REVIEW ARTICLE

# The Diagnostic Accuracy of Coronary Computed Tomography Angiography (CCTA) and Cardiac Magnetic Resonance Imaging Angiography (CMRA) as a Diagnostic Tool for Cardiovascular Disease: A Review

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## ABSTRACT

Coronary artery disease (CAD) is a significant global health concern, posing challenges for individuals and public health systems. Current guidelines emphasize the importance of non-invasive functional or anatomical testing as the first-line approach before invasive procedures. Advances in imaging modalities have been crucial in improving CAD diagnosis and management. This study explores two widely utilized imaging modalities: coronary computed tomography angiography (CCTA) and cardiac magnetic resonance imaging angiography (CMRA). Both techniques are examined for their diagnostic capabilities, safety profiles, and the extent of their clinical application in CAD assessment. Recent technological advancements, such as CT-derived fractional flow reserve and improved perfusion imaging, are also highlighted as supplemental tools for anatomical evaluations. CCTA has shown remarkable progress in image quality and reduced radiation exposure over the past decade, making it a preferred choice for many clinicians. Similarly, CMRA has gained prominence due to enhancements in functional evaluation and tissue characterization. These advancements enable more precise and earlier identification of risks associated with CAD. Both modalities have proven to be effective, yet distinct in their strengths and limitations. This paper provides a comparative analysis of CCTA and CMRA in CAD assessment, offering insights into their strengths and weaknesses. These findings aim to guide physicians in selecting the most appropriate imaging modality tailored to each patient's specific needs, ensuring optimal diagnostic and therapeutic outcomes.

**Keywords:** *Coronary artery disease, cardiac magnetic resonance imaging angiography, coronary computed tomography angiography, heart failure, computed tomography.*

## INTRODUCTION

Cardiovascular Disease (CVD) is a leading cause of mortality and morbidity worldwide. Accurate diagnosis is crucial for effective treatment and improved patient outcomes. Imaging plays a vital role in evaluating cardiovascular conditions, aiding in early detection and management. While echocardiography has been widely used, its limitations in certain clinical scenarios necessitate the use of advanced imaging modalities [1].

Computed Tomography (CT) and Cardiac Magnetic Resonance (CMR) have emerged as valuable non-invasive techniques for assessing cardiovascular diseases. CCTA is highly effective in detecting coronary artery disease (CAD), providing detailed visualization of coronary anatomy, plaque characteristics, and stenosis severity. CMR, on the other hand, offers comprehensive myocardial tissue characterization, functional assessment, and perfusion analysis without radiation exposure. These modalities serve as alternatives or complementary tools to traditional imaging techniques, enhancing diagnostic accuracy [2].

With the continuous advancement of imaging technology, the selection of an appropriate modality depends on various factors, including clinical indications, patient characteristics, and technical feasibility.

This review aims to evaluate the diagnostic accuracy of CCTA and CMR in cardiovascular disease, highlighting their applications, advantages, limitations, and potential future developments [3].

The advances in surgical procedures, catheter-based treatments, and children with congenital heart conditions are the reasons for the increase in the number of adults that are living with these illnesses [4]. These people may have a problem during the echocardiographic exams if, for instance, they had a condition that was not diagnosed in the past or they were surgically treated. The exact structure and hemodynamics of each congenital anomaly need to be known and the ventricle function and valve problems must be precisely evaluated so that these patients are well-managed [5]. The fast-paced growth of imaging technologies like MRA and CTA has culminated in the better visualization of the intricate cardiac structures which, as a result, the evaluation of the unique patient group has become easier. Echocardiography still is the most used imaging tool in the clinical investigation of congenital heart disease, but the MRA and CTA can provide additional valuable information. The fact that choosing a method that will give the highest quality images, will decrease

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Received: December 12, 2024; Revised: February 14, 2025; Accepted: February 14, 2025
DOI: https://doi.org/10.37184/nrjp.3007-5181.1.20

 

the risks for the patient, and will be cost-effective, is the reason why everyone should pick the one that will lead to the best clinical decisions for adults with congenital heart issues [5].

## Diagnostic Performance of CCTA

The diagnostic efficacy of CCTA for obstructive Coronary Artery Disease (CAD) and myocardial ischemia. It delineates the development of CCTA from the invention of the 64-detector row technology in 2005, to the results of the multicenter studies that proved the CCTA's performance in different patient populations. The research proved that the CCTA had a high sensitivity (85%-99%) and specificity (64%-90%) for detecting obstructive CAD. The analysis between CCTA and invasive coronary angiography, looking into the weaknesses such as referral and spectrum biases, was the focus of the methodology [6]. The article also explores the accuracy of CCTA for myocardial ischemia, stating that the results are very good for both diagnosis and risk stratification, based on myocardial perfusion scintigraphy. Apart from this, it talks about the radiation dose variability in CCTA and ways to reduce the exposure, thus, the patient safety issue is stressed [7].

To sum up, the article urges for the best studies to be used to the end of finding out the role of CCTA in the prediction of outcomes and to help with cost-efficient and safe treatment. It gives useful information on the diagnostic capacity of CCTA that describes its role in the management of CAD and myocardial ischemia.

The clinical importance of the CCTA in the diagnosis of patients with suspected CAD. It illustrates CCTA's capability to recognize patients who do not need additional tests and are probably going to be sick. The research also investigates the connection between CCTA-detected coronary artery plaque and the functional measures of ischemia, thus, the CCTA's predictive value for severe CAD and functional ischemia is also proved [8]. The process included determining the CCTA's anatomical measures of plaque extent, location, distribution, and composition about functional myocardial ischemia which was verified by myocardial perfusion scintigraphy (MPS) in the patients with suspected CAD. The study showed that some CCTA results, like the segment stenosis scores and the mixed plaque scores, were related to the scans that were abnormal severely, therefore proving the predictive value of these results for the adverse CAD prognosis [9].

A study involving 4,146 patients assessed the impact of CCTA in the diagnosis and management of coronary artery disease (CAD). Patients were divided into two groups: one receiving standard care and the other undergoing CCTA in addition to standard care. Post-hoc analysis revealed that CCTA helped identify cases of obstructive coronary artery disease that were not detected in the standard care group. This improved diagnostic accuracy led to better risk stratification and timely initiation of preventive therapies. As a result, patients who underwent CCTA had a significantly reduced rate of both fatal and non-fatal Myocardial Infarctions (MI), demonstrating its role in enhancing clinical decision-making and patient outcomes [10].

This study proved that CCTA made the selection process for coronary angiography invasive more accurate, thus, the therapies and revascularization procedures became more targeted and better. This caused a drastic drop in the rate of lethal and non-fatal MI among patients who were assigned to CCTA compared to the ones who were in standard care. This technique encompassed the evaluation of the shift in the obsession of invasive CA, preventive treatment, and clinical results through the national electronic health records. The patients' CCTA outcomes were classified according to the severity of CAD, and the study pursued the participants for a median of 20 months to assess the long-term impact of the CCTA on the clinical outcomes [11]. CCTA in community hospitals, which is the main focus of the article, and the evaluation of chest pain and the diagnosis of CAD. The method consisted of applying CCTA for the first time in the case of Acute Coronary Syndrome (ACS) patients in the emergency rooms. Research that was carried out with 16-slice and 64-slice CCTA showed that the high level of specificity, sensitivity, and undesirable predictive value of the test for diagnosing significant coronary lesions was proven [12].

ROMICAT was a study that evaluated the role of CCTA in the triage of ER patients with ACS and it was found that CCTA allowed the early discharge of many patients with no troponin elevation and non-ischemic ECGs. The ROMICAT study proved that the CCTA is very sensitive and has a perfect negative predictive value for ACS, highlighting its amazing efficiency in ERs [10]. Besides, the CT-STAT trial compared CCTA to the standard care for patients with acute chest pain and showed that CCTA was the reason for the early discharge of most patients, the short diagnosis time, the low radiation exposure, and the reduced costs of the overall management of the disease compared to the conventional. The findings show that CCTA can be a helpful diagnostic tool for CAD and chest pain evaluation in community hospitals, hence, it has the potential to be used as a diagnostic tool for CAD and chest pain evaluation in community hospitals [12].

## Diagnostic Performance of CMRA

CMRA is a precious diagnostic and detective method in the cases of myocarditis, for example. CMRA, when added to echocardiography and PET, is approved for the detection and management of inflammatory intracardial diseases in known patients according to the ESC guideline by heart failure [13]. It is in the use of specific imaging methods in CMRA that the two major types of problem (ischemic and other basing factors) can be swiftly ascertained in acute clinical diagnosis. CMRA-based Lake Louise criteria is the acceptable way to diagnose myocarditis, therefore, cannot be missed, and CMRA has directed the focus on tissue targets including myocardial edema, hyperemia, capillary leak, myocyte necrosis, and fibrosis. This thoroughness allows for a quite adequate diagnosis of myocarditis not to just imagine a single impairment or infection of the area due to the inflammation [14]. The image modality boundary lines will be a great help to prevent misdiagnosis done using imaging methods resulting in a high accuracy and high rate of correct identifications. Although this protocol such as T2-weight imaging which is adapted to detect myocardial edema and LGE (late gadolinium enhancement) imaging technique, which is applied to identify sites of fibrosis and necrosis, are useful in CMRA for myocarditis implementation, some shortcomings exist. LGE in myocarditis is a combination of the non-continuous and the irregular, with the structure that is more speckled from both sides of the sub-endocardium and the transmural layers that are affected separately and in a sporadic manner to differ from ischemic issues. Subsequently, LGE imaging will not be widely used for differentiating inflammation from chronic lesions as it is not considered a specific parameter of those negative indications. As compared to T2 weighting, localization of myocardial edema is more significant with visualization of lengthy T2 values which act as high signal intensity on the imaging. An extremely powerful imaging method that showed its efficiency in restoration of time, T1 mapping, and LGE images might be regarded as a multipara-metric tool with the ability to fulfill the Lake Louise Criteria for the proper diagnosis of myocarditis [14]. These powered imaging techniques today offer a full view and embrace different approaches to the same pathology by providing a basis for many other imaging tools such as echocardiography and PET. MRA, which is an imaging modality of the best kind of alternative with its different techniques and high multipara metric ability serves multifunctional roles such as detecting and assessing heart pathological ailment especially inflammatory diseases such as myocarditis. Standard protocol and criteria such as the Lake Louise Criteria act as a good reference point for doctors to make a more accurate diagnosis for myocarditis and no other types of conditions of the heart. Among the routine CMRA cardiac imaging considers major involvement in the identification of responses at the tissue level for inflammation and damage [15]. Therefore, such responses are more important in managing and treating patients who are suffering from Inflammatory Cardiomyopathy.

## Comparing the Efficacy of CCTA and CMRA

CCTA and vasodilator stress CMRA both are very reliable imaging techniques, and they have managed to get the images of almost 97% of the cases at very high quality [16]. However, the detection of their capacities should be viewed as a good thing if one knows what their main goal is. Usually, CCTA is utilized to diagnose CAD and stress CMRA is for the identification of functional signs of ischemia [17].

CCTA has the highest sensitivity (97%) among all the non-invasive imaging methods for the indicating of the anatomically significant CAD. Nevertheless, it has a lower specificity for both the anatomical (78%) and functional (53%) significant CAD [18]. The low specificity is usually because of partial blooming or blood volume artifacts that make the calcified plaques look bigger than they are, hence, the overestimation of the stenosis severity. Therefore, it is the Agatston score, which evaluates the level of calcification of the coronary artery that is the main issue that stands behind the non-diagnostic CCTA result. The findings also complicate the assessment of the coronary artery stents [19].

Radiological tests, namely CCTA and CMRA, occupy a prominent position in the complex diagnostic cardiological procedures of CAD. CCTA initially invests in anatomical assessment to provide the most precise result for CAD detection. While this technique discriminates, it is prone to artifacts of inappropriate detectors that can undermine the diagnostic by overestimating stenosis severity. Yet such an approach contrasts with stress CMRAs which indicate functionally impaired ischemia, thus exact assessment of the severity of stenosis *via* hemodynamic means is possible [20].

CTA is yet unsurpassed by any other technology in the identification of non-obstructive coronary deposits, which are often diagnosed late only after they rupture and cause a myocardial infarction. On top of that, the modalities used by CCTA are also useful in the detection of plaque vulnerability such as low-attenuation plaques and the Napkin ring sign, which are thus very important as they influence risk stratification and treatment strategies. For instance, the PROMISE and CONFIRM studies together with the SCOT-HEART trial have shown CCTA's ability to influence patient outcomes as it plays a role in guiding therapeutic decision -making and even minimizing invasive engages [21].

The investigation of the diagnostic ability of CCTA *versus* CMRA in children with Kawasaki Disease (KD) was the aim of the research. This study investigated 111 CCTA and 311 CMR scans, with 54 KD patients who underwent both imaging methods for comparison. The research showed that CCTA found more coronary artery aneurysms (CAAs) than CMR, with CMR overlooking 50% of the CAAs discovered by CCTA. The research concluded that CCTA can be a better diagnostic tool than CMR in identifying CAAs in KD patients [22].

The usage of MRI and CT imaging techniques in adults with congenital heart disease. Due to the progress in surgery and catheter-based intervention, the number of adult patients needing the right imaging for diagnosis and management of the disease is increasing. Even though echocardiography has been the main imaging tool, it may be not suitable for adult patients since it has some factors that may be the reason for poor acoustic windows, prior operations, or lung disease. This makes the demand for other imaging systems such as MRA and CTA. The main thing that both MRA and CTA have in common is that they provide better visualization of the complex cardiac anatomy and this helps in the assessment of congenital anomalies, ventricular function, and valvular dysfunction [23].

Noninvasive imaging methods are very important in the diagnosis, and management of ischemic heart disease, a major world health problem that costs a huge amount of healthcare expense. Although CA is still the reference method for the diagnosis of coronary artery stenosis, the high cost and the possible secondary effects of this method, such as vascular access complications and contrast-induced nephropathy, are urging the alternative approach to ischemic heart disease management based on the physiological significance of stenosis [24].

The authors are stressing the importance of the biological effect of coronary artery stenosis for the treatment of the disease. The scientists discuss the different noninvasive cardiac imaging ways that can be used to differentiate the anatomical structure, check the functional aspect of significant stenosis, and detect Myocardial Infarction (MI). Conversely, they also mention the problems of CCTA in the evaluation of the physiological significance of lesions, thus, they import the importance of other imaging modalities being used in combination with it. Several non-invasive imaging techniques such as MR stress perfusion imaging, CT stress perfusion imaging, PET MPI, SPECT MPI, and stress echocardiography are shown as very valuable tools for the assessment of the physiological significance of coronary artery stenosis. The experimentally unknown MI which is an indication of the physiological CAD is most effectively assessed with the cardiac MRI [25].

The authors check the various imaging features of ischemic heart disease, which are CAD, myocardial ischemia, and MI, and they also discuss the advantages and disadvantages of noninvasive imaging techniques. They give the results from the current clinical trials, and then they summarize the present and future situations that are not suitable for these techniques in detecting ischemic heart disease [26].

A case study included in the paper describes a 53-year-old woman presenting with chest pain and undergoing stress perfusion imaging. The scan revealed significant subendocardial perfusion defects during adenosine stress, indicating severe myocardial ischemia. The rest perfusion images appeared normal, while Late Gadolinium Enhancement (LGE) imaging showed focal enhancement in the mid-to-apical inferior wall, suggesting a microinfarction or embolic infarction [24].

The paper also goes into the technical aspects of completely quantitative perfusion imaging, which shows the importance of the exact measurement of the arterial input function and the contrast material circulation through the myocardium, to get the accurate evaluation. The methods like the dual-bolus method that are going to be described in detail for the fully quantitative perfusion imaging, which involves the use of two different contrast material boluses and is optimized for the arterial input function and myocardium assessment are the techniques used [27].

A follow-up was conducted in Adult Congenital Heart Disease (ACHD) patients who have undergone corrective procedures, with a focus on three frequently encountered conditions: the four hearts condition, which embodies tetralogy of Fallot, the transition of the great arteries after the arterial switch operation, and the single ventricle after Fontan operation was mended [28].

The authors emphasize the importance of cardiac CT and MRI in evaluating therapeutic outcomes and identifying potential complications in patients with Adult Congenital Heart Disease (ACHD). Long-term imaging follow-up is essential for monitoring adaptive responses and early detection of complications, particularly in patients who have undergone palliative and/or corrective interventions [29].

Through the paper, the author discusses the surgical methods applied to treat Right Ventricular Outflow Tract (RVOT) obstruction and the possible complications that might occur from them in Tetralogy of Fallot (TOF) repair cases. The paper states that CT and MRI are tools for the early diagnosis of Right Ventricular Outflow Tract (RVOT) dilatation, chronic pulmonary regurgitation, right ventricular dysfunction, aortic root dilatation, and myocardial scar formation. In addition, the article also proves that MRI is the best method for measuring right ventricular volume and function, quantifying pulmonary regurgitation, and detecting myocardial scarring in repaired TOF patients [28].

## DISCUSSION

In the past decade, coronary computed tomography angiography still portrays a remarkable change despite weaker guidelines. STI was at first largely used to elude other causes of coronary CAD in low-risk patients, and without this, it has currently evolved into a crucial tool for risk management as well as therapeutic decision-making, which has vastly improved patient outcomes [4]. Outstanding achievements are contributed by more precise imaging, lowering the level of patient exposure to radiation, and the advantage of getting clinical information along with the anatomic data. Consequently, the current guidelines propose CCTA as the first option for stable chest pain patients and with it to be used as a part of a strategy for ruling in or ruling out non-invasive hemodynamic instability. Generated by these innovations, it seems to be the only safer and more precise option for diagnosing and confirming CAD. Nevertheless, though its obvious advantages outweigh its drawbacks, fewer trials but of higher accrual rate remain the biggest hurdle to its wider adoption. Primarily, the chance of ion iodine contrast-induced nephropathy should be taken, and sometimes the risk of kidney deficiency problems can affect these patients especially cardiac patients that have this illness most commonly [12]. Moreover, radiation exposure, with all its hazards, is another barrier in the way of radiological examinations to be considered in regular practice. Moreover, people specifically suffering from cardiac arrhythmia such as premature contractions or atrial fibrillation can usually see robust perfusion imaging with CMRA not with CCTA image quality will be poor [22]. Under these circumstances, it may trigger the necessity of repeated acquisitions which is why it can be accompanied by greater radiation and contrast agent exposure. Moreover, even though CCTA showed a high performance in judging stents, CT-FR-based fractional flow reserve is always unattainable in certain cases and might be difficult to judge related stenosis. Moreover, CCTA in patients with visible accumulation of coronary calcifications, occluded coronary arteries (with the help of collateral circulation), or a history of Coronary Artery Bypass Graft Surgery (CABG) is associated with additional difficulties.

MRA offers the possibility of high-resolution imaging without the use of ionizing radiation, tissue characterization, and quantification of ventricular function; thus, it can be very beneficial in the evaluation of CAD. On the other hand, CTA has the advantages of having a good spatial resolution, having a short scan time, and being suitable for patients with implanted devices, hence, it is a good alternative for specific cases.

CCTA and CMRA complete each other as parts of the cardiac imaging count. The CCTA is superior in anatomical evaluation and characterization of plaque features while CMRA is a multifunctional tool capable of evaluating ventricular remodeling and prognosis prediction, and with a high preferentiality in cases of suspected CAD patients [20].

The main issue that one should think of while choosing between MRA and CTA for the detection of heart disease in adults is the fact that there are several factors to be considered. MRA is the preferred method because of its high tissue specificity and the absence of radiation, which is why it is used for patients who need to have the same imaging repeated. But CTA has excellent spatial resolution and short scan times which are the reasons why it is a good option for patients with implanted devices or the ones who need quick imaging assessments [23].

Additionally, the CMRA gives us input on the hemodynamic significance of a structure at stenosis, and through non-invasive perfusion testing, the early perfusion defects that indicate ischemia can be identified. Also, echocardiography evaluates the cardiac myocardial and systolic function, moreover, it visualizes the scarred tissue for predicting the prognosis and making the therapeutic decisions. CMRA facilitates the precise evaluation of the condition of various cardiac tissues and currently is employed by clinicians in the treatment of acute coronary events and heart muscle diseases [24]. Generally, a patient with a CAD prefers the CCTA routine unless a young person who's without comorbidities is identified and a case of a person who's not a carrier of any cardiac disorder and one who's not receiving any preventive medication such as statins. Additionally, considering the middle-aged and older patients, as well as the importance of the precaution in young patients and those with myocardial infarction who take ASA and statins, it is also required to follow-up every patient according to their condition [30].

This is proven in the detailed case studies, as the prescription of personalized treatments is most single factor. In particular, the delineation and identification of applications of imaging units considered as well as the proper imaging system installed depending on the situation is the main thing to consider in case of application of the imaging system and tools [28].

## CONCLUSION

To conclude, both MRA and CTA are the two key tools that help to evaluate congenital heart disease in adults. The decision on which modality to use is based on the individual patient factors, the preference, the need for repeated imaging, and the specific clinical issues to be solved. It is significant to know the strengths and weaknesses of each modality to form the best practice them, which in turn will help in improving patient care and ensuring that the patients are properly diagnosed and managed with congenital heart disease.

## LIST OF ABBREVIATIONS

HF : Heart Failure
CAD : Coronary Artery Disease
CCTA : Coronary Computed Tomography Angiography
CMRA : Cardiac Magnetic Resonance Angiography
LGE : Late Gadolinium Enhancement
MPS : Myocardial Perfusion Scintigraphy
CABG : Coronary Artery Bypass Graft Surgery
CAAs : Coronary Artery Aneurysms
ACHD : Adult Congenital Heart Disease
CT : Computed Tomography
ACS : Acute Coronary Syndrome
ECG : Electrocardiogram
FFR : Fractional Flow Reserve
TOF : Tetralogy of Fallot
RVOT : Right Ventricular Outflow Tract

## FUNDING

None.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## ACKNOWLEDGEMENTS

Declared none.

## AUTHORS' CONTRIBUTION

Bisma Maqsood conducted the literature review, developed the conceptual framework, and performed the critical analysis in collaboration with Farheen Gul. All authors contributed to the writing, review, and approval of the final manuscript.

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