

# Machine learning in diagnosis of coronary artery disease

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Cardiovascular diseases continue to be the foremost cause of death among both males and females worldwide.<sup>[1]</sup> Coronary artery disease (CAD) represents a major subtype of cardiovascular diseases. Recent evidence has highlighted a worldwide increase in incidence of CAD clinical manifestations regardless of geographical region.<sup>[2]</sup> Despite a steady decline in CAD mortality in western countries over the past few decades, approximately one-third of the population suffering from CAD will succumb to the disease. Rapid and accurate diagnostic decisions are crucial for patients with CAD and aid in guidance for effective treatment.<sup>[2]</sup> However, various factors may make the process of accurate CAD diagnosis a complex task.

Machine learning (ML) is a technique of algorithms and statistical models that computer systems use to perform a specific task; this technique relies on patterns and inference without explicit instructions.<sup>[3]</sup> In 2014, the ImageNet competition (2014 ILVRC) triggered an era in rapid development for image classification, helping to facilitate the development of deep learning technology in the field of medical imaging. It paved the way for computational models that are aimed at freeing doctors and researchers from heavy repetitive work.<sup>[3]</sup> However, certain factors such as tedious engineering hinder the application of this technology in the field of medical imaging.<sup>[4]</sup> Recently, ML has been applied in a wide variety of scenarios such as diagnosis of disease including cancer, Parkinson's disease, thyroid disease, and various optical disorders,<sup>[5]</sup> aiding with nearly all aspects of medical diagnosis. In the field of CAD diagnosis, the rapid diagnosis of coronary heart disease (CHD) can be realized by ML with the help of electrocardiogram (ECG), phonocardiogram (PCG), coronary computed tomography angiography (CCTA), and coronary angiography. In this review, we systematically introduce and discuss the application of ML in CAD diagnosis based on ECG, PCG, CCTA, and coronary

angiography. It is expected to promote rapid diagnosis, decision making in CAD and development of ML in CAD diagnosis.

ECG records potential distribution on the surface of the body's torso, allowing for clinical inference to be made regarding electrical activity of the heart. Observing the changes in potential displayed by electrocardiograph is useful for the diagnosis of diseases such as CAD, but it lacks diagnostic sensitivity.<sup>[6]</sup> There are various reasons for this, one of which is linked with very low amplitude signal of the ECG machine, making clinicians more susceptible to potential error when reading ECG signal. Furthermore, certain ECG changes in relation to myocardial ischemia do not always regularly appear, highlighting the need for software that can automatically and objectively interpret ECG signals. The ML methodology is capable of decomposing an ECG beat, extracting ECG morphology, and completing the ECG signal analysis process by means of classification, ultimately improving diagnostic accuracy. At present, assisted ECG accuracy in the diagnosis of CAD has reached 99%.<sup>[7]</sup> ECG can detect electrophysiological changes in the heart, which provide the basis for the diagnosis of cardiovascular diseases such as CAD.

The advances achieved in computer and acoustic technologies have facilitated realization of automatic artery sound detection and analysis techniques. PCG is also a fast and effective method for the diagnosis of aortic valve disease, arrhythmia, CAD, and heart failure.<sup>[8]</sup> PCG can be used as a simple and safe method to detect diastolic murmurs from stenotic coronary artery disorders by acoustic sensors placed on the chest wall and provide valuable information on cardiac hemodynamics. The study found that the lower frequency diastolic sound power of patients with CHD increased, and the difference between CAD and non-CAD was about 5 dB at 31.5 Hz; therefore, researchers could use this information to study the diagnosis of CAD.<sup>[9]</sup> Winther

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*et al*<sup>[10]</sup> confirmed that the acoustic system miscellaneous predictive value of CAD diagnosis can reach as high as 82% accompanied by low cost and reduced need for non-invasive imaging techniques and intrusion.

CCTA is a reliable method for detecting CAD. For patients with suspected angina due to CHD, CCTA can also confirm its diagnosis, making intervention possible, and possibly reducing the risk of future myocardial infarction.<sup>[11]</sup> In addition to stenosis, CCTA also allows for non-invasive assessment of atherosclerotic plaque and coronary remodeling.<sup>[12]</sup> However, such measures require subjective visual interpretation of an image, which may result in unnecessary downstream testing and increase in overall cost. Automatic identification of coronary lesions by ML will reduce the variability of such observers and the time required to evaluate the image. Al'Aref *et al* conducted a retrospective study on 94 participants enrolled in the CONFIRM registry who had undergone CCTA. The diagnosis accuracy of obstructive CAD (50% stenosis) by the XGBoost method was 88.1%.<sup>[13]</sup>

At present, the most accurate method for diagnosing CAD is coronary angiography, which is widely considered to be the golden standard for CAD diagnosis.<sup>[2]</sup> Angiography determines the location and scope of arterial stenosis. However, this method still has some inherent defects. Traditional coronary angiography requires experienced physicians to complete the mapping process. Depending on the doctor's skill level, errors may be made when reading a film, and few hospitals are able to save data in the form of reports for future scientific research because of inconvenience and inaccuracy. At the same time, coronary angiography is an invasive and expensive method with a clinical mortality rate of 2% to 3%. Its high cost and risk to patients have prompted researchers to identify cheaper and more effective methods to detect and preliminarily diagnose CAD with the help of data mining, which at present is not the preferred diagnostic method for computer-aided design diagnosis. Alizadehsani *et al*<sup>[14]</sup> implemented Support Vector Machine method with 54 features on 303 CAD patients, and the highest recorded accuracy rates were 86.14%, 83.17%, and 83.50% for the diagnosis of stenosis of left anterior descending (LAD), left circumflex (LCX), and right coronary artery (RCA), respectively.

The morbidity and mortality rates of CAD are increasing each year. Rapid diagnosis of CAD is the key to successful treatment of some serious types of CHD such as acute myocardial infarction. In the diagnosis of CAD, ECG, phonocardiogram, coronary computed tomography, and coronary angiography have their own advantages.<sup>[3]</sup> In recent years, the rise of artificial intelligence is keeping doctors and researchers away from heavy repetitive work. Moreover, in recent years, ML has been applied in many fields. The present study summarizes the research conducted in recent years on rapid diagnosis of CHD with the help of relevant examination equipment through the ML method. In the current work, we can see that the diagnosis and treatment of CHD using ECG has been widely studied with the ML method. However, there are relatively few studies on the use of phonocardiogram,

coronary computed tomography, coronary angiography, and ultrasonic ECG.

We aimed to investigate the prospects associated with the application of ML for CAD diagnosis. Despite the rapid development of ML, its performance has always been limited by the availability and quality of data and tags that require further learning. Therefore, ML may still be limited in the medical field. For CAD diagnosis, although Kumar *et al*<sup>[15]</sup> achieved an accuracy of 100%, the sample size of their studies is limited to 143 cases, and the sample size of other studies was also quite small, highlighting the need for larger-scale clinical trials prior to the use of artificial intelligence devices in clinical practice. In addition, the algorithm lacks abundant training data (such as typical angina pectoris history and depth of archived images and image-related data or text that may not be easily accessible). Without a large number of training data sets, the algorithm may continue to be limited to the identification of some typical cases. Therefore, we anticipate that even the most advanced ML method is more likely to be a powerful complementary factor rather than complete replacement for expert interpretations. In relation to diagnosis with the use of computer-aided design, we can see that the current research relies solely on ECG, PCG, CCTA, and coronary angiography with few studies to combine. Diagnosis with the use of computer-aided design is a complex process and can be made according to the rhythm or sound of arteries, which is particularly related to the high mortality rate of CAD. Early diagnosis is crucial. However, it is not enough to rely on only one detection method. If these two methods are combined and used synthetically to evaluate symptoms of patients, more reliable conclusions can be drawn. In addition, some newly developed noise reduction, dimension reduction and calculation methods provide preconditions for further improving the accuracy of ML in the diagnosis of all types of diseases.

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### Conflicts of interest

None.

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