Chapter 1

Introduction

1.1 Background

Cardiovascular diseases (CVDs) remain the leading cause of death worldwide and represent a major global health challenge. According to the World Health Organization, CVDs account for approximately 17.9 million deaths annually, representing nearly one-third of all global deaths (Di Cesare et al., 2024). Among the various forms of CVD, coronary artery disease (CAD) contributes substantially to global morbidity and mortality. The increasing prevalence of hypertension, diabetes, obesity, smoking, and sedentary lifestyles continues to increase the global burden of CAD, particularly as populations age and unhealthy lifestyle patterns become more common (Bentea et al., 2026; Stark et al., 2024).

A major pathological mechanism underlying CAD is coronary atherosclerosis, a chronic inflammatory disease characterized by the accumulation of lipid-rich plaques within the coronary arteries (Ralapanawa & Sivakanesan, 2021). Progressive plaque formation narrows the arterial lumen and restricts myocardial blood flow, which may result in ischemia, acute coronary syndrome, or myocardial infarction (Frąk et al., 2022). In severe cases, plaque rupture can trigger thrombosis and abruptly obstruct coronary blood flow, leading to life-threatening cardiac events (Lancellotti, 2024). Therefore, accurate identification and localization of atherosclerotic lesions are essential for diagnosis, risk assessment, and treatment planning (Suprayoga et al., 2024).

Medical imaging technologies play an important role in the diagnosis and management of cardiovascular diseases. Modalities such as echocardiography, computed tomography (CT), magnetic resonance imaging (MRI), and coronary angiography provide valuable structural and functional information regarding cardiac anatomy and vascular conditions (Counseller & Aboelkassem, 2023; Rahimah, 2022). Among these techniques, coronary angiography remains the gold standard for visualizing coronary artery stenosis and evaluating atherosclerotic severity. However, image interpretation remains highly dependent on physician expertise and may be affected by image quality, vessel overlap, motion artifacts, and inter-observer variability (Pasdeloup et al., 2025; Vrudhula et al., 2024).

Recent advances in artificial intelligence (AI), particularly deep learning, have shown strong potential in medical image analysis (Tsampras et al., 2025). Deep learning models have demonstrated excellent performance in image classification, object detection, and segmentation tasks across various medical applications. In cardiovascular medicine, these approaches have been applied to coronary artery extraction, stenosis detection, plaque characterization, and cardiac function analysis (Wehbe et al., 2023). As a result, AI-based systems have the potential to improve diagnostic efficiency and reduce subjectivity in image interpretation.

Among modern deep learning models, YOLO (You Only Look Once) has gained significant attention because of its ability to perform object localization and classification within a single network pass while maintaining high computational efficiency (Alhashmi & Al-azawi, 2025; Cai et al., 2025). This capability enables rapid image processing and makes YOLO particularly suitable for applications involving large volumes of imaging data. Furthermore, previous studies have demonstrated the potential of YOLO-based approaches for medical image segmentation and lesion detection tasks, including cardiovascular imaging applications (Abudukelimu et al., 2025).

Despite rapid progress in AI-based cardiovascular imaging, several limitations remain. Many previous studies focus primarily on classification rather than precise lesion segmentation, use limited datasets, or lack practical implementation for clinical use (Counseller & Aboelkassem, 2023; Pasdeloup et al., 2025; Tsampras et al., 2025). In addition, only a limited number of studies integrate AI segmentation models into accessible systems for healthcare professionals. To address this gap, the present study develops and evaluates a YOLOv8-based deep learning model for automatic detection and segmentation of atherosclerotic regions in coronary angiography images and integrates the model into a Streamlit-based web application. Streamlit is a Python-based framework that enables rapid deployment of machine learning models through an interactive web interface, allowing users to perform image analysis without requiring advanced programming knowledge (Chanin Nantasenamat et al., 2023).

1.2 Objective

The main objective of this study is to develop and evaluate an artificial intelligence based application capable of automatically detecting and segmenting atherosclerotic regions from coronary angiography images to support clinical diagnosis and treatment planning. Specifically, this research aims to collect and preprocess angiography image data from an open access source, then develop and train a YOLO-based deep learning model for accurate segmentation of atherosclerotic plaques. The model's performance will be evaluated using quantitative metrics such as the precision matrix, and recall to ensure reliability and accuracy. Finally, the best performing model will be integrated into a user-friendly web based application, enabling clinicians to upload angiography images and receive automated analysis results that highlight potential plaque regions and stent placement sites.

1.3 Hypothesis

It is hypothesized that a YOLO-based deep learning model can be effectively trained to detect and segment atherosclerotic regions from coronary angiography images with high accuracy. The model is expected to achieve strong performance metrics indicating reliable segmentation of plaque regions. Furthermore, integrating this model into a web based application is expected to provide a practical and efficient diagnostic support tool that allows clinicians to visualize plaque locations and identify optimal stent placement sites. Through this approach, the system could enhance the objectivity and consistency of angiography interpretation, ultimately supporting faster and more precise decision making in the treatment of cardiovascular disease.