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Review

Coronary Artery Disease-Reporting and Data System (CAD-RADS): strengths and limitations

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A new standardised reporting system was introduced recently for coronary computed tomography (CT) angiography interpretation called CAD-RADS (Coronary Artery Disease-Reporting and Data System). Like any other new reporting platform, CAD-RADS has both advantages and disadvantages. Consistency in reporting, better clarity of communication, and more streamlined clinical recommendations are the major strengths of CAD-RADS. It has many limitations such as misinterpretation of CT angiography findings inherent to any CT angiography examination and unique disadvantages like misclassification of abnormalities, potential to misguide the referring physicians by suggesting management based on a single score. In addition, CAD-RADS does not include the details on location and extent of disease in the coronary arteries, coronary anomalies and other cardiac and extra cardiac findings.

Introduction

Coronary computed tomographic angiography (CCTA) is an accurate tool in the evaluation of coronary artery disease (CAD). Due to its non-invasive nature, high negative predictive value in ruling out significant CAD, and recent technological advances, the use of CCTA has increased enormously.[1] The most beneficial aspect of CCTA is its ability to exclude CAD confidently in a non-invasive method.[2,3] Both the American Heart Association/Society of Cardiovascular Computed Tomography (AHA/SCCT) and the British National Institute for Health and Care Excellence (NICE) guidelines recommend CCTA as an appropriate test to rule out obstructive CAD in low-to intermediate-risk patients with stable or acute chest pain[4,5]. Unlike many other imaging studies, CCTA is reported equally by both radiologists and cardiologists depending on their experiences and institutional practices. As a result and also because of lack of standardised reporting patterns, there is non-uniformity and inconsistency in the reports. This in turn can bring variability in the way test results are interpreted by the treating/referring physicians, thereby impacting the patient care. Using common language and terminology to provide a clear and accurate description of coronary anatomy and pathological changes can help to create uniform and organised reports that are more easily interpreted by the end users. Similar approaches have already been tried and established in other areas such as breast, liver, and prostate imaging, and such reporting systems help in the effective communication of abnormal findings in a streamline fashion to the referring physicians, which in turn translates into more efficient clinical decision-making.[6–8]

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CAD-RADS

The structured reporting system for CCTA was introduced in 2016 by Cury *et al.* called the "Coronary Artery Disease–Reporting and Data System" (CAD-RADS).[9–11] It is the first attempt to provide a simple, concise, and accurate classification of CAD. This new tool is expected to improve the communication and ease the understanding of the CCTA report with the additional inputs of further investigations and management recommendations. The usage of CAD-RADS has been adopted by many institutions around the world in the last 2 years, although it is still not widely accepted due to various factors such as expected initial hesitancy to a new system, time needed for training, and acceptance from the referring physician.[12] Moreover, the clinical impact on the patient prognosis has not been widely studied. One recent report proves that higher CAD-RADS scores are associated with more risk of cardiac events, thereby providing important prognostic information, and the scores also help provide guideline-based post-CCTA care[13]; however, to better understand the long-term impact on radiology workflow and patient care, it is essential to incorporate and use CAD-RADS in a widespread way. In this review, we have enumerated the strengths and various limitations of the implementation of CCTA, which will help to better understand the new system and assist in using it in routine clinical practice.

The CAD-RADS is a multisociety collaborative effort involving the Society for Cardiovascular Computed Tomography (SCCT), the American College of Radiology (ACR), and the North American Society for Cardiovascular Imaging (NASCI), and it is endorsed by the American College of Cardiology (ACC).[11] The involvement of multiple disciplines makes the CAD-RADS widely acceptable by both radiologists and cardiologists, which is of paramount importance for the success of any guideline. This recommendation is intended for two groups of patients[1]: patients presenting with stable chest pain and[2] patients presenting with acute chest pain, negative first troponin, negative or non-diagnostic electrocardiogram, and low to intermediate risk.

CAD-RADS aims to classify the CTA-based results on the severity of stenosis and to link these data to clinical patient management.[14] The indication for coronary CTA, imaging protocols, and performance standards remains the same. Interpretation, training standards, and quantification of coronary arterial stenosis are based on the 2014 SCCT reporting guidelines in both acute and non-acute settings.[15]

Degree of stenosis, high-risk anatomy, plaque morphology, image quality, stents, and coronary artery bypass grafts are evaluated to decide the final CAD-RADS category. It should be noted that CAD-RADS classification is only complementary to the conclusion of the report and does not replace it, as the detailed information on the location and extent of coronary plaque and stenosis is not incorporated and will only be available in the descriptive report.[10,16]

CAD-RADS categories[9–11]

There are six CAD-RADS categories based on degree of luminal diameter stenosis. This is adapted from SCCT 2014 recommendations[15] (Table 1). They range from CAD-RADS 0 (absence of plaques and stenosis) to CAD-RADS 5 (presence of at least one total occlusion) in both acute and non-acute settings. It is based on the most severe coronary finding. Apart from these six categories, an additional category, N, is added, which represents non-diagnostic study. Furthermore, category 4 is subdivided into4A—single- or two-vessel 70–99% stenosis—and 4B—left main >50% or three-vessel obstructive (>70%) disease. This classification is applicable only for vessels >1.5 mm in diameter.[11] Although the CAD-RADS classification is the same for patients presenting with stable and acute chest pain, the interpretation and further management can differ between the two groups based on the category[9–11]

CAD-RADS 0

This category represents complete absence of any plaques or stenosis. It is interpreted as absence of CAD in stable chest pain and as "ACS highly unlikely" in acute chest pain. Both patient groups need no further cardiac investigations and search for non-cardiac cause of chest pain is recommended.

CAD-RADS 1

This category included luminal diameter stenosis of <25% and also includes plaque with positive remodelling and no evidence of stenosis. It is interpreted as minimal non-obstructive CAD in stable chest pain and as "ACS highly unlikely" in acute chest pain. Both patient groups need no further cardiac investigations and search for non-cardiac cause of chest pain is recommended. The only difference from CAD-RADS 0 is that these patients are recommended risk-factor modification for preventing disease progression and future ACS.

CAD-RADS 2

This category represents mild stenosis of 25–49% and is interpreted as mild non-obstructive CAD in stable chest pain and as "ACS unlikely" in acute chest pain. Management is very similar to CAD-RADS 1 with no need for further cardiac investigations and patients are suggested to

Table 1
Grading of coronary artery stenosis based on Society for Cardiovascular Computed Tomography (SCCT) recommendations.

Category	Stenosis grade	Stenosis percentage
0	Normal	0%
1	Minimal	1–24%
2	Mild	25–49%
3	Moderate	50–69%
4	Severe	70–99%
5	Occluded	100%

undertake preventive measures and lifestyle changes. The only additional recommendation in this category is if there is high clinical suspicion of ACS or vulnerable plaque features on CTA, patient needs to be admitted to the hospital for observation and cardiac consultation.

CAD-RADS 3

This category represents stenosis of 50–69% and is interpreted as moderate CAD in stable chest pain. Further evaluation with functional testing is recommended to detect inducible ischaemia either by exercise or pharmacological stress, but it should be noted that coronary stenoses <70% are often undetected by functional testing.[17] Management often involves a combination of anti-ischaemic and preventive pharmacotherapy along with risk-factor modification.

CAD-RADS 3 is interpreted as "ACS possible" in the acute setting, and patients need to be admitted for cardiology consultation followed by functional testing and if necessary invasive coronary angiography (ICA). Anti-anginal and preventive treatment with risk-factor modification is recommended similar to stable chest pain.

CAD-RADS 4

This included two sub-categories 4A—single- or two-vessel 70–99% stenosis—and 4B—left main >50% or three-vessel obstructive (>70%) disease. It is interpreted as severe CAD in stable chest pain and 4B is considered more severe than 4A. ICA and possible revascularisation is recommended in 4B and either ICA or functional testing in 4A. CAD-RADS 4A and 4B are interpreted as "ACS likely" in acute chest pain. Patients need to be managed in-house by cardiologists with ICA and possible revascularisation. Anti-anginal and preventive pharmacotherapy with lifestyle changes are the same for both the patient groups.

CAD-RADS 5

This category represents 100% stenosis and it is essential to differentiate acute and chronic total occlusion as it decides the need for immediate revascularisation. It is interpreted as chronic total occlusion in stable chest pain. This needs multidisciplinary consultations followed by ICA and/or viability assessment to assess various factors such as lesion length, calcification at the proximal cap, and degree of collateralisation to decide on the further management including revascularisation.[9,17] It is interpreted as "ACS very likely" in the acute setting and needs urgent ICA followed by revascularisation if appropriate. Anti-anginal and preventive pharmacotherapy with lifestyle changes are the same for both the groups.

CAD-RADS N

This is a confusing category as it is used both as a main category and as a modifier (see below). CAD-RADS N is used if the study is not fully diagnostic and interpretable segments shows stenosis <50%. These patients need evaluation with alternate diagnostic test to rule out obstructive CAD and guide further management. It is the same for both acute and stable chest pain[10].

Modifiers

In addition to the main categories, there is option to add modifiers at the end of each category (separated by a forward slash) to provide additional relevant information. Four modifiers are available: N (non-diagnostic), S (stent), G (graft), and V (vulnerability). If more than one modifier is applicable, it needs to be separated by the symbol "/" (forward slash) and written in the same order as above.[9–11]

N (non-diagnostic)

As opposed to category N, modifier N is used if the study is not fully diagnostic and interpretable segments shows stenosis >50%. Letter "N" is added after the highest stenosis category (CAD-RADS 3, 4 OR 5) separated by symbol '/'. Management is based on main category and not on the modifier.

S (stent)

This modifier indicates the presence of at least one stent in any of the coronary segments. Stent is evaluated for in-stent stenosis and is treated like any other coronary segment. The CAD-RADS main category still depends on the most severely stenosed segment, which could be the stented or non-stented vessel.

G (graft)

This modifier denotes the presence of at least one coronary artery bypass graft (arterial or venous graft). Again graft is treated like any other coronary segment and assessed for stenosis. The bypassed vessel (occluded or not) is not evaluated for classification and only the bypass graft is considered in the categorisation.

V (vulnerability)

Certain features, such as positive remodelling, low-attenuation plaque, spotty calcification, and the napkin-ring sign, have been described as high-risk features associated with future ACS. The modifier, V, is used when at least two high-risk plaque features are present in the same plaque.[18] Although there is not enough literature to guide management, high-risk plaque features, especially in acute chest pain, warrants close monitoring and further testing based on clinical and biochemical parameters. If it is associated with CAD-RADS 2, close clinical observation and/or hospital admission is recommended in acute settings. More aggressive management in the form of ICA should be considered if high-risk features are identified in CAD-RADS 3 category.[19]

Strengths

Consistency

As discussed in the introduction, there is high variability in the reporting of abnormalities in CCTA due to various factors such as enormous increase in the number of studies, reporting differences between radiologists and cardiologists, and also amongst trainees, and the tendency to follow one's own style of reporting in free text. This new standardised framework for CAD assessment CAD-RADS helps to provide a more uniform and consistent report with the usage of common language and accepted terminologies.[20,21] In addition, a recent study showed excellent interobserver agreement in assigning CAD-RADS categories including the degree of stenosis and modifiers, leading to a more consistent final report[22]

Communication

There is improved communication with the usage of a standardised system as the report becomes more uniform with standard terminologies. Although it can be argued that the CAD-RADS does not provide adequate clarity to non-specialists, it does help to streamline the referrals to the specialists. Non-specialists can make quicker and more appropriate referrals using the categories as compared to conventional reports, which are difficult to understand for them. Even for specialists, the uniform and concise reports helps in effectively communicating the major finding in their busy clinic schedule. The chances of a referring physician calling for clarifications and complaining about vague inconclusive reports are drastically reduced with the use of CAD-RADS[20,23]

Clinical management

The most essential component that has been added to the CAD-RADS is the recommendations for post-coronary CTA clinical management. This includes two components[1]: further diagnostic tests such as functional/stress testing and ICA, and[2] therapeutic options, such as risk-factor modification, initiation of anti-ischaemic therapy, and/or revascularisation. In the acute setting, it assists in making crucial decisions such as hospital admission, specialist consultation, or discharge with outpatient follow-up. By connecting the CCTA findings with post-test care, CAD-RADS has the potential to improve point-of-care decision-making and promote guideline-driven follow-up care. Incorporating CAD-RADS into the clinical decision-making process may play a role in reducing over-referral for additional testing with invasive ICA, especially in patients without severe CAD who are asymptomatic or not on medical therapy.[17,20,24–26]

Research and education

Using a structured reporting pattern in the long run will help in registry data collection, which then can be used to assess the impact of CAD-RADS on the clinical outcomes. It also improves the ease of data collection, data integrity, and creates large data pool for future research studies. It is possible to compare and contrast reports from different physicians and institutions for peer review and quality assurance with the aim of identifying areas to concentrate improvements of report quality. The availability of meaningful data helps in training the residents and fellows. The structured system results in effective communication of data to the digital systems, which will help in developing automated systems and advanced artificial intelligence algorithms in the future.

Limitations

CAD-RADS is a relatively new system for standardisation of CCTA reporting. Like any new tool, the usage of CAD-RADS is associated with many errors and limitations.

Misinterpretation

Misinterpretation is more of a limitation of CCTA itself rather than CAD-RADS scoring system. It is inherent to any form of CT angiography, and it is encountered in CCTA as well. It is discussed here as a limitation of CAD-RADS to highlight the fact that misinterpretation of CCTA findings will lead to assigning incorrect categories.

Stenosis severity. The most important component of CCTA reporting is the accurate assessment of the severity of stenosis. Using stenosis ranges based on the SCCT recommendations has led to high reproducibility of stenosis grading[15]; however, there is still potential intra- and inter-reader variability in the assessment leading to incorrect category assignment.[27] This can either be an under- or overestimation of disease severity resulting in inadequate management or excessive downstream investigations, respectively.

Vulnerable plaques. CAD-RADS recommends the use of modifier "V" when a vulnerable plaque is identified in any of the coronary artery. A plaque can be labelled as vulnerable when any two of the four high-risk features, namely low-attenuation plaque (<30 HU), positive remodelling, spotty calcification, and the napkin ring sign (low-attenuation centre with a peripheral high-attenuation rim), are present. The presence of high-risk features warrants aggressive management in the form of hospital admission and ICA depending on the primary CAD-RADS category[19,28]; however, identification of high-risk features needs advanced training and there is high interobserver variability among the reporting physicians.[19] Misinterpretation can lead to prolonged hospital stay and/or excessive diagnostic tests. Another potential error with vulnerable plaques is misclassifying presence of two high-risk features in two different plaques as "V" as against the CAD-RADS recommendation of identifying two high-risk features within the same plaque (Fig 1).

Misclassification

This error is unique to any standardised scoring system. After accurate assessment of degree of stenosis and other

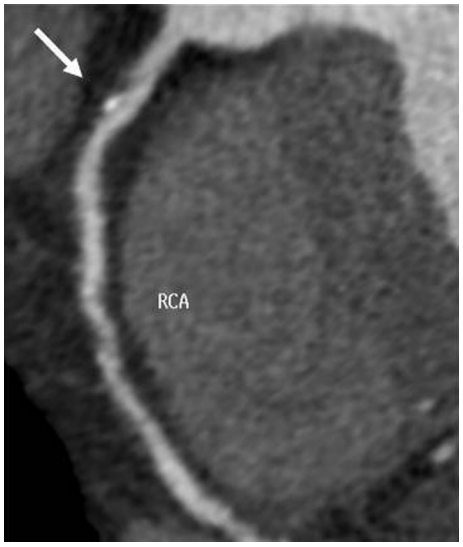

Figure 1 Low-attenuation plaque with spotty calcification in the proximal RCA (arrow) causing mild stenosis. Correct interpretation is CAD-RADS 2/V as two high-risk plaque features are present within the same plaque. RCA, right coronary artery.

ancillary features, the next step is to assign an appropriate category. This can be a problem even for expert readers who are not well versed with the CAD-RADS system and its pitfalls. One way to reduce these types of errors is to use automated systems instead of manual categorisation.[29]

Category N. This is a constant source of error as "N" is used both as a main category and as a modifier. CAD-RADS N is used if the study shows multiple non-diagnostic segments and stenosis is <50% in the interpretable segments. N is used as a modifier only with CAD-RADS 3, 4, or 5, i.e., stenosis >50%. This is important as the further management largely depends on the main category. If the main category is N, then alternate imaging is recommended to effectively rule out CAD. In contrast for modifier N, the management depends on the associated main category (3, 4, or 5). For example, CAD-RADS 1/N and 2/N do not exist and instead should be reported as CAD-RADS N[9,14] (Figs 2 and 3).

Category 4A/4B. Another source of error is the incomplete assignment of category 4. CAD-RADS 4 has two subcategories: 4A, a single or two vessels with severe 70–99% stenosis and 4B, three-vessel severe stenosis or left main stenosis >50%. It is essential to assign the appropriate subcategory, as ICA with revascularisation is recommended in 4B.[10,14]

Graft and stents. Appropriate modifiers G for CABG grafts and S for stents need to be used for proper classification. There are some default rules that need to be followed to avoid misclassification[9–11] (Fig 4)[1]: bypassed coronary segments should not be considered for classification[2]; bypass grafts should be treated like a native coronary vessel for stenosis assessment[3]; stented vessel should be treated as a native coronary vessel and assessed for in-stent stenosis[4]; difficulty in evaluating stent patency is common and should be assigned appropriate category (category N/S or modifier N/S depending on the degree of stenosis in the diagnostic segments).

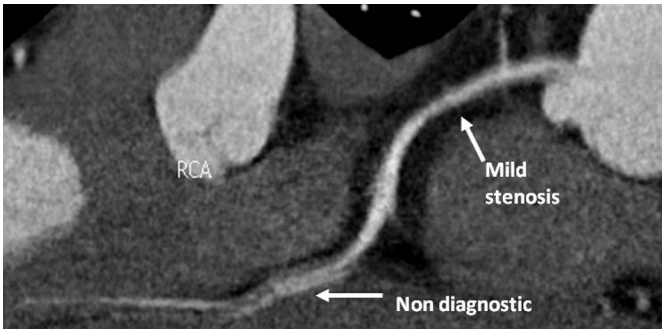

Figure 2 Mild stenosis in the proximal RCA with non-diagnostic mid RCA due to motion artefacts. Common mistake: correct interpretation is CAD-RADS N and not CAD-RADS 2/N. N is used as a main category if stenosis is <50% and it is used as a modifier if the stenosis is ≥50%. RCA, right coronary artery.

Missing components

Extent of disease. CAD-RADS classification is based on the most severely stenosed coronary segment. It gives information only on a single coronary segment. Details of stenosis in the other coronary segments and vessels are not incorporated in the CAD-RADS. Although this single score helps to guide the appropriate next step, it does not account for the presence of disease in rest of coronary arteries, which can influence the management decisions and predict future cardiac events.[30,31]

Location of disease. Again CAD-RADS only describes the degree of stenosis and provides no information on the location of stenosis. It is crucial to know the exact location of lesion as it is known that the management options are

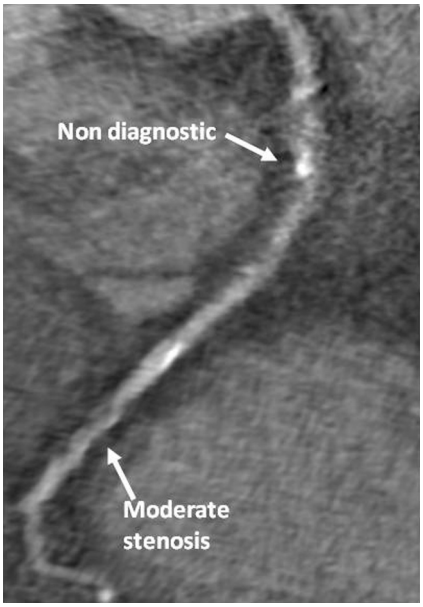

Figure 3 Non-diagnostic proximal and mid RCA due to motion artefacts and moderate stenosis in the distal RCA. Correct category is CAD-RADS 3/N and CAD-RADS N as the stenosis is ≥50%. RCA, right coronary artery.

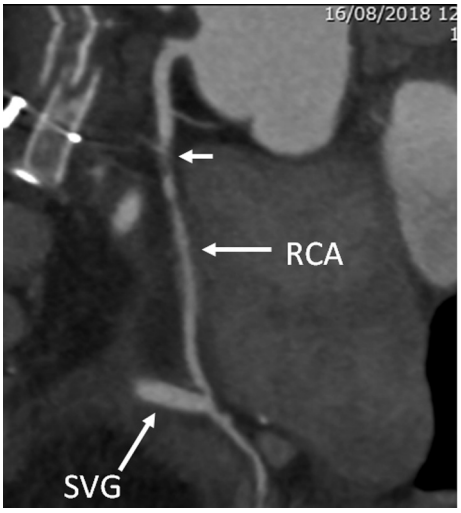

Figure 4 SVG graft to distal RCA. Good flow distal to graft with only minimal stenosis. Severe stenosis in the proximal RCA (arrow) should not be taken into account for assigning the category. Correct category is CAD-RADS 1/S. Common mistake is assigning CAD-RADS 4A for this lesion. RCA, right coronary artery; SVG, saphenous vein graft.

different for the same degree of stenosis in the proximal and distal segments. CAD-RADS considers the presence of diseases in the left main as high risk and classifies >50% stenosis in the left main as category 4B. This is different from the 2014 ESC/EACTS guidelines, which consider the proximal left anterior descending (LAD) artery stenosis >50% and two-vessel stenosis >50% with impaired left ventricular function as high risk along with left main disease.[32]

Coronary anomalies. CAD-RADS does not take into account the presence of underlying coronary arterial normal variants and anomalies. Although many of these are of no clinical significance, some can be dangerous, such as malignant course (coursing between the aorta and pulmonary artery) resulting in sudden cardiac death.

Cardiac and extra-cardiac findings

CCTA may show other cardiac or extra cardiac findings that can be significant or non-significant. This can be in the form of a prosthetic valve, coronary anomaly, or cardiac tumour. Extra-cardiac findings are often incidental with little clinical significance; however, potentially significant features can be encountered, such as significant disease in the other great vessels of mediastinum, lung cancers, which might need appropriate further imaging or treatment. CAD-RADS focuses only on the most severely stenosed vessel, and in the current version, there is no place for other cardiac and extra-cardiac findings.

Misguidance

Further investigation. Recommendations for the next step in the management of patients with acute or stable chest pain is one of the unique features of CAD-RADS. Although it is considered as a useful feature, there are arguments that it might lead to further diagnostic tests that can be avoided.[9–11,17] For example, in CAD-RADS 3, functional testing is the next step in management algorithm. This category includes a large group of people and functional imaging in all could result in test stacking and the main purpose of CCTA, which is to rule out significant disease, gets defeated. CAD-RADS 3 in a diagonal branch can be managed medically before embarking on further diagnostic testing whereas same category in the proximal LAD needs functional imaging. Hence, this form of blind universal recommendation of functional testing in all CAD-RADS 3 has the potential to misguide the treating physician especially non-specialist or general physicians.[12]

Treatment options. Again similar to further investigations, therapeutic recommendations based on CAD-RADS score can become a potential problem for the treating physicians. For example, treatment is different for acute and chronic total occlusions even though their scores are the same. Acute occlusion needs urgent ICA followed by revascularisation. In contrast, chronic occlusions may not need urgent intervention and management depends on other factors such as lesion length and degree of collateralisation. Similarly, CAD-RADS 4 in proximal LAD needs more urgent attention than a CAD-RADS 5 in a side branch or non-LAD vessel. Suggesting a uniform treatment option based on the CAD-RADS score along may be of less clinical utility and can lead to mismanagement in the hands of non-expert physicians.[14]

Conclusion

CAD-RADS is a new beginning in the standardisation of CCTA reporting. It has attempted to simplify the abnormalities into a single number and makes uniform recommendations for further testing and treatment. This has the potential for more uniform reporting, easily understandable and actionable by the treating physicians; however, it is associated with various interpretation and classification errors, which can be reduced by adequate training and using automated systems. The major controversy is in the further testing and treatment recommendations, which has both positive and negative attributes as discussed above. In addition, this system does not give information on the extent and location of the plagues, and the final score is based only on the severity of stenosis in a single segment, which may not be enough to make a clinical decision.

Conflict of interest

The authors declare no conflict of interest.

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