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The Importance of Coronary CT Angiography in Diagnosis of The Coronary Artery Disease: Review Article

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ABSTRACT

Background: The development of plaque in the blood vessels is the reason of coronary artery disease [CAD], a dangerous condition that results in reducing the heart blood flow and the development of chest pain. Major risk factors involve smoking, high blood pressure, diabetes, inactivity, alcoholism, elevated cholesterol, and an inadequate diet. CAD is more prevalent in older adults, and males are at a higher risk of developing it than women. Symptoms of CAD involve chest pain, shortness of breath, and heart attack.

Aim of the work: This review article aimed to identify the importance of coronary CT angiography in diagnosis of CAD.

Methods: in this study 35 previous article about the important diagnostic test in diagnosis of CAD were examined to point out the superiority of coronary computed tomography angiography [CCTA]. We used Google Scholar, Science Direct, PubMed, and other internet databases. Additionally, the writers combed through relevant literature for references, however they only included researches covering the years from 2004 to 2023. Due of lack of translation-related sources, documents in languages other than English were excluded. Also, works in progress, unpublished publications, abstracts from conferences, and dissertations that did not form part of broader scientific investigations were excluded.

Results and conclusion: There are a lot of diagnostic tests for diagnosis of CAD including coronary computed tomography angiography [CCTA], electrocardiogram, echocardiogram, exercise assay, nuclear assay, cardiac catheterization and X-ray picture. Coronary computed tomography [CT] angiography is being utilized more frequently to diagnose CAD as a result of its enhanced diagnostic accuracy and reduced invasiveness. The high radiation dosage of coronary CT angiography, which contributes to radiation-induced malignancy, offsets the high diagnostic value of the procedure.

Keywords: Coronary artery disease; coronary CT angiography; Non-invasive diagnosis: Cardiac Imaging.

Coronary artery disease

Coronary artery disease [CAD] is a disorder that encompasses a wide range of other diseases and contributes to a variety of health risks. This article delves into the comprehensive examination of the pathophysiology, types, signs, and symptoms of CAD [1].

The heart is a critical component of the human organism. Regulation of blood pressure and purification of blood by transporting it to the lungs are the primary functions of the heart. The other function is to ensure that all body organs receive equal amounts of pressurized blood containing O_2 and to remove CO_2 from all body organs. Heart failure, cardiomyopathy, pericarditis, CAD, aorta disease, arrhythmia, heart valve disease, and peripheral heart disease are among the numerous heart diseases that can result in mortality. CAD is one of the most perilous diseases, as it results in a gradual mortality as a result of the cholesterol's deposition in the heart's arteries. The heart muscle is affected by atherosclerosis, which is the result of cholesterol accumulation in the arteries, resulting in the formation of plaque in the arteries [2].

Plaque is a mixture of a viscous substance, cholesterol, waste products, the fibrin hormone, and calcium, which is responsible for coagulation. Among cardiovascular illnesses, it is the most common. This involves unstable and stable angina, sudden cardiac arrest and myocardial infarction. Atherosclerotic vascular disease, atherosclerotic heart disease, and coronary heart disease are among the diverse terms used to refer to this condition. The prevalence of CAD has increased significantly as a result of the modern lifestyle, which includes a lack of exercise and the consumption of unhealthy food. Approximately 8 out of every 10 individuals will develop CAD in conjunction with chronic kidney disease [CKD]. End stage renal disease (ESRD) combined with CAD results in kidney dialysis and transplantation worldwide. There is a likelihood that the number of patients worldwide who suffer with ESRD and CAD is lower than that of those who are affected with CKD [3].

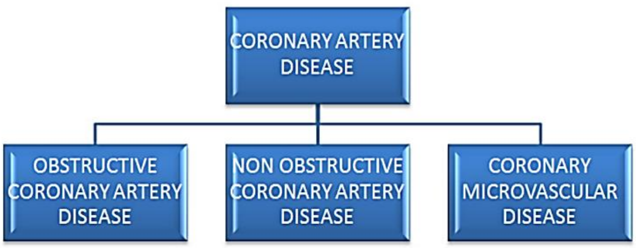

Figure 1: Types of coronary heart disease [CAD] [3]

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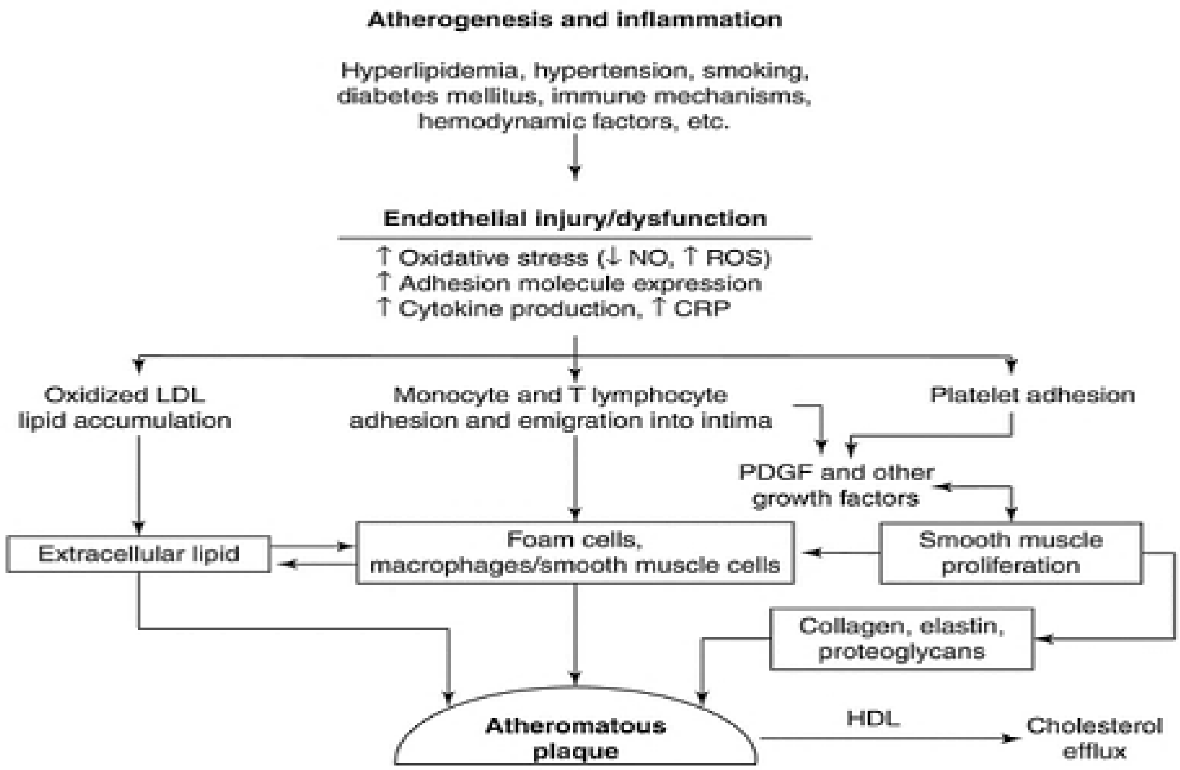

Figure 2: Pathophysiology of coronary heart disease [CAD] [3].

Diagnosis: In addition, there are numerous diagnostic tests, such as:

Electrocardiogram [ECG]: A cardiogram performed by an associate in nursing is a recording of the electrical signals that traverse the heart. Proof of a previous or ongoing heart failure is typically disclosed in the association of nursing graphical record [4].

Echocardiogram: An association of nursing sonogram is a diagnostic tool that employs sound radiation to generate images of the heart. The doctor will determine whether or not all components of the center wall contribute unevenly to the pumping activity of your heart during an ultrasound. During a heart failure, components that are susceptible to frailty may endure damage or inadequate oxygenation. This might indicate a disease such as arteria coronaria illness or other diseases [5].

Exercise assay: If the symptoms are most commonly experienced during physical activity, your physician may recommend that you operate a treadmill or stationary bike during your examination. In certain instances, a sonogram may be conducted in conjunction with these exercises. Frequently, this is referred to as a tension echo. An alternative to exercise is the use of medication to stimulate the heart in certain instances [6].

Nuclear assay: This examination is analogous to an exercise test, however it incorporates visual aids into the visual records. It monitors the flow of blood to your cardiac muscle during periods of relaxation and tension. The bloodstream is injected with a tracer, and specialized cameras are used to observe the areas of the heart that suffer from a decreased blood supply [7].

Cardiac catheterization and X-ray picture: The gentle insertion of a tube into an artery or vein in the neck, arm, or pelvis, and subsequently up to the heart, is the essence of an internal organ catheterization procedure. The conduit cannot be placed in the correct position using X-rays. Dye is occasionally administered through the catheter. The dye is used to enhance the visibility of blood vessels in photographs and to describe any blockages. A balloon will be inflated and inserted through the catheter to improve the flow of blood in your coronary arteries if you have a blockage that requires treatment. The expanded artery is typically maintained open by a mesh tube [stent] [8].

Cardiac CT scan: The physician will identify metallic element deposits in your arteries by conducting a CT scan of the center, which will result in their narrowing. Arterial coronary disease may also occur when a significant amount of metallic element is discovered. A CT coronary X-ray image is generated by administering a contrast dye intravenously [IV] during a CT scan, which results in the creation of detailed images of the cardiac arteries [9].

Coronary computed tomography angiography [CCTA]: The development of CT technology during the late 1990s led to the emergence of CCTA, which was distinguished by enhanced temporal and spatial image resolution. The CCTA is capable of generating three-dimensional, high-resolution images of the heart, its epicardial arteries, and the primary vessels using thin-slice images. The scanner generates X-rays that are precisely synchronized with the patient's cardiac cadence by employing ECG-gating when 64-detector or more CTs are utilized. The utilization of prospective scan triggering enables the visualization of the coronary arteries at a high resolution with minimal radiation exposure [2–3 mSv] [10].

In addition, there is increasing evidence that CCTA is clinically useful for guiding the management of CAD at different stages. This includes detecting early subclinical atherosclerosis and assessing acute chest pain in patients with known CAD who do not have myocardial injury. The CCTA can identify both nonobstructive and obstructive CAD, guide medical and interventional therapy to enhance outcomes, and help with risk prognosis due to its excellent diagnostic accuracy and negative predictive value [11]. Technical aspects: Non-invasive visualization of moving coronary arteries is a difficult task. This is due to their continuous movement throughout the cardiac cycle and their relatively small diameter. The best diagnostic tool for rendering coronary arteries optimally acquires the entire dataset in a matter of tens of milliseconds ["temporal resolution"], can synchronize with the cardiac cycle ["gating"], and can visualize structures at sub-millimeter resolution ["spatial resolution"]. In order to see the coronary arteries with diagnostic picture quality, 64-slice CT scanners could fulfil these criteria. Since then, CCTA's diagnostic accuracy has been further boosted by a slew of technological advancements in both hardware and software [12]. This was achieved by implementing dual-source CT, which resulted in a transition from 125–175 ms to 65–75 ms in temporal resolution. Furthermore, the entire length of the heart could be covered in a single pulse as a result of advancements in detector technology. High isotropic spatial [best 0.35 mm] and temporal [best 65 ms] resolutions are achieved by the majority of contemporary scanners, resulting in exceptional image quality. These parameters, however, still fall short of the resolution offered by invasive coronary angiography [ICA] [0.2 mm and 30 ms, respectively] and are less than half of the necessary resolution [13].

Advancements in image processing software were in direct correlation with advancements in hardware technology. Thus, the conventional "filtered back projection" is being replaced by "iterative reconstruction" as the computational power has elevated over the past two decades. This minimizes the radiation exposure of the patients by reducing the disturbance in the image and reducing the necessity for strong currents during the acquisition process [14].

Protocol choice: Currently, scanners are adaptable in terms of the protocol used to acquire data. This must always be customized to the unique clinical query [left ventricular function, status of the coronary arteries, and follow-up CCTA] and the specific individual [heart rate, irregularities in heart rate, habitus]. In general, three kinds of ECG-gated protocols may be implemented during the acquisition of a CCTA [Figure 3] [15].

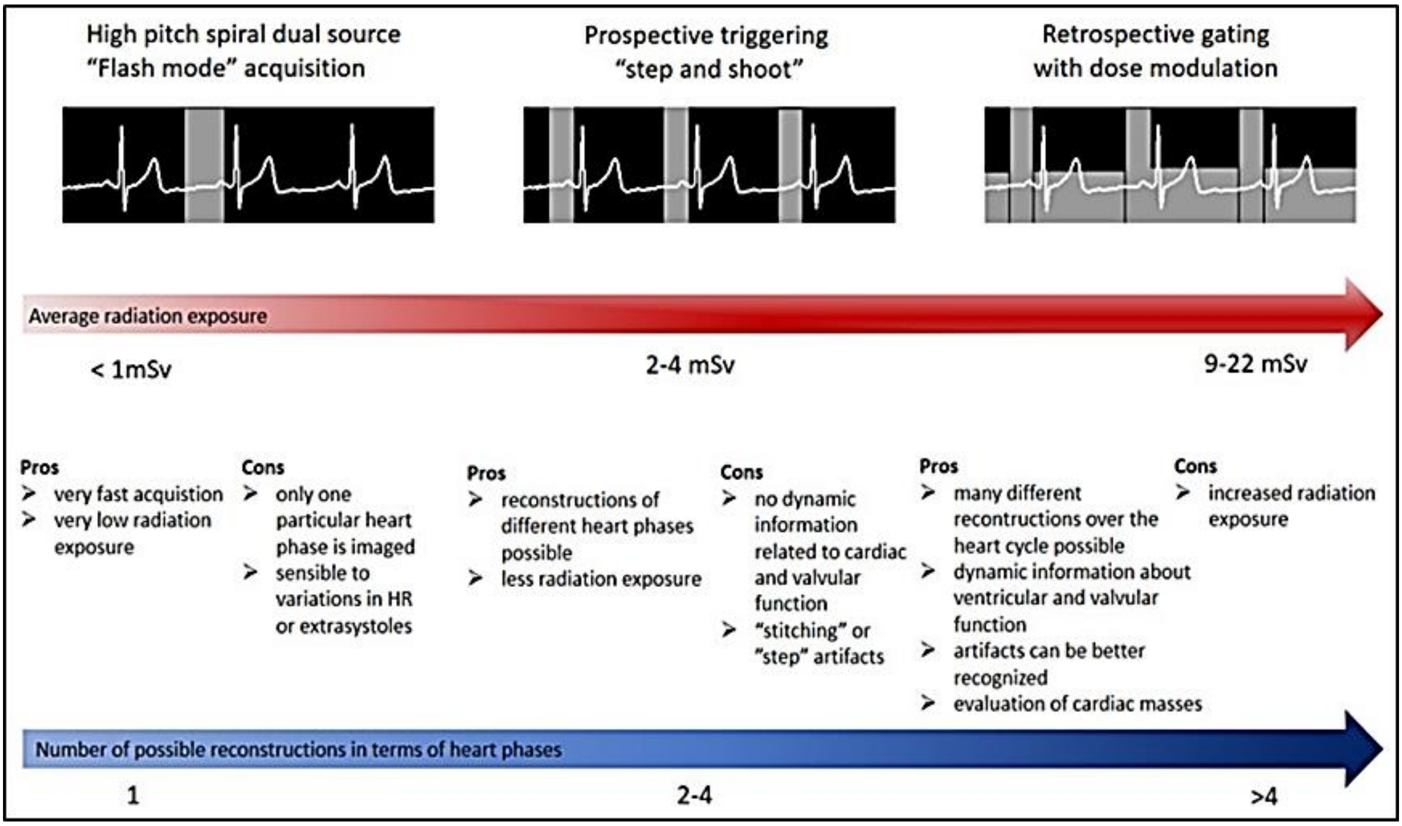

Figure 3: Scan modes used in CCTA with advantages and disadvantages as well as radiation exposure for each of the different acquisition approaches [16].

The initial acquisition method employed in CCTA was retrospective ECG-gated acquisition in "spiral" or "helical" mode. Data are captured throughout the entire cardiac cycle when retrospective gating is implemented. One of the primary advantages of this protocol is its capacity to reconstruct CCTA acquisitions at different stages of the cardiac cycle. Also included additional information on valvular anatomy and function, as well as cardiac volumes and function. The patient's elevated radiation exposure is the primary drawback. Therefore, the implementation of a dose-modulation algorithm is currently underway, despite the selection of this protocol. Outside of the coronary artery imaging time frames that have been selected, this algorithm reduces the tube current by approximately 20%. Despite the minimal radiation dose, it is still possible to assess cardiac and valvular function. Coronary arteries exhibit the least movement during the cardiac cycle, as determined by an analysis of their motion. Therefore, either mid-diastole [60–70% of the RR cycle] or end-systole [30–40% of the RR cycle] are the best times to acquire [17].

As a result, it is conceivable that the most advantageous period for image acquisition would be within these time frames. With the prospectively ECG-triggered axial acquisition in mind, the subsequent protocol was developed. This scan mode, which is also referred to as "step and shoot," or "sequential" enables the acquisition of images without the need for table movement. However, the majority of the detectors are smaller than the heart's length, necessitating multiple heartbeats to envelop the entire heart. In general, this method of acquisition produces images that exhibit exceptional contrast and relatively low radiation exposure. However, the shortcomings of this protocol are primarily characterized by the presence of "stitching" or "step" artefacts and a relatively limited number of potential cardiac phase reconstructions, particularly when heart rate variability is present between the layers. This protocol is particularly beneficial for patients who have atrial fibrillation or irregular heartbeats. The acquisition of data in diastole would be relatively meaningless in these patients due to the significant variation in diastole from beat to beat [18].

A "step and shoot" acquisition started during systole often produces very good images, even though the coronary arteries don't move much at end-systole and irregular heart rates don't affect the systole as much [Figure 4]. In conclusion, techniques that enable the collection of data necessary for a complete characterisation of the coronary tree during a single pulse have been developed thanks to technological improvements in the last decade. Two separate approaches, one specific to each scanner, exist for this purpose. Depending on the patient's heart rate, scanners with a detector coverage of ≥ 16 cm can obtain an entire dataset in a single pulse, all without the patient having to move [19].

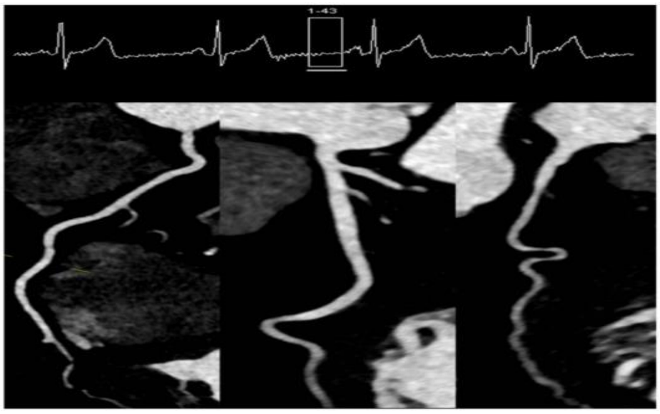

Figure 4: "Step and Shoot" protocol triggering during systole in a patient with atrial fibrillation and a heart rate of 114/min [16].

However, dual-source scanners enable the sampling of the entire dataset in a single pulse through the use of an ECG-triggered high-pitch "spiral" acquisition [a pitch value of approximately 3] or the so-called "Flash" mode. These acquisitions provide the patient with extremely high contrast images that are free of "stitching" artifacts and have a minimal radiation exposure [typically less than 1 mSv] [**Error! Reference source not found.**]. Conversely, the acquisition mode's primary drawbacks are its high reliance on cardiac rhythm and its restricted ability to reconstruct images within a single time point [20].

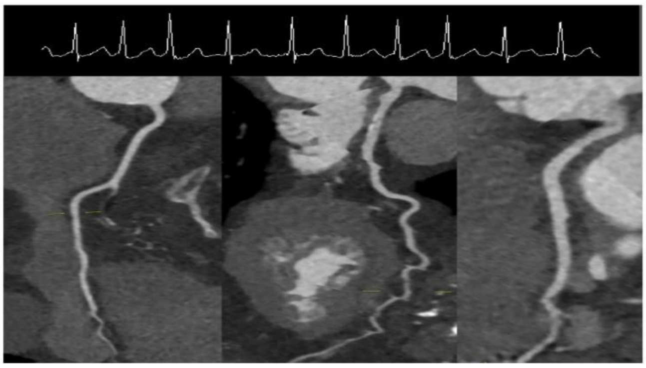

Figure 5: High-pitch dual source spiral protocol ["Flash" mode] in a patient with a stable heart rate of 58/min [16].

Diagnostic accuracy of CCTA: Based on data from the National Cardiovascular Data [NCD] Registry, imaging modalities such as SPECT, MRI, functional testing, and stress echocardiography may often detect or exclude major coronary stenoses with quite good accuracy. About two-thirds of patients had non-invasive functional testing done before elective ICA, and most patients still can't get a definitive diagnosis of obstructive CAD. Sixty-four percent of patients who selected for ICA were part of the NCD registry, and sixty-four percent of those patients had already done functional testing. Less than half of the patients with abnormal functional test results on the next ICA were found to have non-obstructive stenoses, which accounted for around 55% of the 52%. Hence, functional imaging's clinical usefulness has come under question [21].

Because of this, researchers have been looking at other ways to improve the pre-ICA prediction of obstructive CAD risk, with CCTA being the main focus. Enhancing regular CCTA to the level of MRI and PET modalities without sacrificing sensitivity is possible with the integration of CT-FFR and CT perfusion [CTP]. Nevertheless, it is less specific than FFR **[22]**.

Prognostic value of CCTA

In the last ten years, a substantial amount of evidence has been accumulated regarding the outcomes of patients who undergo CCTA. The efficacy of CCTA in providing prognostic information for individuals with CAD across the spectrum is supported by recent data. This encompasses high-risk individuals with recurrent chest discomfort and low-risk individuals with subclinical atherosclerosis. The results of CCTA are utilized to inform clinical decisions and management that are designed to improve outcomes. In comparison with both cardiovascular risk factors and a coronary artery calcium [CAC] score, the incremental prognostic value of a CCTA in symptomatic patients has been consistently demonstrated in a variety of registry studies **[23]**. The risk assessment is enhanced by the detection and quantification of atherosclerotic plaque prior to the occurrence of an obstructive coronary lumen stenosis [> 50% of the diameter] through the provision of a comprehensive anatomical evaluation of the coronary arteries by CCTA. The extraordinary prognostic value of a normal CCTA, particularly in terms of event-free survival, has been confirmed by additional research over a period of 5 to 10 years. The value of CCTA, however, extends beyond the simple distinction between normal [no CAD] and abnormal [CAD present] outcomes. But CCTA is more effective than only finding normal [no CAD] and abnormal [CAD present] outcomes. With respect to both non-obstructive and obstructive CAD, CCTA is linked to a less favorable outcome compared to usual coronary arteries **[24]**.

For both non-obstructive and obstructive lesions, there is a link between the number of vessels affected and mortality. Regardless of the degree of stenosis, the researchers found a high association between the number of segments with plaque and survival. They also developed a score based on these criteria **[25]**.

CCTA and practice guidelines

In individuals who are suspected of having coronary artery disease [CAD], the clinical decision-making process for cardiac testing relies on determining the pre-test likelihood of CAD. Patients with intermediate pre-test probability have the greatest benefit from testing, whereas those with extremely low or high pre-test probabilities see less benefit, as stated in Bayes' Theorem. Comparative to alternative modalities, CCTA is cost-effective, has a comparable positive predictive value, and has a significant negative predictive value. These factors all support this recommendation. If functional imaging was non-diagnostic, ICA could be taken into account. Individuals with equivocal CCTA or known CAD were the only ones who were advised to undergo functional imaging. To evaluate the implications for prognostic and diagnostic purposes of the revised modifications to the 2016 NICE guideline, **Adamson *et al.*** **[26]** demonstrated that the participants from SCOT-HEART were subjected to a post-hoc analysis.

- **CCTA for stable CAD in clinical practice**

A clinical framework was proposed to enhance the outcomes of new onset, stable chest discomfort of suspected coronary origin in accordance with the NICE guideline. In contrast to functional imaging, the capacity of CCTA to execute an anatomical assessment of the coronary arteries served as the foundation of this framework. Both obstructive and non-obstructive atherosclerotic plaque can be more easily identified and quantified using this examination. As a result, the patient's subsequent treatment is contingent upon the presence of either obstructive or non-obstructive plaque at the time of stable chest pain confirmation and CCTA. Standard ischemia-guided management is advised in the presence of obstructive plaque. Behavioral, aggressive lifestyle, and pharmaceutical preventative strategies are used to improve the outcomes of cardiovascular disease when non-obstructive plaque is predominant **[27]**.

Despite the fact that ICA provided symptomatic alleviation to patients with refractory angina, there was no discernible difference in primary or secondary outcomes between an initial conservative strategy [optimal medical therapy] and an initial invasive strategy. A more modern approach to assessing and treating stable angina was proposed in light of the ischemia trial's findings. In this context, CCTA should be administered to a patient with stable angina at the outset. In the absence of atherosclerosis, the optimal medical treatment of functional angina requires risk factor modification and lifestyle therapy **[28]**.

If there is modest non-obstructive CAD [< 70% stenosis by visual inspection] in 1-2 vessels, it is suggested to use a single antiplatelet and lipid-lowering treatment. Also required is little medical treatment. In cases where there is significant non-obstructive or obstructive CAD [≥70% on visual evaluation], further medical treatment may be necessary, including antithrombotic, intense cholesterol lowering [e.g., high-intensity statin, ezetimibe], or anti-inflammatory medication. When symptoms persist despite optimum medical treatment, coronary artery bypass grafting [CABG] or percutaneous coronary intervention [PCI] may be explored. Finally, revascularization should be considered in alongside rigorous medical therapy in cases when left main or 3-vessel CAD, diabetes mellitus, or ischemic cardiomyopathy [ejection fraction < 35%] are detected **[29]**.

An expert consensus document on CCTA was published by the Society of Cardiovascular Computed Tomography [SCCT] in 2021 to offer supplementary guidance on its feasibility in clinical practice. In the presence or absence of known CAD, they emphasized a wide range of clinical indications for CCTA, such as stable chest pain. Based on the substantial data that supports the considerable decrease in the rate of incident MI with CCTA in comparison with functional testing methodologies and the increased utilization of preventive medical therapies, the recommendations are made [11].

In particular, they determined that CCTA should be the primary assessment method for patients with stable atypical/typical chest pain, coronary anomalies, anginal equivalents, and prior CABG, particularly when the primary objective is the location of the left internal mammary artery or graft patency, and there is no known CAD. In addition, CCTA is a valid test to evaluate patients who have stable typical or atypical chest pain or anginal equivalents, known CAD, coronary stents larger than 3 mm, proximal non-bifurcation thin strut stents smaller than 3 mm, younger patients with a low-intermediate probability of CAD, patients suspected of having aortic dissection, and as a functional test to improve the accuracy of diagnosis and prognosis [30]. The optimal medical therapy for patients with stable CAD, as determined by CCTA, is the defining characteristic of management. Coronary atherosclerosis's progression is halted and its effects are mitigated through the use of pharmacologic interventions and an aggressive lifestyle in this therapy. If symptoms persist despite best medical treatment for stable CAD, revascularization may be an option to improve quality of life. [31].

There are advantages and disadvantages to CCTA. Atherosclerosis imaging is reliably accomplished through invasive coronary angiography and non-invasive CTCA, as well as to a lesser extent, coronary magnetic resonance imaging. However, functional tests are employed to evaluate symptoms in a more precise manner. Primary prevention, which encompasses lifestyle modifications and pharmacotherapy to alter risk factors and prognoses, is predicated on a diagnosis of coronary atherosclerosis. In patients who had symptoms of ischaemia, a decision for ischaemia-guided myocardial revascularization should be informed by physiological assessments, functional testing, or invasive management, in addition to medical therapy for obstructive CAD [32].

For small vessel disease, CTCA fails to provide a resolution. Myocardial ischaemia testing is required for the diagnosis of microvascular angina. This testing typically involves non-invasive procedures, such as stress testing with cardiovascular magnetic resonance [CMR] or positron emission tomography, or invasive tests of coronary vascular function [functional coronary angiography]. The majority of patients who attend chest pain clinics are women, and obstructive CAD is not evident in the majority of these patients. Due to the initial emphasis on the exclusion of obstructive CAD, numerous patients are left with ambiguous management and perplexing chest symptoms. There are variations in the natural history of ischaemic heart disease [IHD] between males and females. The prevalence of obstructive coronary artery disease [CAD] is higher in males, whereas ischaemia with no obstructive coronary arteries [INOCA] is higher in females. Among these conditions are vasospastic angina and microvascular angina [33].

Compared to patients with obstructive CAD, patients with small vessel disease experienced worse quality of life and physical limitations due to angina in the prospective, all-comers CorMicA registry, which involved patients undergoing clinically indicated CTCA. In addition, the utilization of functional assessments in conjunction with angiography resulted in a revaluation of the diagnosis and modifications to the treatment regimen in fifty percent of the participants in the study.

Quality of life and symptom improvements were achieved over the course of a year by means of CorMicA's stratified medicine intervention, which connected test findings with mechanistically targeted treatment. However, compared to the standard treatment group, the CTCA-guided group in the SCOT-HEART study showed less improvement in angina and quality of life. Based on these results, it is clear that CTCA-guided treatment without functional testing is not the best way to relieve symptoms, especially since very few people who report chest pain actually have obstructive CAD. This strategy's advantages and disadvantages are presented in Table 1) [34].

Table 1: The advantages and disadvantages of a CTCA -first approach [35]

Advantages	Disadvantages
Diagnosis of coronary atherosclerosis (high sensitivity) to inform the decision for preventive medical therapy and improve prognosis	Excluded patients—arrhythmias, tachycardia, severe renal dysfunction, contraindications to beta-blocker—asthma, heart block
FFR_{CT} provides data on the functional significance of coronary atherosclerosis increasing specificity for flow-limiting CAD, optimizing the decision for invasive management.	Heart rate control—prescription of beta-blocker or rate-limiting calcium channel blocker entailing physician and pharmacy visits before the hospital visit for the CTCA scan
Incidental findings (cardiac and thoracic)	Potential for contrast media reaction
Scan generally well tolerated by patients	Ionizing radiation exposure
Brief scan duration facilitates 'high throughput' clinical service imaging	In stable populations referred for CTCA, most individuals do not have obstructive CAD, leaving the diagnosis and onward management of symptoms uncertain in many referred patients
	No data for microvascular function or myocardial ischaemia
	Limited specificity for quantifying lumen loss due to atherosclerosis (moderate specificity leading to false positive results), especially within coronary calcification and stents
	FFR_{CT} exclusion criteria include history of coronary revascularization, atrial fibrillation
	In patients with persisting symptoms and no obstructive CAD, additional visits for downstream functional tests may be necessary, extending the care pathway
	In ACS, a CTCA-first strategy has no prognostic benefit, prolongs hospital stay, increases hospital costs
	Clinical service: the CTCA scan and report are usually not provided during the initial clinic visit, hence repeated visits are needed
	FFR_{CT} adds to initial costs; downstream and overall costs may not increase
	Cost-effectiveness uncertain, e.g. SCOT-HEART health economics analysis not available

ACS, acute coronary syndrome; CAD, coronary artery disease; CTCA, computed tomography coronary angiography; FFR_{CT}, computed tomography-derived fractional flow reserve

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CONCLUSION

CCTA is a practical tool for the early diagnosis of CAD. It is non-invasive and effortless to operate. Furthermore, CCTA is capable of precisely identifying and locating the sites of coronary stenosis and severity of stenosis. Consequently, it is worthy of extensive use as a screening test for suspected CAD.

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