ISSN 2618-1584 Vol. 5, Issue 3: 39-44, DOI: 10.25236/FMSR.2023.050306

Advances in coronary heart disease and research of vectorcardiogram

Yang Shu[1,a], Lihua Li[1,b,*]

[1]*Department of Cardiology, The First Affiliated Hospital of Chongqing Medical University, Chongqing, China*
[a]*thuztz@163.com,* [b]*lilihua926@126.com*
[*]*Corresponding author*

Abstract: *Coronary atherosclerotic heart disease is a type of disease in which the oxygen supply to the heart is reduced due to reduced blood perfusion to the heart, which cannot meet the normal physiological metabolism of the heart. In recent years, with the improvement of living standards and changes in dietary structure, the incidence of coronary heart disease is gradually increasing. In clinical practice, electrocardiogram is mostly used for early heart diseases detection. Abnormal ST segment and T wave of electrocardiogram are important basis for diagnosis of coronary heart disease. Vectorcardiogram is one of the diagnostic contents of electrocardiogram, and its changes are related to the occurrence, development and prognosis of many cardiogenic diseases.*

Keywords: *Vectorcardiogram; Myocardial ischemia; Myocardial infarction; Prognosis*

1. Introduction

Coronary atherosclerotic heart disease is a relatively common disease in the cardiovascular field. Insufficient coronary blood supply and oxygen supply is its main pathogenesis, which seriously endangers human health. In recent years, through the intervention of risk factors of coronary heart disease and the implementation of secondary prevention, the mortality rate of coronary heart disease has been reduced, but it is still the first cause of death in patients[1]. Vectorcardiogram(VCG) is a part of electrocardiogram (ECG), which has a certain diagnostic value in cardiovascular diseases such as coronary heart disease, cardiac structural changes such as atrial enlargement, ventricular hypertrophy, and cardiac conduction diseases[2]. This paper will introduce the progress of vectorcardiogram in coronary heart disease detection and research.

2. The detection method of VCG

A series of changes in the resting potential occur due to external stimuli or changes in the myocardial cells themselves, which are called depolarization and repolarization. When the heart is depolarized, the electrical activity generated at each moment is called vectors representing the instantaneous mean electric forces from the heart. Observed from a spatial perspective, each vector exhibits different directions and magnitudes. Since the heart is a three-dimensional structure, these vectors generated by the electrical excitation face in all directions in space, and the tips of each vector can be connected, constituting a spatial vector loop, also known as three-dimensional vectorcardiogram, which displays the magnitude and direction and running speed and direction of these mean electric forces. And then the spatial vector loop is projected from three different and mutually perpendicular planes (frontal, horizontal, and sagittal), and the images formed on each plane are planar vector loops, which are called planar vectorcardiogram.

The vectorcardiogram respectively shows the depolarization vector of the atrium, the depolarization vector of the ventricle and the repolarization vector of the ventricle in the form of "P, QRS and T loops". In clinical[3], the abnormality of QRS loop and T loop of vectorcardiogram has a certain sensitivity in the diagnosis and prognosis evaluation of coronary heart disease. And the QRS loop index includes the angle between QRS and T loop(QRS-T angle), the maximum voltage of the QRS loop vector and the flatness of the QRS loop, while the T loop index includes the maximus vector amplitude of the T loop, the rotation direction of the T loop, and the length/width ration of the T loop and so on.

ISSN 2618-1584 Vol. 5, Issue 3: 39-44, DOI: 10.25236/FMSR.2023.050306

3. VCG and chronic exertional angina

The main mechanism of chronic exertional angina is transient myocardial ischemia, which is manifested in vectorcardiogram and electrocardiogram as changes of the QRS loop of ventricular depolarization vector, T loop of ventricular repolarization vector and ST segment. In Lefen Yin's study[4], 84 patients with coronary heart disease were selected as the test group, and 84 healthy subjects were selected as the control group at the same time. The QRS and T loop index of the two groups were quantitatively analyzed after the both groups completed the planar vectorcardiogram examination. There was no difference in general information such as age and gender between the two groups($P>0.05$). The results showed that the QRS and T loop abnormalities of the vectorcardiogram are of great significance for the diagnosis of myocardial ischemia, which can be manifested as the increase of the angle between QRS loop and T loop. Compared with the healthy subjects of the control group, the test group has abnormality in T loop index such as the length/width ratio of the T loop, the running direction of the T loop, and the angle between QRS loop and T loop, whose difference was statistically significant($P<0.05$).

A total of 150 patients with coronary heart disease were selected in the study of Xiuyun Ding et al[5]. All of these patients had completed the planar vectorcardiogram and conventional 12-lead electrocardiogram. Among them, 123 cases had abnormal QRS loop and T loop, and the diagnostic consistency rate was 82%; 86 cases had ST-T segment changes, the diagnostic consistency rate was 57%, whose difference was statistically significant. Among the patients with abnormal vectorcardiogram, there were 95 cases with abnormal QRS-T angle, 120 cases with abnormal length/width ratio of T loop, and 78 cases with abnormal T loop orientation and steering. And the QRS-T angle and the length/width of the T loop have the highest diagnostic consistency rate with ECG in the above mentioned indexes. Myocardial ischemia can cause a series of changes in ventricular depolarization and repolarization, which are manifested as the changes of the QRS and T loop of VCG and ST-T segment of ECG. The results showed that the VCG has higher detection rate to patients with coronary heart disease than ECG; and VCG and ECG both have a relative high detection rate for patients with multi-vessel lesions, and VCG is more advantageous for patients with one or two mild vascular lesions, which indicates that changes of the QRS loop and T loop of the vectorcardiogram have a higher sensitivity for the diagnosis of coronary heart disease, especially when the angiostenosis is mild. The number of abnormal ventricular depolarization and repolarization indexes can be used to evaluate the severity of coronary heart disease. In this study, there were 28 patients with three-vessel lesions, and 26 of them had four abnormal indexes; and there were 67 patients with double-vessel lesions, and 60 of them had more than 3 abnormal indexes, all of which indicates that the more abnormal indexes of QRS and T loop of the vectorcardiogram, the more severe the coronary heart disease of the patient. Analysis of QRS and T loop indexes showed that the abnormal QRS-T angle and T loop orientation had the highest coincidence rate with ECG diagnosis(95% and 85%, respectively), suggesting that the abnormality of these two indicators had the highest significance in the diagnosis of myocardial ischemia. Aigars Rubulis[6] et al followed up 187 patients with stable angina pectoris for 8 years and analyzed ST vector, QRS-T angle and the shape of T loop indexes and so on. During the follow-up, there were 16 patients with cardiovascular death and 19 patients with myocardial infarction, and 89 patients did not have cardiovascular events. The results suggest that the increased QRS-T angel is helpful in predicting the occurrence of cardiovascular death and myocardial infarction.

When the vectorcardiogram is used to diagnose coronary heart disease, the abnormal myocardial depolarization and repolarization caused by myocardial ischemia are mainly manifested in the abnormality of the QRS and T loop. When there are more abnormal vectorcardiogram indexes, it often indicates that the angiostenosis is severe. Among the indexes of QRS and T loop, the abnormality of QRS-T angle and T loop orientation have the highest diagnostic value for myocardial ischemia, and the QRS-T angle has a certain value in the prognosis of patients with stable angina.

4. VCG and asymptomatic myocardial ischemia

Asymptomatic myocardial ischemia refers to the presence of coronary artery stenosis in anatomy, and the patient doesn't have symptoms such as chest tightness, chest pain, palpitations, etc. It is one of the main causes of myocardial infarction or cardiac sudden death. The reasons of an asymptomatic patient may include: 1) patient's tolerance for pain, 2) the small area and(or) short duration of myocardial ischemia, 3) ischemic preconditioning[7]. The shift of ST segment of electrocardiogram is the basis for diagnosing myocardial ischemia. However, it is difficult to diagnose myocardial ischemia with 12-lead ECG when the patient has a mild coronary artery stenosis with no obvious clinical symptoms. Lijuan

ISSN 2618-1584 Vol. 5, Issue 3: 39-44, DOI: 10.25236/FMSR.2023.050306

Sun's retrospective clinical study[8] selected a total of 55 patients with asymptomatic myocardial ischemia who had underwent 12-lead electrocardiogram, planar vectorcardiogram and three-dimensional vectorcardiogram. All 55 patients were completed with coronary angiography and its results were used as the standard to analyze the diagnostic value of vectorcardiogram for silent myocardial ischemia. The results showed that there were significant statistical differences among the sensitivities of these three methods. For the diagnosis of asymptomatic myocardial ischemia, the specificity and sensitivity of three-dimensional vectorcardiogram are far superior to those of 12-lead electrocardiogram and planar vectorcardiogram, which can provide guidance for clinical treatment. Xiangrui Meng's study[9] further explored the specific indexes of the planar and three-dimensional vectorcardiogram. The data of 12-lead ECG, planar VCG and three-dimensional VCG were collected from 176 hospitalized patients. The planar VCG and the three-dimensional VCG collected indexes such as the amplitude of the T loop maximum vector, the QRS-T angle, the length/width ratio of the T loop, the elevation angle of the ST vector and the horizontal angle of the ST vector, and used the results of coronary angiography as the standard. The results showed: 1) the sensitivity and specificity of three-dimensional VCG were higher than those of 12-lead ECG and planar VCG, and had higher positive rate for diagnosing asymptomatic myocardial ischemia. 2) the amplitude of T loop maximum vector, QRS-T angle, ST vector, the length/width ratio of T loop, the elevation angle and the horizontal angle of ST vector were measured by the planar VCG and the three-dimensional VCG, and there was statistically significant difference between these values($P<0.05$). Ali Reza Mehri Dehnavi[10] et al selected 60 patients with suspected myocardial ischemia and 10 healthy subjects who both had completed exercise test, and used the results of coronary angiography as the standard. The results showed that the sensitivity(70%) and specificity(86%) of VCG were higher than those of ECG(60%, 70%, respectively), suggesting that the VCG is superior to ECG for the detection of myocardial ischemia of coronary heart disease. In addition, for the diagnosis of myocardial ischemia, the diagnosis results of VCG and exercise test have a good consistency(90%), suggesting that the VCG can be used for differential diagnosis when the ECG cannot diagnose myocardial ischemia. The sensitivity and specificity of ECG and planar VCG for the diagnosis of myocardial ischemia in patients with asymptomatic myocardial ischemia are not high, and the ventricular repolarization vector indexes of the three-dimensional VCG, such as QRS-T angle and the detection of ST vector have unique clinical significance for improving the diagnosis of asymptomatic myocardial ischemia.

5. VCG and myocardial infarction

Acute myocardial infarction is characterized by rapid onset, rapid progression and high mortality. Early diagnosis and intervention can save many lives and significantly improve the prognosis of patients. The ECG's direct and convenient characteristics make it an important way to diagnose acute myocardial infarction. Electrocardiogram is of great importance in the diagnosis and triage of acute coronary syndrome(ACS), especially during the hyperacute phase, the "golden hour", when the likelihood of myocardial salvage is greatest. According to the guidelines for Interventional Treatment of Coronary Heart Disease[11], whether the ST segment elevated of the ECG is one of the main criteria for determining whether a patient needs primary PCI. However, some studies[12] have shown that some patients with ACS have completely occluded culprit vessels, and the ST segment of these patient's ECG is not elevated(namely, non-ST segment elevation ECG). For some patients with acute myocardial infarction who lack typical ECG changes, the combined use of VCG and ECG can improve the detection rate of cardiovascular adverse events. Guoli Zhou[13] et al used the results of coronary CTA examination as the standard, and analyzed 169 patients with myocardial infarction with atypical electrocardiogram and the diagnostic value of VCG. The results suggested that in the analysis of the two examination methods in 136 patients with inferior wall, anterior septal myocardial infarction with atypical electrocardiogram, the sensitivity, specificity, positive predictive value, and negative predictive value(87.5%, 75.8%, 93.7%, 59.5%) of VCG diagnosis were higher than those of ECG diagnosis(58.0%, 48.5%, 82.4%, 21.9%), which suggests the diagnostic value of VCG for such patients. Arie C. Maan[14] et al studied the VCG and ECG of 84 patients undergoing elective percutaneous transluminal coronary angioplasty(PTCA). The average balloon occlusion time was 260±76s. The study measured the magnitude and direction of ST segment, ST vector and QRS loop vector of VCG after 3 minutes of balloon occlusion, and studied the sensitivity of their changes(ΔST, ΔVG) to coronary artery occlusion. Among them, 46/84 (55%) patients showed ST segment elevation ECG after 3 minutes of occlusion, and the combined use of VCG and ECG can confirm that 73/84(87%) patients were ischemic. The results showed that the combined use of VCG and ECG can significantly improve the detection of patients with completed ECG who urgently need catheter intervention.

ISSN 2618-1584 Vol. 5, Issue 3: 39-44, DOI: 10.25236/FMSR.2023.050306

Li Juang's study[15] selected a total of 74 patients with acute myocardial infarction who underwent coronary angiography. A total of 70 patients with myocardial infarction could be detected by 12-lead ECG, the detection rate was 94.59%, and 4 cases were missed, and the missed detection rate was 5.41%. Comparing the results with the VCG, the results suggested that the detection rate of ECG for acute myocardial infarction was higher, and the VCG can more clearly show the location and range of myocardial infarction, especially for focal myocardial infarction, and the diagnosis of multiple myocardial infarction and myocardial infarction with bundle branch block will be more effective. R. Correa[16] et al applied ECG-VCG combined technology to identify 95 cases of myocardial infarction and the sites of myocardial infarction of these patients. A total of 161 ECG recordings obtained from 95 patients with myocardial infarction after the onset of myocardial infarction, and the ECG of 52 healthy subjects were taken and used as the control group. The results showed that between healthy and myocardial infarction subjects, there were significant differences in the projected areas of T loops and QRS loops on the X, Y, and Z axes of the VCG(sensitivity 95.78%, specificity 94.23%, accuracy 95.23%). The projected areas of the ST vector and QRS loops on the X,Y and Z axes showed significant difference between anterior and inferior myocardial infarctions(sensitivity 89.80%, specificity 84.78%, accuracy 89.80%). Mithilesh K, Das[17] and others proposed the concept of fragmented QRS wave(fQRS) in 2006, which refers to the rapid and sudden change in the direction of ventricular electric movement, which is related to the myocardial scar in the corresponding part. This can be manifested in the abrupt folding or turning of the QRS loop of the VCG, which reflects the decreased planarity of the QRS loop. Studies by Saurav Chatterjee[18] and others confirmed that fQRS has a higher sensitivity than pathological Q waves in the diagnosis of myocardial infarction. Golriz Sedaghat[19] et al studied the circularity, flatness, thickness and the rotation angle of the QRS loop of VCG of 81 healthy subjects and 8 patients with sustained monomorphic ventricular tachycardia(SMVT) after myocardial infarction. The results suggested that the plane index of the QRS loop decreased in 8 patients with SMVT, and the detection sensitivity of fQRS of 12-lead ECG was lower than that of VCG(31%). It suggested that the value of the vectorcardiogram in the detection od the local scar of the myocardium. For patients with acute myocardial infarction, the electrocardiograms has more advantages in the diagnosis than the vectorcardiogram. The combine use of these two methods helps to identify patients with myocardial infarction. The vectorcardiogram can be used to evaluate the location and severity of myocardial infarction and the prognosis of patients, and the combined application of vectorcardiogram can better evaluate whether patients need emergency PCI.

6. VCG and prognosis of coronary heart disease

The QRS-T angle of the vectorcardiogram refers to the angle between the maximum vector of the QRS loop and the maximum vector of the T loop, which can reflect the relationship between the ventricular depolarization vector and the ventricular repolarization vector. Current studies have found that the QRS-T angle of the vectorcardiogram is closely related to the prognosis of patients with myocardial ischemia, heart failure, malignant arrhythmia and sudden cardiac death[20, 21]. Sergio Raposeiras- Roubín[22] et al followed up about 467 patients with acute myocardial infarction with a left ventricular ejection fraction of 40% for 3.9 years(2.1 to 5.9 years), of which 217 died(47.5%). Analyzing the indexes of vectorcardiogram of the dead patients, it was found that the plane QRS-T angle was higher (116.6±52.8 vs 77.9±55.1, $p < 0.001$). Among the indexed of the vectorcardiogram, the QRS-T angle is the most accurate index to predict all-cause cardiac death, and it is helpful to evaluate the prognosis of patients with myocardial infarction. Rubulis[6] et al followed up 187 patients with coronary heart disease for 8 years, and analyzed the value of ventricular repolarization vector indexes in predicting cardiac death and myocardial infarction after completing the vectorcardiogram. The results suggested that the QRS-T angle and the distortion of the T loop were independent predictors. Ryanne A. Brown[23] et al analyzed the data of electrocardiogram and vectorcardiogram of 370 patients with imaging-proven cardiac disease(including coronary artery disease, hypertrophic cardiomyopathy, or left ventricular systolic dysfunction) and 210 healthy controls. The results suggested that the QRS-T angle of the three-dimensional VCG is more valuable in diagnosis than the QRS-T angle of the planar VCG. A total of 22 studies including 164171 people were included in the meta analysis study of Xinlin Zhang[24]. The results showed that the frontal QRS-T angle has a good prognostic value and is a valuable predictor for all-cause death and cardiac death. The three-dimensional QRS loop of healthy individuals is located on a plane, and Sayantani Choudhuri[25] and others found that the flatness of the spatial QRS loop is a diagnostic and prognostic indicator of acute myocardial infarction. With the reperfusion, recovery and salvage of the diseased myocardium in patients with acute myocardial infarction throughout the course of the disease and during the long-term follow-up, the spatial QRS loop's flatness will also be restored. In the diagnosis of acute myocardial infarction, electrocardiogram is more advantageous, and the vectorcardiogram has

ISSN 2618-1584 Vol. 5, Issue 3: 39-44, DOI: 10.25236/FMSR.2023.050306

certain value for the location and range of myocardial infarction, mainly manifested in the abnormality of QRS loop and T loop projected area and the flatness of spatial QRS loop. The QRS loop's flatness is a highly restricted and sensitive parameter that is a characteristic feature of the normal heart and can be used as a test for diagnosis screening of normal heart, and the loss of flatness may be a prominent feature of AMI. When evaluating the prognosis of patients with myocardial infarction, the QRS-T angle and the flatness of the QRS loop can be used to evaluate the location and extent of myocardial infarction and the prognosis of patients.

7. Discussion

Myocardial ischemia can cause a series of changes in the electrical activity of ventricular repolarization, mainly manifested as changes of the QRS loop and T loop indexes of the vectorcardiogram, and ST segment changes and T wave abnormalities of the electrocardiogram. Asymptomatic myocardial ischemia is an important type of coronary heart disease and an important risk factor for acute myocardial infarction and even cardiac sudden death. 12-lead electrocardiogram is a routine examination method for coronary heart disease, and coronary angiography has certain limits due to its invasiveness. Vectorcardiogram provides a new diagnostic method to help the diagnosis of such patients. For patients with stable angina and acute myocardial infarction, VCG is helpful to evaluate the degree of lesion and prognosis and clinical work. However, there are too many analysis indexed of VCG, and there is no international quantitative index of VCG at present, which has caused difficulties in the practical application of VCG. More in-depth research is need to improve and refine the diagnostic criteria.

References

[1] W. C. Members, J. S. Lawton, J. E. Tamis-Holland, et al., 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines, Journal of the American College of Cardiology, 2022, 79, e21-e129

[2] G. E. Burch, The history of vectorcardiography[J]. Med Hist Suppl, 1985, 103-131

[3] H. Bingxian and L. Chunshan, The Basis of Vectorcardiogram [M]. Xinjiang: Xinjiang Science and Technology Press, 2013, 548

[4] Y. Lefen, Observation on 84 cases of coronary heart disease with abnormal T loop in vectorcardiogram [J]. China Practical Medicine, 2015, 10, 52-53

[5] D. Xiuyun, L. Jianhua, L. Lei, et al., Clinical value of diagnosis of coronary heart disease by changes of T loop of vectorcardiogram[J]. Shandong Medicine, 2002, 42, 43-44

[6] A. Rubulis, L. Bergfeldt, L. Rydén, et al., Prediction of cardiovascular death and myocardial infarction by the QRS-T angle and T vector loop morphology after angioplasty in stable angina pectoris: an 8-year follow-up[J]. J Electrocardiol, 2010, 43, 310-317

[7] A. H. Ahmed, K. Shankar, H. Eftekhari, et al., Silent myocardial ischemia: Current perspectives and future directions[J]. Exp Clin Cardiol, 2007, 12, 189-196

[8] S. Lijuan, The value of T loop repolarization parameters of three-dimensional vectorcardiogram in the diagnosis of asymptomatic myocardial ischemia[J]. Health Today, 2016, 15, 349-349

[9] M. Xiangrui and W. Hongyu, The T loop's repolarization parameters' value in the diagnosis of asymptomatic myocardial ischemia[J]. Chinese Medical Science, 2013, 3, 15-17

[10] A. R. M. Dehnavi, I. Farahabadi, H. Rabbani, et al., Detection and classification of cardiac ischemia using vectorcardiogram signal via neural network[J]. Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences, 2011, 16, 136

[11] W. Bing, L. Yi and H. Yaling, Guidelines for the diagnosis and treatment of stable coronary heart disease[J]. Chinese Journal of Cardiology, 2018, 46, 680-694

[12] S. Man, C. Rahmattulla, A. C. Maan, et al., Acute coronary syndrome with a totally occluded culprit artery: relation of the ST injury vector with ST-elevation and non-ST elevation ECGs[J]. J Electrocardiol, 2014, 47, 183-190

[13] Z. Guoli and Y. Weiya, Study on the value of vectorcardiogram in diagnosis of atypical myocardial infarction[J]. Chinese Journal of Coal Industry Medicine, 2011, 14, 375-376

[14] C. C. ter Haar, A. C. Maan, S. G. Warren, et al., Difference vectors to describe dynamics of the ST segment and the ventricular gradient in acute ischemia[J]. J Electrocardiol, 2013, 46, 302-311

[15] J. Li, Diagnostic value of ordinary electrocardiogram and vectorcardiogram in myocardial infarction[J]. Medicine and Health, 2017, 2, 228-229

[16] R. Correa, P. D. Arini, L. S. Correa, et al., Identification of Patients with Myocardial

ISSN 2618-1584 Vol. 5, Issue 3: 39-44, DOI: 10.25236/FMSR.2023.050306

Infarction:Vectorcardiographic and Electrocardiographic Analysis [J]. Methods Inf Med, 2016, 55, 242-249

[17] M. K. Das, B. Khan, S. Jacob, et al., Significance of a fragmented QRS complex versus a Q wave in patients with coronary artery disease[J]. Circulation, 2006, 113, 2495-2501

[18] S. Chatterjee and N. Changawala, Fragmented QRS complex: a novel marker of cardiovascular disease[J]. Clinical cardiology, 2010, 33, 68-71

[19] G. Sedaghat, E. Ghafoori, J. W. Waks, et al., Quantitative assessment of vectorcardiographic loop morphology[J]. Journal of electrocardiology, 2016, 49, 154-163

[20] C. Voulgari and N. Tentolouris, Assessment of the Spatial QRS-T Angle by Vectorcardiography: Current Data and Perspectives[J]. Curr Cardiol Rev, 2009, 5, 251-262

[21] C. Voulgari, S. Pagoni, S. Tesfaye, et al., The spatial QRS-T angle: implications in clinical practice[J]. Curr Cardiol Rev, 2013, 9, 197-210

[22] S. Raposeiras-Roubín, A. Virgós-Lamela, N. Bouzas-Cruz, et al., Usefulness of the QRS-T angle to improve long-term risk stratification of patients with acute myocardial infarction and depressed left ventricular ejection fraction[J]. Am J Cardiol, 2014, 113, 1312-1319

[23] R. A. Brown and T. T. Schlegel, Diagnostic utility of the spatial versus individual planar QRS-T angles in cardiac disease detection[J]. J Electrocardiol, 2011, 44, 404-409

[24] X. Zhang, Q. Zhu, L. Zhu, et al., Spatial/Frontal QRS-T Angle Predicts All-Cause Mortality and Cardiac Mortality: A Meta-Analysis [J]. PLoS One, 2015, 10, 169-174

[25] S. Choudhuri, T. Ghosal, D. P. Goswami, et al., Planarity of the spatial QRS loop of vectorcardiogram is a crucial diagnostic and prognostic parameter in acute myocardial infarction[J]. Med Hypotheses, 2019, 130, 109251