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Machine Learning Approaches for Detecting Coronary Artery Disease Using Angiography Imaging: A Scoping Review

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Abstract. This scoping review aims to identify and summarize the current literature on Machine learning (ML) approaches for detecting coronary artery disease (CAD) using angiography imaging. We comprehensively searched several databases and identified 23 studies that met the inclusion criteria. They employed different types of angiography imaging including computed tomography and invasive coronary angiography. Several studies have used deep learning algorithms for image classification and segmentation, and our findings show that various machine learning algorithms, such as convolutional neural networks, different types of U-Net, and hybrid approaches. Studies also varied in the outcomes measured, identifying stenosis, and assessing the severity of CAD. ML approaches can improve the accuracy and efficiency of CAD detection by using angiography. The performance of the algorithms differed depending on the dataset used, algorithm employed, and features selected for analysis. Therefore, there is a need to develop ML tools that can be easily integrated into clinical practice to aid in the diagnosis and management of CAD.

Keywords. Coronary artery disease, Detection, Machine learning, Literature Review

1. Introduction

The most common cause of death in the world is coronary artery disease (CAD). To prevent CAD from progressing and lower the risk of a heart attack or stroke, early

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recognition is crucial. To detect CAD, medical imaging techniques including computed tomography (CT) and angiography are frequently used[1]. However, due to the complexity of the disease and the wide range in image appearance, accurate detection and diagnosis of CAD from images can be difficult[2].

Machine learning models can learn complicated patterns from massive volumes of data and uncover tiny traits that human experts may miss. Convolutional neural networks in particular are effective methods for automatic feature extraction and image segmentation[3, 4]. Using X-ray angiography imaging, a number of techniques have been developed to automatically segment and detect the coronary arteries. The efficiency, quality, and performance of CAD diagnosis can be greatly enhanced by ML application to medical imaging[5].

This scoping review seeks to give an overview of the present status of the field's research, identify the various techniques and algorithms that have been used to detect CAD in medical imaging, and assess how well each of these techniques performs in terms of sensitivity, precision, F-score and any relevant findings.

2. Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guideline was followed for this scoping review. The goal of this scoping review is to identify the most effective state-of-the-art machine learning techniques currently being utilized to analyze medical images for the detection of CAD.

Articles published in English, focusing on deep learning techniques for angiography imaging detection of CAD and using quantitative data analysis are included. Articles focusing on non-machine learning techniques, not pertinent to CAD, and not published in peer-reviewed journals are excluded.

2.1. Data Sources and Search Strategies

In this study, Scopus, Medline (through PubMed), and Web of Science were all searched electronically. The keywords “machine learning”, “deep learning”, “coronary artery disease”, “diagnosis”, and “detect” and their synonyms were used in the search strategy.

2.2. Data extraction and synthesis

All of the identified studies were examined independently by two reviewers (RS and SH). Based on the inclusion and exclusion criteria, the reviewers skimmed the titles and abstracts of the articles and eliminated any that were irrelevant. We received the whole text of the remaining papers and checked their eligibility. A pre-made data extraction form was used to extract the data. The form asked for information about the authors, year, country, and sample size, the deep learning model that was employed, imaging modality, performance metrics, and relevant findings. The results offered a summary of the findings. The synthesis identified the most popular imaging modalities, performance indicators, and deep learning models. The overall analysis identified the most preferred imaging modalities, performance indicators, and deep learning models.

3. Results

In this review, 23 studies were considered (Figure 1). The studies were carried out in a number of nations, with China accounting for the majority of them, followed by the United States, Japan, South Korea, and Saudi Arabia. The number of images in the samples ranged from 32 to 10,000. Coronary Computed Tomography Angiography (CCTA) and Invasive Coronary Angiography (ICA) were the imaging techniques used.

Recently Convolutional neural networks (CNNs), in particular, have emerged as the most popular deep learning model for image classification and feature extraction tasks in computer perception[5, 6]. Combination techniques and U-Net models are the most often used models. Wavelet analysis and Region of Interest (ROI) analysis were the most common methods of feature extraction employed in investigations. F-score, accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC-ROC) as performance indicators were reported and varied among research as the valid criteria. Several studies have described successfully segmenting coronary arteries in angiography images using a modified U-Net model, achieving high levels of accuracy, sensitivity, specificity, and Dice similarity coefficient (Table 1).

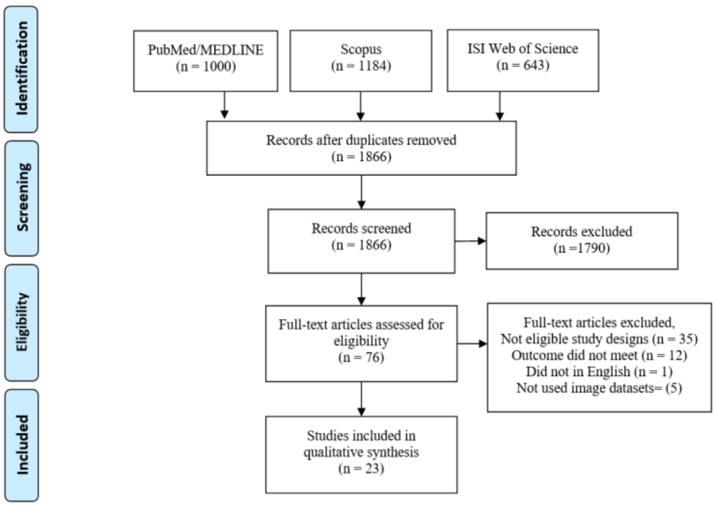

Figure 1. Flow diagram for the selection of studies and literature searches.

Table 1. The extracted features from reviewed papers

First Author (Year)	Applied method	Best Performance Metric	Dataset size
Zhu (2021)	U-Net ++ Feature fusion Network	Accuracy (99.9%), Sensitivity (97%), Precision (80%), Mean DSC (0.88)	300 CCTA in each group
Yi (2021)	ResU-net2	Accuracy (79.8%), Sensitivity (74.3%), Specificity (85.6%), PPV (84.3%), NPV (76.1%)	1287 CCTA
Tao (2022)	Bottleneck Residual U-Net	Sensitivity (87.7%), Specificity (97.8%), Accuracy (97%), AUC (0.99)	134 X-ray coronary angiograms
Pal (2022)	ResNet152- V2	Accuracy (81%), Recall (76%), Precision (86%), Specificity (87%), F-score (80%), AUC (0.87)	1148 Coronary artery angiography images

Huang (2022)	(3D) U-Net architecture, bottle-neck model, growing iterative prediction network model	Accuracy (82.08%), Sensitivity (79.02%), specificity (86.52%), PPV (79.02%), NPV (86.52%), AUC (0.83)	346 CCTA
Park (2022)	Efficient Net, U-Net	Precision (75.6%), Recall (69.2%), F-score (71.7%)	394 XA/CTA
Algarni (2022)	Attention-based Nested U-Net, VGG-16, ASCARIS model.	Accuracy (97%), Specificity (93%), Sensitivity (89.2%)	130 X-ray coronary angiograms
Zhao (2021)	FP-U-Net++	Dice similarity coefficient (0.88), Sensitivity (85%), Specificity (99%)	314 ICA
Han (2020)	U-Net Convolutional Networks, V-net Fully Convolutional Neural Networks, Semantic Segmentation Network	Accuracy (86%), Sensitivity (88%), Specificity (85%), PPV (73%), NPV (94%)	100 CCTA
Zhu (2021)	PSPNet network	Accuracy (95.7%), Sensitivity (94%), Specificity (95%)	CAG
Pan (2021)	3D Dense-U-Net	DSC (0.96), Accuracy (94%)	474 CCTA
Masuda (2021)	GoogleNet, Inception v3	AUC (0.83)	191 CCTA
Yang (2019)	SimpleNet, ResNet101, DenseNet121, InceptionResNet-v2	F1-score (91.7%), Recall (92.1%), Precision (92%)	3309 X-ray coronary angiography
AlOthman (2022)	FAST algorithm, DenseNet-161, back propagation method	Accuracy, Precision, Recall, F-Measure and Specificity (98%), AUC (0.93)	2364 CCTA 716 CCTA
Han (2023)	Resnet50, Feature Pyramid Network, PSSTT	F1-score (90.88%), Sensitivity (89.56%), Precision (92.27%)	233 XRA
Ovalle-Magallanes (2022)	HBGM	Accuracy (0.89), Precision (0.9), Sensitivity (0.87), and F1-score (0.91)	10,000 images
Xian (2020)	U-Net	Precision (90.1%), Recall (89.8%), F1-score (90%)	3200 X-ray angiography images
Cui (2020)	2D U-Net, 3D U-Net	Average Dice (0.76)	32 cardiac CTA
Chen (2020)	3D U-Net architecture	Sensitivity (94%), Specificity (63%), PPV (94%), NPV (59%)	1271 vessels and 1872 segments CCTA
Candemir (2020)	3DCNN	Accuracy (90.9%), PPV (58.8%), Sensitivity (68.9%), Specificity (93.6%), NPV (96.1%)	493 CCTA
Kurata (2019)	Prototype ML algorithm (onsite ML-based CT-FFR computation)	Sensitivity (87%), Specificity (38%), PPV (65%), NPV (71%), Accuracy (66%)	74 CTA
Zellweger (2018)	Memetic pattern-based algorithms (MPA)	Sensitivity (68%)	987 coronary angiography
Kang (2015)	SVM-based learning algorithm	Sensitivity (93%), Specificity (95%), Accuracy (94%), ROC/AUC (0.937)	42 CTA

4. Discussion

Studies have shown that deep learning techniques can recognize CAD from medical images more accurately than both conventional machine learning algorithms and human expertise. For instance, recognizing CAD from angiography images with an accuracy of 90.6% outperformed other machine learning algorithms [2, 6, 7]. However, additional study is required to confirm the findings and ascertain their clinical applicability. The choice of which approach to employ for image analysis ultimately depends on a number of variables, including the difficulty of the task, the size of the dataset, and the available computational resources.

5. Conclusion

Finally, machine learning algorithms have shown potential in detecting CAD using angiographic images. However, more study is needed to evaluate the effectiveness of these approaches in bigger datasets using standardized image acquisition protocols. These models can assist clinicians in making faster and more accurate diagnoses, leading to better patient outcomes. Integrating machine learning in medical imaging analysis can revolutionize the diagnosis and treatment of CAD, ultimately leading to better patient outcomes and quality of life.

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