063
Positive	158	76.0	47	50.8	205	66.1		
Negative	50	24.0	55	49.2	105	33.9		
DECG							4.15	.025
Positive	132	68.4	42	31.6	174	56.1		
Negative	61	31.6	91	68.4	136	43.9		
CA							4.72	.018
Positive	117	70.5	52	36.1	169	54.5		
Negative	49	29.5	92	63.9	141	45.5		

CA=coronary angiography, DECG=dynamic 12-lead electrocardiogram, ECG=electrocardiogram.

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 old and 75 cases (67.0%) in the group of young patients were positive for ST-T change 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,

Table 4

Multivariate logistic regression analysis of coronary heart disease.

Variable	Standard error	*P*	OR	95% Confidence interval of OR	
				Floor level	Upper limit
Smoking history	2.150	.307	9.005	.133	608.514
Hypertension	2.223	.682	2.489	.032	194.327
Diabetes	.745	.551	1.560	.362	6.722
Cancer	.584	.580	.724	.231	2.274
Family history	1.746	.743	1.772	.058	54.249
Symptom	2.870	.358	.071	.000	19.800

OR=odds ratio.

Table 5

Evaluation of ECG ST-T ischemic changes in the diagnosis of CHD.

	CA						
	Positive	**Negative**	**Total**	**Specificity %**	**Sensitivity %**	**PLR**	**NLR**
CECG				33.7%	66.0%	0.99	1.0
Positive	142	63	205				
Negative	73	32	105				
DECG				36.3%	51.3%	0.81	1.34
Positive	97	77	174				
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.

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.[14] It was also found that the microvascular difference between the genders make an important role. An NHLBI WISE[15] study showed that approximately half of the coronary angiograms reveal microvascular dysfunction in women with non-obstructive CHD. Han et al[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[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.[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

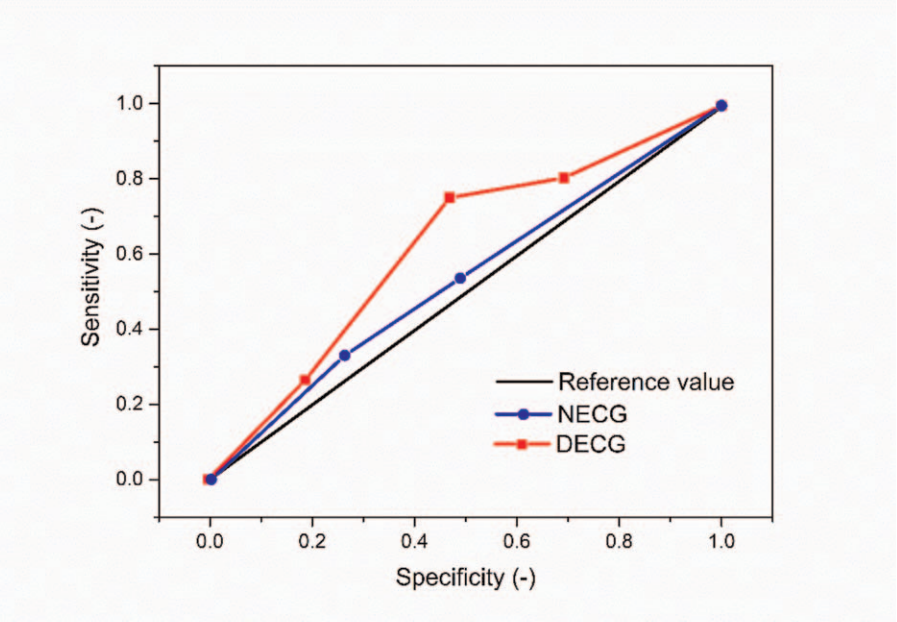

Figure 1. ROC curve of data fitting. ROC = receiver operating characteristic.

possibility of excluding or diagnosing CHD was still not significant enough. In addition, multivariate logistic regression analysis was performed in this study, and the results showed that smoking, hypertension, diabetes, and family history were all independent risk factors for CHD.

The recognition of patients with CHD has heavily relied on the ECG for assessing ST-segment changes, T inversion, and Q-wave appearance associated with ischemia. Mahmoodzadeh et al[19] found that each ECG parameter independently could poorly predict CHD with very low sensitivity, however, predictive power was significantly increased when considered more parameters together. Therefore, judgment about the presence of CHD should be performed on the sum of ECG parameters findings. Moreover, many non-coronary arteries can cause ST-T changes, which are indistinguishable from ECGs of myocardial ischemia. In addition, several patients who are clinically undiagnosed can also exhibit abnormal ST-T changes. Therefore, clinicians should strictly control the operation of ECG in combination with patient symptoms, medical history, risk factors, CECG, DECG, and CA to improve the correct diagnosis rate of CHD, reduce the unnecessary psychological burden of patients, and reduce the use of medical resources.

5.1. Limitations

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

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References

[1] Bahekar AA, Singh S, Saha S, Molnar J, Arora R. The prevalence and incidence of coronary heart disease is significantly increased in periodontitis: a meta-analysis. Am Heart J 2007;154:830–7.

[2] Humphrey LL, Fu R, Buckley DI, Freeman M, Helfand M. Periodontal disease and coronary heart disease incidence: a systematic review and meta-analysis. J Gen Intern Med 2008;23:2079–86.

[3] Gianrossi R, Detrano R, Mulvihill D, et al. Exercise-induced ST depression in the diagnosis of coronary artery disease. A meta-analysis. Circulation 1989;80:87–98.

[4] de Luna AB, Cygankiewicz I, Baranchuk A, et al. Prinzmetal angina: ECG changes and clinical considerations: a consensus paper. Ann Noninvasive Electrocardiol 2014;19:442–53.

[5] Holmvang L, Andersen K, Dellborg M, et al. Relative contributions of a single-admission 12-lead electrocardiogram and early 24-hour continuous electrocardiographic monitoring for early risk stratification in patients with unstable coronary artery disease. Am J Cardiol 1999; 83:667–74.

[6] Nakashima M, Hashimoto H, Kanamaru M, Nagaya T, Hashizume M, Oishi H. Experimental studies and clinical report on the electrical alternans of ST segment during myocardial ischemia. Jpn Heart J 1978;19:396–408.

[7] Saetre HA, Selvester RH, Solomon JC, Baron KA, Ahmad J, Ellestad ME. 16-lead ECG changes with coronary angioplasty. Location of ST-T changes with balloon occlusion of five arterial perfusion beds. J Electrocardiol 1992;24(Suppl):153–62.

[8] Daly CA, Clemens F, Sendon JL, et al. The clinical characteristics and investigations planned in patients with stable angina presenting to cardiologists in Europe: from the Euro Heart Survey of Stable Angina. Eur Heart J 2005;26:996–1010.

[9] Horácek BM, Wagner GS. Electrocardiographic ST-segment changes during acute myocardial ischemia. Card Electrophysiol Rev 2002;6: 196–203.

[10] Rosenmann D, Mogilevski Y, Amit G, Davrath LR, Tzivoni D. High-frequency QRS analysis improves the specificity of exercise ECG testing in women referred for angiography. J Electrocardiol 2013;46:19–26.

[11] Fesmire FM, Percy RF, Bardoner JB, Wharton DR, Calhoun FB. Usefulness of automated serial 12-lead ECG monitoring during the initial emergency department evaluation of patients with chest pain. Ann Emerg Med 1998;31:3–11.

[12] Rude RE, Poole WK, Muller JE, et al. Electrocardiographic and clinical criteria for recognition of acute myocardial infarction based on analysis of 3,697 patients. Am J Cardiol 1983;52:936–42.

[13] Edenbrand L, Pahlm O, Lyttkens K, Albrechtsson U. Vectorcardiogram more sensitive than 12-lead ECG in the detection of inferior myocardial infarction. Clin Physiol 1990;10:551–9.

[14] Tykocki NR, Boerman EM, Jackson WF. Smooth muscle ion channels and regulation of vascular tone in resistance arteries and arterioles. Compr Physiol 2017;7:485–581.

[15] Reis SE, Holubkov R, Conrad Smith AJ, et al. Coronary microvascular dysfunction is highly prevalent in women with chest pain in the absence of coronary artery disease: results from the NHLBI WISE study. Am Heart J 2001;141:735–41.

[16] Han SH, Bae JH, Holmes DRJr, et al. Sex differences in atheroma burden and endothelial function in patients with early coronary atherosclerosis. Eur Heart J 2008;29:1359–69.

[17] Wong TY, Klein R, Sharrett AR, et al. Retinal arteriolar narrowing and risk of coronary heart disease in men and women. The Atherosclerosis Risk in Communities Study. JAMA 2002;287:1153.

[18] McCabe JM, Armstrong EJ, Kulkarni A, et al. Prevalence and factors associated with false-positive ST-segment elevation myocardial infarction diagnoses at primary percutaneous coronary intervention-capable centers: a report from the activate-SF registry. Arch Intern Med 2012;172:864–71.

[19] Mahmoodzadeh S, Moazenzadeh M, Rashidinejad H, Sheikhvatan M. Diagnostic performance of electrocardiography in the assessment of significant coronary artery disease and its anatomical size in comparison with coronary angiography. J Res Med Sci 2011;16:750–5.