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CAD-RADS—A New Clinical Decision Support Tool for Coronary Computed Tomography Angiography

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Abstract

Coronary computed tomography angiography (CTA) has been established as an accurate method to noninvasively assess coronary artery disease (CAD). The proposed “Coronary Artery Disease Reporting and Data System” (CAD-RADS) may enable standardised reporting of the broad spectrum of coronary CTA findings related to the presence, extent, and composition of coronary atherosclerosis. The CAD-RADS classification is a comprehensive tool to summarise findings on a per-patient-basis dependent on the highest-grade coronary artery lesion, ranging from CAD-RADS 0 (absence of CAD) to CAD-RADS 5 (total occlusion of a coronary artery). In addition, it provides suggestions for clinical management for each classification, including further testing and therapeutic options. Despite some limitations, CAD-RADS may facilitate improved communication between imagers and patient caregivers. As such, CAD-RADS may enable a more efficient use of coronary CTA leading to more accurate utilisation of invasive coronary angiograms. Furthermore, widespread use of CAD-RADS may facilitate registry based research of diagnostic and prognostic aspects of CTA.

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Introduction

Coronary computed tomography angiography (CTA) has been developed into a powerful non-invasive tool to assess coronary arteries in patients with low to intermediate likelihood of obstructive coronary artery disease (CAD) in outpatient as well as emergency settings [1]. The biggest strength of CTA is the ability to exclude CAD reliably and non-invasively. A recent analysis, the PROspective Multicenter Imaging Study for Evaluation of Chest Pain trial (PROMISE), has shown that CTA outperforms functional stress testing in predicting adverse cardiac events at 2-years of follow-up among patients with stable chest pain [2, 3]. Therefore, the PROMISE trial, among other clinical trials, has led the American Heart Association/Society of Cardiovascular Computed Tomography (AHA/SCCT) and the British National Institute for Health and Care Excellence (NICE) guidelines to consider CTA as an appropriate test to rule out obstructive CAD in patients with stable or acute chest pain and low-to-intermediate risk [4, 5].

In the past, CTA reports mainly focused on CAD exclusion or sole description of coronary artery lesions as recommended by the current Society of Cardiovascular Computed Tomography (SCCT) guidelines [6]. Nevertheless, the rapid technical progress has led to an improvement of CTA technology, especially the spatial and temporal resolution. Current scanners can achieve spatial resolution of 0.4 mm [7]. Meanwhile, latest guidelines recommend spatial resolution below 1 mm [8]. Temporal resolution can reach 40 ms and depends on the gantry rotation time and the number of X-ray tubes. Advancements in image quality have facilitated development of various new scanning and post-processing techniques (i.e. perfusion imaging, computed tomography-derived fractional flow reserve (CT-FFR)), which have substantially improved the initially moderate specificity of the CTA [9, 10]. Meanwhile, a high level of expertise is mandatory for the image interpretation to allow appropriate clinical management decision-making and to avoid unnecessary additional downstream testing.

Cury et al. introduced the “Coronary artery disease–Reporting and Data System” (CAD-RADS), which represents the first scoring system that enables standardised, simple, per-patient classification of CAD [11]. This novel reporting tool has a potential to improve communication between imagers and referring physicians by providing simplified reports, including suggestions for subsequent clinical care. Since its introduction in 2016, CAD-RADS has been used increasingly around Europe and the United States, but widespread adoption of the classification has not been established yet. The requisite for successful implementation of the CAD-RADS classification heavily relies on the willingness and determination of the whole CTA community to report and incorporate CAD-RADS into the routine clinical practice.

This special report aims to encourage the reader to implement CAD-RADS into routine clinical practice. It succinctly describes how to systematically approach CAD-RADS, summarises the classification's strengths and limitations, outlines the most common pitfalls, and addresses future perspectives.

Using the CAD-RADS classification

Description

CAD-RADS aims to classify the CTA-based results and to integrate this classification into clinical patient management. However, neither does it intend to make changes to the indication for coronary CTA nor the scan protocols. Hence, indications and protocols should follow the latest SCCT, ESC, and AHA guidelines [4, 8, 12–14]. Also the subsequent scan interpretation and estimation of potential stenosis grades should be performed in concordance with the 2014 SCCT reporting guidelines in both emergent and elective CAD assessment settings [6].

CAD-RADS classification requires CTA-derived information about the stenosis grade, high-risk anatomy, plaque morphology, image quality, stents, and/or coronary artery bypass grafts. The CAD-RADS classification is based on the most severe coronary finding and ranges from CAD-RADS 0 (absence of any plaque) to CAD-RADS 5 (at least one occlusion) [11]. Stenoses of 50–99% need to be evaluated very carefully, acknowledging potential high-risk anatomy. A single stenosis of 70–99% corresponds regularly to CAD-RADS 4A, but multiple stenoses of 70–99% in all three coronary arteries (obstructive 3-vessel CAD) or a single 50–99% stenosis in the left main coronary artery are considered as high-risk anatomy, and are classified as CAD-RADS 4B, requiring more aggressive management (Figure 2).

Additionally, CAD-RADS allows one to add modifiers (i.e. single letters) at the end of each classification to provide extra information on lesion vulnerability, presence of stents, coronary bypass grafts (CABG), or potentially non-diagnostic image quality. The modifier “V” indicates the presence of an atherosclerotic lesion, with at least two high-risk plaque features defined as positive remodeling, low-attenuation plaque, spotty calcification, or napkin-ring sign [15, 16]. In patients with prior coronary interventions, presence of coronary artery bypass graft (CABG) and stent are noted as “G” and “S”, respectively. In these cases, CAD-RADS acknowledges the stent- and CABG-patency and does not account for treated or bypassed lesions. Assuming that there is a patient with known and bypassed LAD occlusion, patent CABG, and additional moderate stenosis in the RCA, the moderate stenosis must be included in the classification and the “G” at the end indicates presence of the CABG (i.e.: CAD-RADS 3/G).

Cases with combination of non-diagnostic segments and segments with mild stenoses (i.e.: CAD-RADS 0 to 2) are classified as CAD-RADS N and require further testing to rule out obstructive CAD. Scans with non-diagnostic segments, but at least one moderate stenosis (i.e. CAD-RADS 3 to 5) should not be classified as non-evaluable scans (CAD-RADS N); instead, the modifier “N” should be added after the stenosis category to express presence of obstructive CAD and limited interpretation (e.g.: CAD-RADS 3/N). Incidental non-coronary

cardiac and extra-cardiac findings per CTA should be reported separately, as these findings are currently not part of the CAD-RADS classification.

Clinical management recommendations differ between acute chest pain patients in the emergency setting and elective patients with stable chest pain. Per definition, emergent patients often present with acute chest pain, negative first troponin, negative or non-diagnostic electrocardiogram and low-to-intermediate risk of acute coronary syndrome (ACS) (thrombolysis in myocardial infarction (TIMI) risk score < 4) [11]. In this patient group, CAD-RADS focuses on the ACS identification and the management recommendations vary from no further investigation to immediate revascularisation. Despite the acute emergency settings, it is important to note that not every total occlusion (CAD-RADS 5) needs an immediate revascularisation. Chronic occlusions are not uncommon [17] and should always be considered. If chronic occlusions are present, individual multidisciplinary consultation is recommended to determine further work-up.

In patients with stable chest pain, the clinical management recommendations range from a consideration of non-atherosclerotic chest pain sources to a referral for invasive diagnostic correlation per invasive coronary angiography, and potential intervention. In this patient group, recommendations are based on the clinical guidelines published by Fihn et al. in 2012 [18], which have been updated in 2016 [19].

In general, CAD-RADS classification does not substitute the impression section provided by the reading physician, and should always be interpreted in conjunction with the clinical scenario and patient-specific information.

Pitfalls and limitations

Although CAD-RADS already represents a sophisticated step towards standardised reporting and communication of coronary CTA findings, an inconsistent or inaccurate usage of the nomenclature poses a risk for misinterpretation. Thus, we have provided some representative examples of common errors encountered while using CAD-RADS, and a brief guide to help interpreting physicians avoid these. Potentially, there are two different common error types leading to reporting inconsistency. One originates from the image interpretation whereas the other error is related to the subsequent CAD-RADS scoring. In coronary CTA interpretation, a proper assessment of the CAD extent, severity, and characteristics is largely dependent on the reader's clinical skills and experiences. Despite proper CAD assessment, even experienced readers might misclassify cases due to lack of knowledge of the CAD-RADS classification. In addition, potential inter- and intra-reader variability in coronary lesion description may alter all further steps in the CAD-RADS reporting process, leading to inadequate patient management and a higher rate of unnecessary downstream testing. Thus, an accurate stenosis identification and grading are essential for high quality reports. Prior studies have demonstrated that stenosis assessment in coronary CTA is highly reproducible [20]. Utilisation of structured reporting platforms and physician education are highly desirable to improve communication between physicians through reporting uniformity.

Despite rather simple CAD-RADS stenosis grading, common mistakes include the incomplete use of the stenosis category CAD-RADS 4. It is mandatory to acknowledge potential high-risk anatomy for further management recommendations. The modifier “A” indicates single- or two-vessel disease (stenosis 70–99%). The modifier “B” stands for a presence of high-risk anatomy, defined as three-vessel obstructive CAD (> 2 stenoses; 70–99%) or at least one lesion (50–99%) in the LM. Based on these modifiers, the patient management recommendations may vary. Likewise, a false use of the modifiers may increase the ambiguity in patient management and, simultaneously, may reduce data integrity.

Another common pitfall regarding modifiers is the use of categories which do not exist. For example, the categories “1/N” or “2/N” are incorrect in case of combination of minimal or mild stenoses with non-diagnostic segments. (Figure 1). In this case, relevant stenoses cannot be reliably excluded and CAD-RADS N represents the proper class.

Regarding the modifier “V”, the identification of high-risk plaque features in coronary CTA provides important prognostic information [21] and may lead to a more aggressive management or further testing. Unfortunately, proper assessment of high-risk plaque features remains challenging. Recent literature reports moderate reproducibility and high variability among readers [22]. According to the original CAD-RADS consensus paper, the modifier “V” requires two high-risk plaque features to be present in one distinct lesion [11]. Consequently, another source for misinterpretations is the incorrect use of the modifier “V” if the high-risk plaque features are distributed throughout the entire coronary tree or if neighboring lesions are interpreted as one lesion and are not discriminated correctly (Figure 1).

Coronary CTA represents an appropriate method to assess coronary artery bypass grafts [6, 8]. In CAD-RADS, the modifier “G” should be applied if CABG is present. To achieve a correct CAD-RADS classification, potential CABG stenoses and other untreated lesions in the native coronaries should be treated equally. All grafts are treated as coronary vessels and potential stenoses should be reported if appropriate. Same routine should be applied if coronary stents are present and in-stent stenosis is detected (modifier “S”). However, sufficient evaluation of stent patency may not always be possible and non-evaluable stents should be treated as non-diagnostic segments.

The CAD-RADS classification has several limitations that need to be addressed [23]. Although this simplified score has the ability to classify patients based on severity of the maximal stenosis, it does not account for the extent of the coronary artery disease, which has a significant prognostic value for adverse cardiac events [24]. Essentially, the high-risk anatomy, as defined by CAD-RADS, differs from the 2014 ESC/EACTS guidelines definition that considers proximal LAD lesion (and impaired ventricular function), whereas “4B” refers to a LM stenosis 50–99% or obstructive three-vessel disease in CAD-RADS [25]. Further, the CAD-RADS system does not consider the location of lesions, therefore, a severe stenosis in one of the proximal coronary segments might be described by the same CAD-RADS category as a severe stenosis in a distal side branch. Lastly, due to potentially complex conditions in coronary anatomy, CAD-RADS might not appropriately classify

patients with coronary anomalies. These patients continue to require comprehensive reports and individual management recommendations. The process of classification, the determination of clinical management and possible pitfalls are summarised in the provided summary Figure 2.

Future perspectives

Worldwide, the computed tomography (CT) community is still in an early phase of implementing CAD-RADS into routine daily clinical practice. The impact of CAD-RADS on CTA-based patient management and outcome is still unknown. Thus, further studies are warranted to evaluate the impact of CAD-RADS recommendations on patient outcome, downstream actions and their relation to current clinical guidelines. Specifically, leveraging the data of large randomised coronary CTA trials and registries (PROMISE, SCOT-HEART, ROMICAT, and CONFIRM) [2, 26–28] may be the first attempt to evaluate the performance of the novel CAD-RADS classification retrospectively.

Within the CAD-RADS classification, the scoring of the most severe stenosis will remain the most important step that guides clinical management. The detection of high-risk plaque features requires a high level of expertise. Quantitative measures of high-risk plaque features, such as low HU attenuation, are influenced by various acquisition parameters. Hence, consequent standardisation of the acquisition techniques may help to reduce the variability caused by technical aspects.

Besides improvements of the scanning technique, various novel post-processing techniques have been introduced to clinical practice. Recently, in a prospective study of 160 individuals, Plank et al. suggested absolute values of coronary cross-sections to be more accurate in diagnosing hemodynamically relevant stenoses compared to the broadly used percentages [29]. Moreover, experts in the field have underlined the role of the novel CT-FFR and CT-based ischemia provocation tests as a non-invasive way to assess functional relevance of coronary stenosis [9]. A growing body of evidence demonstrates the benefits of revascularisation in flow limiting lesions as identified by invasive fractional flow reserve [30]. CT-FFR correlates well with invasive measurements, can increase specificity of CTA by assessing lesion specific ischemia, and may reduce the number of unnecessary invasive coronary catheterisations [9]. Moreover, dynamic perfusion CT imaging has shown an improvement in diagnostic accuracy of CTA by the detection of hemodynamically significant coronary lesions [10] and may further allow differentiation of viable, ischemic, and infarcted myocardium [31]. Additional imaging biomarkers have revealed to improve individual risk stratification. For instance, volume quantification and tissue characterisation of coronary plaques have been proposed for cardiac event risk stratification [32, 33]. Pericardial fat tissue and liver attenuation, have been identified as promoters of coronary atherosclerosis and seem to be associated with increased plaque vulnerability [34, 35]. In the future, the combination of functional and anatomical parameters may provide the most adequate information. Thus, CAD-RADS should remain an evolving document to consider novel approaches in CAD assessment.

CAD-RADS has the potential to perform well if compared to other structured reporting tools, such as breast imaging (BI)-RADS for mammography and breast ultrasound, which have revealed an improvement of patient care and research applications [36–38]. The implementation of standardised reporting platforms with included logical operations and plausibility checks may reduce the rate of human errors and may increase the accuracy and benefits of CAD-RADS. In the future, automated classification systems may combine image analysis and standardised reporting tools leading to more reliable and faster CAD-RADS assessment, particularly valuable in emergency setting. Additionally, combinations of diverse reporting tools may become useful to assess multiple organs. For example, the combination of CAD-RADS and the Fleischner Society guidelines for management of incidental lung nodule detection [39] or Lung-RADS [40] might be useful, since the coronary CTA automatically captures large parts of both lungs. Finally, CAD-RADS as a powerful standardised reporting tool may facilitate further research, especially by improving comparability of national and international registries, and may provide a straightforward mechanism to quality assurance.

Conclusion

CAD-RADS represents a first attempt to establish a consistent CTA-based classification among patients with suspected CAD. It aims to improve communication with referring physicians and includes suggestions for subsequent clinical management. Since CAD-RADS provides a standardised framework for reporting and communication of findings, we strongly support its utilisation to achieve uniform and consistent CTA reporting. Nevertheless, CAD-RADS still has limitations which may lead to misinterpretations. Therefore, we believe that CAD-RADS should be an evolving document, keeping abreast of the rapid technical development. Potential combination of anatomical and functional coronary assessment, interaction with other established reporting tools, and further research using standardised data may be key for the improvement of interdisciplinary communication and patient care in the future.

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Abbreviations and acronyms

ACS	acute coronary syndrome
AHA	American Heart Association
CABG	coronary artery bypass graft
CAD	coronary artery disease
CAD-RADS	Coronary artery disease–Reporting and Data System
CT	computed tomography
CTA	computed tomography angiography

FFR	fractional flow reserve
HU	Hounsfield units
LAD	left anterior descending
LM	left main
NICE	National Institute for Health and Care Excellence
RCA	right coronary artery
SCCT	society of cardiovascular computed tomography
TIMI	Thrombolysis in myocardial infarction

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Key points

1. CAD-RADS is a tool to standardise coronary CTA reports.
2. CAD-RADS includes clinical treatment recommendations based on CTA findings.
3. CAD-RADS has the potential to reduce variability of CTA reports.

Figure 1. Common mistakes in CAD-RADS classification

A: mild stenosis in the proximal RCA with a non-diagnostic mid RCA segment due to severe motion artifacts. In the case of minimal to mild stenoses but non-diagnostic remote segments, CTA cannot appropriately guide further management. Hence, here the proper CAD-RADS category is “N” and not “2/N”. B: tandem LM and LAD lesions with high-risk plaque features. In this case, the modifier “V” would be incorrect because both high-risk plaque features are distributed throughout multiple lesions and do not belong to one distinct lesion. C: stenosis treated by a CABG. The severe distal LAD stenosis proximally to the LIMA graft should not be considered for stenosis classification, since the LIMA graft is patent.

CABG = coronary artery bypass graft; LAD = left anterior descending; LIMA = left internal mammary artery; LV = left ventricle; RCA = right coronary artery; RV = right ventricle.