Machine Learning Identification of Patients with Non-ST Segment Elevation Acute Coronary Syndrome Using High-resolution Magnetocardiography

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Abstract

The aim of this study was to develop an automated assessment of non-elevated acute coronary syndromes (ACS). Major field-like, time-domain and image-like features that could be explained by electrophysiological mechanisms were extracted from the study population for modeling. A total of 723 cases of magnetocardiography data were selected for 50% cross-validation, and the clinical information of the patients in the validation set was evaluated by professional doctors. All patients underwent coronary angiography. The results show that the accuracy of MCG is 86.6%, the precision is 89.8%, the sensitivity is 81.9%, the specificity is 91.1%, the F1 score is 85.6%, the area under ROC curve is 0.9338, the sensitivity is 69.4%, the specificity is 73.2%.

The results of this study indicate that it has important research and application value for ACS patients, especially those patients whose ECG does not indicate typical ST segment changes. The magnetocardiodiagnostic method proposed in this study provides a rapid and accurate diagnostic tool for clinicians and improves the interpretability of MCG data. In addition, some of the features revealed in this study may be related to the location of ischemia, providing an opportunity for further research.

1. Introduction

Acute coronary syndrome (ACS) is caused by sudden coronary artery blockage. In high-income countries, coronary heart disease is an important cause of death, accounting for about one third of all deaths [1]. Acute coronary syndrome (ACS) is caused by sudden coronary artery blockage. In high-income countries, coronary heart disease is an important cause of death, accounting for about one third of all deaths [1]. Early warning and timely diagnosis are critical to saving the lives of ACS patients. ACS includes acute ST-segment elevation myocardial infarction (STEMI), acute non-ST-segment elevation myocardial infarction (NSTEMI) and unstable angina pectoris (UA), with different pathological manifestations and treatment strategies. Electrocardiogram, cardiac markers and coronary angiography are the main medical means for diagnosing acute coronary syndrome. Early warning and timely diagnosis are critical to saving the lives of ACS patients. ACS includes acute ST-segment elevation myocardial infarction (STEMI), acute non-ST-segment elevation myocardial infarction (NSTEMI) and unstable angina pectoris (UA), with different pathological manifestations and treatment strategies. Electrocardiogram, cardiac markers and coronary angiography are the main medical means for diagnosing acute coronary syndrome. However, ECG does not have ideal sensitivity and specificity for ACS. Cardiac markers and coronary angiography are invasive and require a longer examination time.

Magnetocardiography (MCG) is a passive, non-contact, non-invasive, non-radiative test of heart function that records the magnetic field generated by heart point activity. MCG is a magnetic image of the electrical activity of the heart, and although MCG and electrocardiogram (ECG) reflect the same electrical activity of the heart, MCG has the advantage of no contact, no conduction error, and higher spatial resolution

At present, the mainstream sensors used in MCG devices are: superconducting quantum interferometer (SQUID) sensors and optical pump magnetometer (OPM). The clinical diagnosis of MCG is still largely dependent on the clinical experience of the clinician, which limits its acceptance in the clinic. Therefore, an automatic MCG diagnosis system that can give early warning and diagnose in time is extremely important. Recent advances in machine learning suggest the advantages of discriminant class classifiers for automated clinical detection of heart disease. Kwon et al. used MCG to record the cardiac magnetic field data of patients, and used five features including the direction of the magnetic field map of the T-wave peak to evaluate the ability of MCG parameters to diagnose coronary heart disease. The sensitivity was 73.5%

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and the specificity was 70.7%[2]. Tao et al. extracted 164 time domain features, frequency domain features and information theory features by segmenting T-waves from average MCG records. Three best-performing classifiers were used and integrated to diagnose ischemic heart disease cases, with accuracy rates of 74%, 68% and 65% for LAD, LCX and RCA, respectively [3].

Table 1.Selected studies on the automatic detection using MCG

Authors	Database	Performance	Feature typpe
Kwon *et al.[2]*	ACS without segment elevation :364	Sensttivity :84% Specificity :85%	5 features related to the direction of the magnetic field diagram of the T-wave peak
Tao *et al.[3]*	CAD :227 Control :347	Accuracy :94.03% Precision :86.56%	164 features(time domain, frequency domain, information theory)

Past studies have shown promising results in automated detection of cardiovascular disease, but the publicly available data sets consist of typical case data with representative characteristics, so they may have different effects in the laboratory and in the clinic, which will affect the clinical application of the study results. The data set of this study was derived from the myocardial ischemia clinical research project of Qilu Hospital of Shandong University.

2. Materials

FIG. 1 shows the cardiomagnetic system used in this study, which mainly includes magnetic shielding device, non-magnetic bed, OPM array, and data processing device. In the process of MCG measurement, subjects were supine on a non-magnetic bed, and the subjects and OPM array were in the magnetic shielding device. The OPM array was automatically raised and lowered to 2cm above the subjects' forechest, and MCG data were collected for 3min for each subject.

Data of 723 patients with chest pain were collected using the MCG measurement system. Of the 723 patients included in the study cohort, Among them, there were 51 ACS patients with st segment elevation, 302 ACS patients without st segment elevation (including 97 clinically diagnosed NSTEMI and 205 clinically diagnosed UA), and 370 non-ACS patients with chest pain. All patients in the study cohort underwent coronary angiography, and patients with UA had at least one coronary artery stenosis greater than 90%.

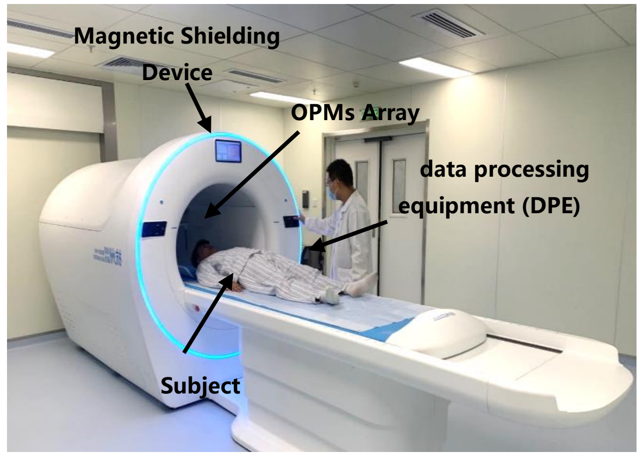

Figure 1. MCG measurement System

3.Methods

3.1 System overview

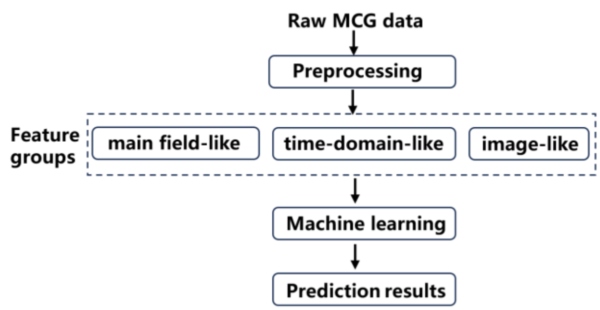

Figure 2. MCG measurement System

Figure 2 shows the automatic diagnosis process of MCG data for ACS patients established in this study. First of all, the collected data is preprocessed, including: removing the baseline drift of the signal, filtering, stacking and averaging the MCG signal of 3 minutes, locating each frequency band within the heartbeat range, and obtaining the available cardiomagnetic data. According to the 36×1000 magnetocardiogram data obtained after pretreatment, the butterfly diagram of magnetocardiogram was drawn through multi-channel superposition, and 2D isomagnetic map and 2D pseudo-current density map were drawn by selecting important moments in the beat, as shown in Figure 3. Then, according to the current conduction mechanism of cardiac repolarization, three kinds of features are extracted from the obtained magnetocardiogram: home field features, time domain features and image features. Finally, the extracted magnetocardio characteristic parameters are trained by machine learning model, and finally an automatic diagnosis system for ACS patients based on MCG is obtained.

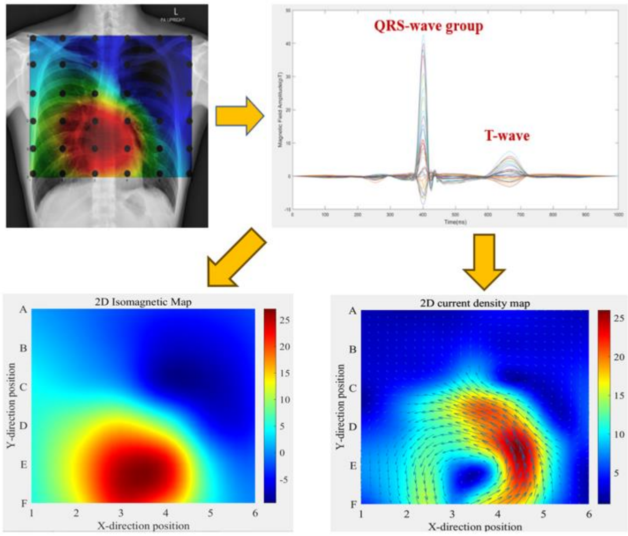

Figure 3. MCG maps

3.2 Feature extraction

In Table 2, we summarized the extracted three types of features, including 36 main field features, 6 time domain features and 6 image features. At present, the traditional characteristics applied in the field of magneto-cardiogram research mainly include the graphical description of each band of one-dimensional magneto-cardiogram curve, the description of global and local magnetic field information in two-dimensional magneto-cardiogram, and the description of vector information in two-dimensional magneto-cardiogram.

We believe that magnetocardiography is actually a magnetic imaging of cardiac electrical activity, and vector information is very important. Therefore, on the basis of the current mainstream cardiomagnetic characteristics, we first add the cardiomagnetic curl field characteristics. As a vector operator in vector analysis, curl can provide the rotation property of the cardiomagnetic vector field at a certain point, so as to indicate whether the cardiac current will have abnormal deflection or distortion at this point. In addition, the myocardial ischemia of ACS patients will affect the repolarization process of patients' ventricular myocytes, which will become an important reference for us to automatically detect ACS patients. In this study, the changes of 2D magnetocardiogram characteristic parameters in time dimension were considered to evaluate the myocardial health status of the subjects completely.

3.3 Classifiers

The criteria for selecting a classifier in this study were: (1) suitable for classification of small and medium-sized data sets, (2) able to handle data of different dimensions, and (3) good performance in psychomagnetic related studies. In order to obtain better predictive stability and robustness in small data sets, we choose the support vector machine (SVM) model as the supervised classifier for modeling. SVM can effectively deal with data sets with very large feature Spaces. It maps data to high-dimensional Spaces through kernel techniques. Therefore, we believe that SVM model is the most suitable classification model for our research problem.

Table 2.Extracted features

Group	Feature list	Number
Main field	Magnetic field strength ratio R/T Maximum value of positive and negative magnetic field at T wave vertex T-wave starting point positive and negative magnetic field maximum The magnitude and direction change of the distance from the beginning of T wave to the end of T wave Total curl at the vertex of T-wave Total angular velocity at the apex of T-wave	36
Time domain	QT interval ST interval QRS interval T-wave duration	6
Image	The area ratio of the positive and negative circles of the T-wave peak The area ratio of the positive and negative circles of the T-wave origin	6

4.Result

To evaluate the ACS automatic detection model established in this study, magnetocardio data from 723 patients were used. These included 51 ACS patients with st segment elevation, 302 ACS patients without st segment elevation (97 clinically diagnosed with NSTEMI, 205 clinically diagnosed with UA), and 370 non-ACS patients with chest pain. All patients underwent coronary angiography, and the clinical information of patients in the validation set was evaluated by professional doctors. In this study, all 205 UA patients had at least one coronary artery stenosis >90%. The data of 723 patients were predicted using the trained model, and the corresponding indicators were calculated to evaluate the predictive ability of the model.

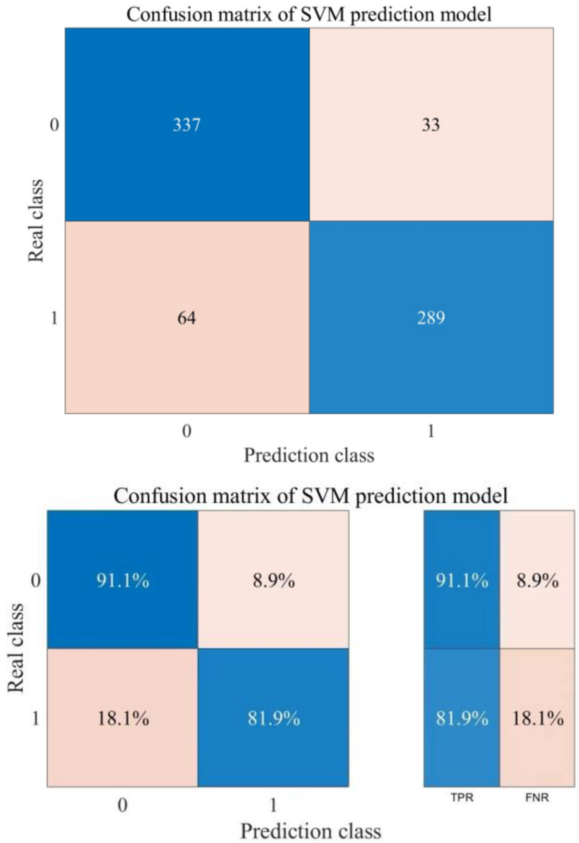

Figure 4. Prediction results of the model

FIG. 4 shows the confusion matrix of ACS automatic monitoring system. The sensitivity, specificity, positive predictive value, negative predictive value, accuracy and F1 score of the model can be obtained as 91.1%, 81.9%, 89.8%, 84.0%, 86.6% and 85.6%, respectively.

FIG. 5 shows the ROC curve of the automatic monitoring system for ACS patients in this study, AUC=0.9338, indicating that the prediction system has a good overall prediction performance.

5.Discussion

This study demonstrated that MCG has a great diagnostic advantage over ECG in ACS patients, especially those without ST segment elevation. In addition, the extracted magnetocardio characteristic parameters may be related to cardiac ischemia location, which provides an opportunity for further research on cardiac ischemia localization based on MCG.

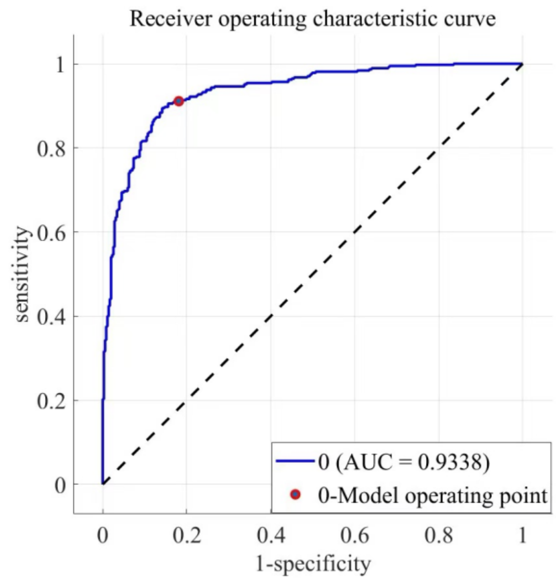

Figure 5. ROC operating curve of the predictive model

References

[1] “World Health Organization.”

[2] Kwon, et al., “Non-invasive magnetocardiography for the early diagnosis of coronary artery disease in patients presenting with acute chest pain.” *Circulation Journal : Official Journal of the Japanese Circulation Society* ,vol. 74,no. 7, Jul. 2010.

[3] R. Tao et al., "Magnetocardiography-Based Ischemic Heart Disease Detection and Localization Using Machine Learning Methods," in *IEEE Transactions on Biomedical Engineering*, vol. 66, no. 6, pp. 1658-1667, June 2019.

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