# Coronary Artery Stenosis Detection using 3D CTA

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***Abstract:*** In today's world, Coronary heart diseases( CHD) or coronary artery diseases (CAD) are one of the most crucial life-threatening diseases. People in millions around the world are losing their lives due to heart attacks and other cardiac disorders[8]. Thus, according to [1] 0ne-third of deaths around the globe are caused by CHD. This disease is not only in adults but also in infants[9]. Coronary artery disease (CAD) reaches around 610,000 deaths each year (almost one in every four deaths.) Unfortunately, it has turned out to be the third greatest cause of death, accounting for 17.8 million fatalities per year. In the largest cause of death worldwide, with the passage of time mortality rate due to CHD has the United States, healthcare services for CAD are predicted to cost more than $200 billion per year. While coronary artery disease is a leading cause of mortality and disability, it can be avoided.(1) Thus, it is high time to take this into account, and therefore, non-invasive techniques have proved to make it possible to investigate the affected patient without any surgical cut or operative procedures. The non-invasive technique used is computed tomography (CT), which is used in place of the traditional catheterization method, which is a risky as well as time taking process. Whereas, CT, is just like capturing pictures, with the advancement in imaging equipment to investigate the internal organs of the human body with an accuracy of sub-millimeters.

***Introduction:*** Heart is the most important and hardest working organ of the human body. It is the responsibility of the heart to properly pump blood, to provide oxygen and other essential nutritional supplements to the entire body[12]. Thus, health of heart is essential to be well-maintained in order to stay alive. Heart has a network of veins, supplying oxygenated blood to the heart muscles,

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termed as coronary arteries [12].Deposition of calcium, lipids or any cholesterol material in these arteries causes stenosis ( blockage) in flow of blood to the heart muscles , which results in death of heart tissues.[11]Consequently, there can be various causes of cardiac diseases, among those blockage(stenosis) in arteries and veins are the most hazardous to human life.Stenosis is composed of fatty acids, calcium deposition and cholesterol etc which cause blockage in the pathway of blood towards heart , which results in death of heart tissues due to lack of oxygenated blood supply.Coronary tree is the network of arteries, which is responsible for transporting blood to all the parts of the heart. Eventually, the transport of blood gets blocked or obstacles due to jamming caused by calcium depositions , fatty materials, lipids and cholesterol which result in stenosis. Likewise , CHD occur due to occurrence of stenosis and oxygen deprived heart muscles.Basically, the Plaques(stenosis) are of three types. Although all three are risky to life, but the soft plaque is more often to cause sudden death. Calcified Plaques are composed of calcium depositions and appear to be bright and hard in texture. Whereas, the non-calcified plaques are made up of cholesterol, lipids and fatty acids and the third type is the mixed plaque , which is caused by both calcified and noncalcified plaques, as its name indicates , it is a mixture of calcium and lipids. Difference in composition of plaques, lead to difference in intensity values. In addition to this, non-calcified are challenging to be predicted at early stage, usually they are failed to be predicted and are suddenly ruptured , causing the affected person to loose their precious life. This challenge is due to resemblance of soft plaques with the intensity of blood, and low intensity profiles causing it to be a bit difficult to predict at an initial stage. On the other hand, calcified plaques consist of high intensity values and are clearly brighter in appearance than the blood. The aim is to predict the stenosis at early stage , as said by the clinicians that the diagnosis of plaques at start level can be the life saving in case of patients especially with soft plaques . Unfortunately , the rupture is the moment when soft plaque is noticed for the first time. In order to save precious lives, prediction of coronary plaques , with main focus on the soft plaque is carried out by using non-invasive CT technique,non- Invasive techniques have proved to be worth implementation, as they have multiple advantages as compared to invasive methods. Patients are also more satisfied and safe as no surgical cuts and procedures are taken place in order to detect the plaques . With the advancement of technology, non-invasive methods are introduced to detect the plaques , in order to improve medical practitioners capability to deal with CHD. Invasive techniques have proved to be worth implementation, as they have multiple advantages as compared to invasive methods. Patients are also more satisfied and safe as no surgical cuts and procedures are taken place in order to detect the plaques [10].

***Literature review:***

In this research paper , the authors have suggested a method for predicting coronary heart disease using machine learning techniques. The authors examined relevant research articles on the use of machine learning to predict CHD after reviewing CHD.Along with this ,they have also done comparison analysis of numerous research articles relating to CHD prediction and the methodology used in those papers[4].

Authors used a public dataset of 573 records in a study to accurately predict the existence of heart disease. The dataset was processed using the DT and NB classification techniques. The authors used the MATLAB data analysis tool to replace all missing variables and then generated accuracy results to measure model performance. On the dataset in question, the published results showed that DT is more accurate than NB [5].

Research has been carried out in order to see if regional calcification patterns on a CT coronary artery calcium scoring (CCS) correlate with stenosis and plaque formation that isn't calcified. Quantitative catheter angiography (QCA), coronary CT angiography, and coronary CT angiography were used to examine 106 individuals (cCTA). CCS was calculated both

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globally and for each artery individually. Each calcification was characterised as a calcified nodule, shell-like, or diffuse based on its morphological pattern. non-calcified plaque was assessed using cCTA investigationsThe global CCS has a poor correlation with stenosis. Regional calcium distribution and specific patterns of calcification, on the other hand, are linked to stenosis and non-calcified plaque. Thus, vessel-based rather than global calcium quantification and differentiation of specific morphological patterns of calcification could improve the specificity of CT calcium scoring for identifying individuals with obstructive disease [6].

In this work [7], they have done research in order to analyze and do estimation of the usage of various machine learning algorithms to predict the coronary heart disease by doing classification with the help of collection of all attributes in dataset and developing models of classification. Classification models namely Random Forest, K-Nearest Neighbours, and Decision Tree are developed to estimate the risk factor in coronary heart diseases. Along with that they have also implemented K-fold Cross-Validation for algorithms. So this research gave the result that prediction of heart disease in an individual is possible , it can be predicted that whether a person has chances of being affected by heart disease or not, within the next ten years . So once an algorithm is successful in giving accurate prediction results , than individuals can be treated thus they can be given medications as prevention from disease or cure can be done in a more better and effective way.

In [8] research has been done with the aim to understand the feasibility in detecting coronary artery lesions by implementing the new scanner " Computed tomography scanner" with sixteen detectors and rapid gantry rotation. An assessment of coronaries is carried out with CTA of coronaries but still a limitation of image quality occurs because images are impaired due to motion artifacts and calcifications. Multislice spiral computed tomography was used to examine sixty individuals who were scheduled for conventional coronary angiography (CCA) (MSCT). Calcium scores and contrast-enhanced coronary visualisation were used to assess evaluability, the existence of coronary artery lesions, and the proper clinical diagnosis.A total of 54 of these were appropriately assessed by the MSCT. Twenty-one lesions were overlooked or underestimated wrongly. The sensitivity was 72% and the specificity was 97%.

In [3] comparison has been done on various rearches been done , which are analyzed in this research paper, in order to predict CHD, using machine learning and deep learning techniques . Various techniques are developed to predict CHD, thus no work is done to compute stenosis.

***Methodology:***

Coronary heart disease are increasing day by day , this is due to plaques. . First of all, segmentation is performed to extract three dimensional (3d) coronary arteries. Afterwards, we have obtained centreline throughout the segmented coronary arteries with the use of Fast marching method[14]. Subsequently, 2d slices are achieved with the help og certerline. Lastly, we were capable to visually a analyze the slices and perform our investigation to find whether a patient is normal or affected with CHD.. In addition to this, color jet is applied to the slices, to produce visible results. The diameter shrinks of veins , thus plaques existence causes this shrink in diameter. By adding the color jet on slices, different intensities are appearing with different colors, plaque are displayed brighter in contrast to the blood and vein wall, and this automated application in this way can work to automate the detection process.

The dataset used here is rotterdam ( Coronary Artery Evaluation Framework).This dataset has a record of 18 patients. Along with the patient CT data, Reference Stenosis values are also provided by expert clinicians for comparison of research outcome. CTA Volumes ( Computed tomography Angiography) are used in this , basically these volumes are in 3D, we have turned them into 2D slices, after that we have investigated each slice by using image processing technique. Basically, the plaques and rest of vein and lumen segments are having different intensity values. The calcified plaques

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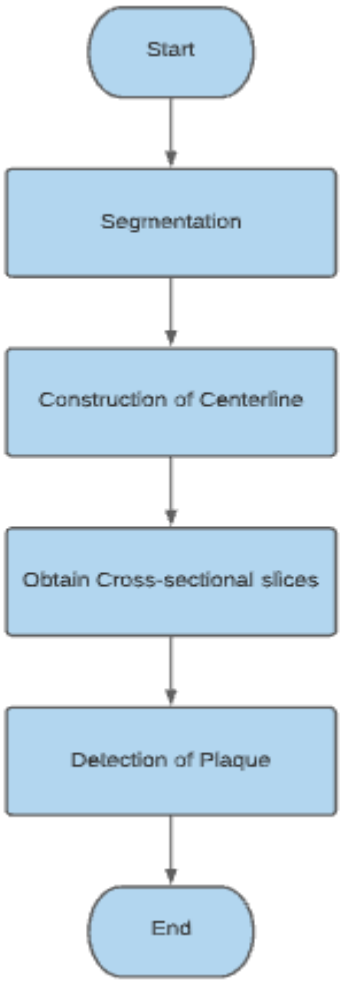
appear to be clearly brighter than the rest of vein segment. Whereas, the non-calcified plaque has intensity values resembling with the blood, but comparatively brighter than the blood. The abnormality ( sudden brightness) can be clearly seen from the resulting 2D slices.




***Results:*** The research and study initiated to detect and investigate the coronary arteries for the presence of plaques, causing a blockage in way of blood flow towards the heart has come up with the following results in the shape of 2d slices with clear visibility of plaques in coronary arteries causing CHD. Thus, aiming to highlight the intensity differences, the color jet is applied on the slices, which were basically black and white slices segmented from the CTA volumes. After the slices are obtained color jet map is implemented to apply color contrast on the slices. Additionally, this color contrast helps to distinguish between blood, fat(non-calcified plaques) and calcium depositions( calcified plaques) . The red color is the blood flowing in arteries, yellow is color in the middle of the red is basically the plaque, thus in this way one can perform visual analyses of arteries and detect plaques.

These results are visible in the following Matlab figures.

There are basically 3 slices of affected patient , with the Fig.1 and last Fig.3 howing the normal slices , whereas the Fig.2 is the affected slice (comprising of plaque), with yellow color interrupting the red color.

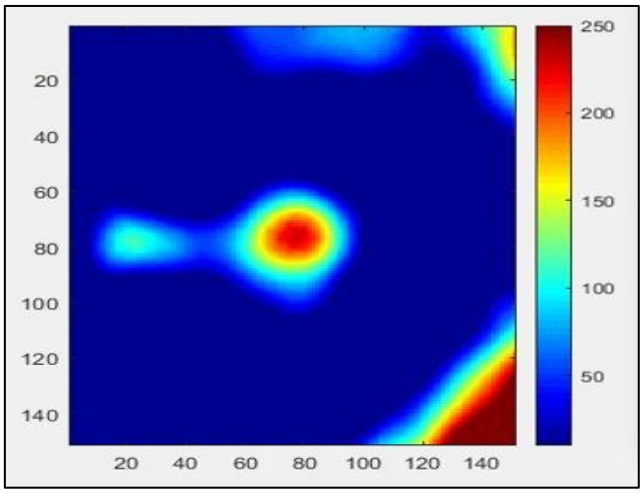



Fig.1 Slice of a normal segment, with no plaque.

Red color represents the blood whereas yellow is artery wall .

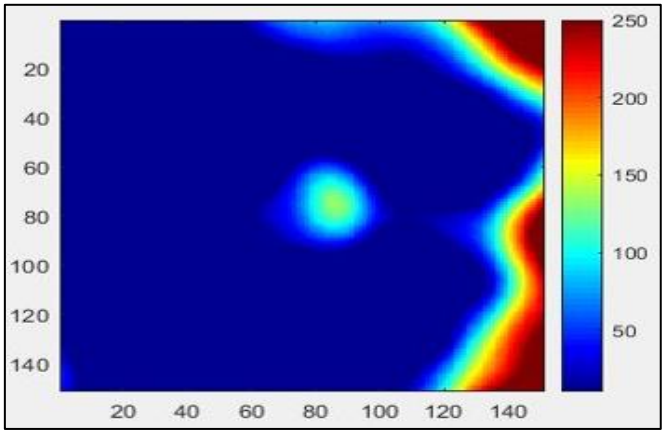



Fig. 2 Slice of an abnormal patient as there is plaque which

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is evident from the presence of yellow color in mid of vein and total absence of red color, which means there is great occlusion in an artery, thus blood flow disturbed.

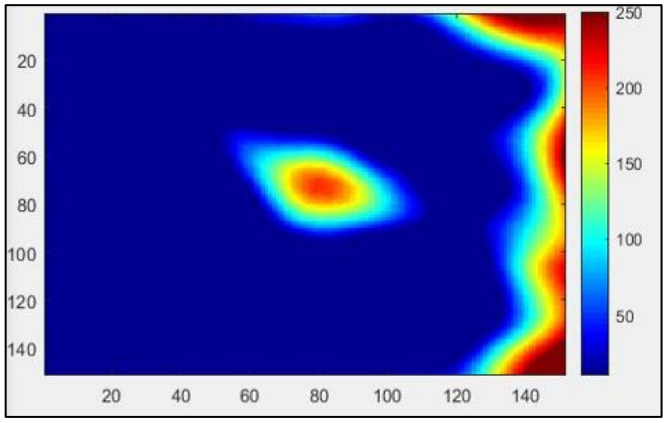


Fig 3. This is normal patient's slice, There is proper blood flow , evident from red color, thus no plaque , as no interruption of yellow in mid of vein diameter.

***Conclusion:***

In this work, we have a total of 20 patients evaluated, out of which 18 patients were detected with coronary plaque. These 18 affected patients are of two categories , one having calcified plaques( 12 patients), whereas other ones have non-calcified plaques(6 patients). Thus, we have achieved an accuracy of 85%.

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