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CAD-RADS™ : Coronary Artery Disease - Reporting and Data System: An Expert Consensus Document of the Society of Cardiovascular Computed Tomography (SCCT), the American College of Radiology (ACR) and the North American Society for Cardiovascular Imagin...

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CAD-RADS

Coronary Artery Disease – Reporting and Data System: Collaboration of SCCT, ACR, ACC & NASCI

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CAD-RADS

Coronary Artery Disease – Reporting and Data System

Management Guidelines

INTRODUCTION

The field of coronary CT Angiography (CCTA) has advanced dramatically since the introduction of 64-slice CT scanners only 10 years ago(1). In response, professional societies have fulfilled the important responsibility of developing practice standards. These societies have prepared Clinical Guidelines, Expert Consensus Documents, and Multi-Societal Appropriateness Criteria for the proper use of coronary CT Angiography (2-8). These documents provide the basis for the medical community to practice evidence-based medicine and appropriate imaging utilization for the community's shared fundamental goal: to identify the most appropriate imaging modality for specific clinical scenarios. In short, this translates into imaging the right patient at the right time with the best study to beneficially impact clinical outcomes.

Achieving this goal requires imaging protocols optimized with respect to image quality, diagnostic accuracy, and radiation dose. Training and interpretation standards are then important for standardized accurate reporting with relevant information. Standardized, structured reporting decreases variation among practitioners. Finally, linking the final impression in the report with actionable information guides patient management and is important to demonstrate the value of imaging in patient care.

Other fields in medical imaging (notably breast imaging via BI-RADS) capitalize on standardized reporting linked with actionable information to guide next steps in patient management (9). BI-RADS standardized reporting of screening mammograms allows clinicians worldwide to know exactly what to expect from the report and take action. Moreover, ACR BI-RADS® facilitated accumulation of data for registries and databases, allowing better tracking of individual patient outcomes with specific imaging findings.

Since then, we have seen the creation of...

- LI-RADS™ (Liver Imaging Reporting and Data System) (10) for standardization reporting in patients with chronic liver disease,
- Lung-RADS™ (Lung CT Screening Reporting and Data System) for standardization reporting of patients undergoing CT lung screening in high-risk smokers (11) and
- PI-RADS™ (Prostate Imaging Reporting and Data System) criteria to improve early diagnosis and treatment of prostate cancer using multiparametric MRI (12), among other efforts.

To this end, the purpose of this document is to create a standardized reporting system for patients undergoing coronary CT angiography (coronary CTA) to link with logical next steps in patient management. The report system is named CAD-RADS (Coronary Artery Disease Reporting and Data System) and is intended for reporting of patients undergoing coronary CT angiography with suspected or known coronary artery disease either in the outpatient, inpatient or emergency department setting.

Recently, more specific guidelines and publications have indicated the need to link results from a coronary CTA study in patients presenting to the emergency department with chest pain to guidance of next steps in patient care (13-14). For example, patients with normal coronary CTA are discharged home. However, patients with mild non-obstructive coronary artery disease (CAD) (1-49%) are

discharged home but with follow-up consultation with their cardiologists or primary care physicians to initiate measures such as preventive therapies. Patients with moderate stenosis (50-69%) would be referred for further cardiac investigation with functional imaging or further monitoring. Finally, patients with severe stenosis (>70%) are admitted, and often sent to the cardiac catheterization laboratory (13,14). To allow for the appropriate selection of therapy after coronary CTA, lesion stenosis severity should be reported semi-quantitatively according to the guidelines, such as those recommended by the Society of Cardiovascular Computed Tomography (Table 1: 0, 1-24%, 25-49%, 50-69%, 70-99%, and 100% occluded) (2).

The goal of CAD-RADS is to create standardization of report terminology for coronary CTA results in order to improve communication of results to referring physicians in a clear and consistent fashion and to better guide clinical decision making. This will offer an important mechanism for peer review and quality assurance, ultimately resulting in improvement to quality of care.

CORONARY CT ANGIOGRAPHY IN STABLE CHEST PAIN PATIENTS

A common practice in cardiology is to identify which patients who are presenting with stable chest pain symptoms actually have obstructive coronary artery disease (CAD). A detailed clinical history, risk factors assessment and physical examination are critical to determine the patient's pretest probability of CAD. Non-invasive diagnostic testing is commonly used, particularly in intermediate risk patients, to determine which patients have obstructive CAD for subsequent management and often to determine the need for referral to invasive coronary angiography (ICA). The overall goal is to identify patients with obstructive CAD and/or myocardial ischemia who will benefit from coronary revascularization in terms of improved clinical outcomes.

Recently, the low diagnostic yield of elective ICA to detect obstructive CAD in the CathPCI Registry of the National Cardiovascular Data Registry (NCDR) involving almost 400,000 patients has been reported (15). Only 37.6% of patients had obstructive CAD, defined as $\geq 70\%$ stenosis. In a subsequent publication with the updated NCDR data the prevalence of obstructive coronary artery disease was reported as remaining low at 42%(16). In this latter report, a pre-procedure non-invasive test was performed in 64% of patients with the vast majority undergoing stress testing with SPECT MPI (78%). A high rate of non-obstructive disease was found in the patients with prior noninvasive stress testing. The rate of obstructive CAD in patients undergoing stress SPECT was 44.5% and stress echo was 43.8%. The only non-invasive imaging test that showed the majority of patients having obstructive CAD was coronary CTA, with obstructive CAD by ICA being shown in 69.6% of patients ($p < 0.0001$). Therefore, this data suggests that CCTA is superior as an effective gatekeeper to the catheterization lab, when compared to alternative techniques.

In patients presenting with stable chest pain, two recent large prospective multi-center randomized trials (PROMISE (17) and SCOT-HEART (18)) compared an initial strategy of CCTA versus a either traditional strategy of functional testing (PROMISE) or usual care (SCOT-Heart). The PROMISE study demonstrated—in 10003 patients that CCTA is a viable alternative to stress testing for assessment of stable chest pain patients. Importantly, an initial strategy of CCTA led to only 28% of patients receiving invasive catheterization without obstructive CAD as compared to a functional strategy with the stress test strategy that led to 52% of those patients subsequently receiving an invasive catheterization and found to have no obstructive CAD.

The SCOT-HEART trial, another large prospective multi-center trial in more than 4000 patients, compared a CCTA strategy to usual care in patients referred to chest pain clinics. They demonstrated that the use of CCTA led to changes in diagnosis in 1 in 6 patients and subsequent treatment strategies in 1 in 4 patients. They found a 38% reduction of cardiac death and non-fatal myocardial

infarction (MI) when compared to the standard of care, which was of borderline significance. When the delay between requesting testing and change in therapy recommendations by the physicians in Scotland of over 6 weeks in the centers was taken into account, a very significant reduction in death and MI was observed in the CCTA arm. Both PROMISE and SCOT HEART trials (17, 18) provide compelling evidence that CCTA will become part of the everyday testing armamentarium and support expanded use of CCTA for evaluation of patients with stable chest pain. These studies provide convincing evidence to revise clinical guidelines, and coverage and medical necessity rules.

CORONARY CT ANGIOGRAPHY IN ACUTE CHEST PAIN PATIENTS

In patients presenting with acute chest pain to the emergency department, four large randomized trials (CT-STAT, ACRIN-PA, ROMICAT II and CT-COMPARE) compared a coronary CTA strategy to current standard of care including stress testing (19-22). The collective results of these trials likewise have been clear: these studies consistently demonstrate the safety of a negative coronary CT angiogram to identify patients for discharge from the emergency department with very low rates of subsequent major adverse cardiovascular events (< 1%). These trials also show greater efficiency in terms of, greater proportion of patients being directly discharged, shorter time to discharge and shorter length of stay. Together, these trials provide evidence supporting the first-line use of coronary CTA in the emergency department in appropriate patients with low to intermediate pre-test probability of acute coronary syndrome.

Data demonstrating successful translation of the randomized trial data to real-world settings increase confidence in coronary CTA as a robust technique for this application. Two large studies demonstrated “real-world” experience of successful implementation of a coronary CTA program in the ED in a large urban Hospital and a large healthcare system (23-24). Moreover, they confirm the findings of the prior randomized trials that if coronary CTA is implemented together with a dedicated chest pain algorithm protocol, it is possible to improve efficiency in care by reducing the length of stay in the majority of patients using a quicker and safe strategy.

There are some limitations to the currently mentioned available studies. Some studies had a low prevalence of ACS, such as the CT-STAT trial. Some may argue that no test at all would also be an option. Therefore, it is important to follow appropriate guidelines in the use of Coronary CTA in the Emergency Department and avoid its use in very low risk patients. The other potential limitation is the detection of stable CAD not related to patient's symptoms and the potential for over-treating these patients. Well-defined protocols need to be in place, with the consideration of further assessment of intermediate lesions (50-70%) with functional testing before intervention. It is important to mention that Coronary CTA has relative contra-indications such as: patients with atrial fibrillation, renal dysfunction and contrast allergy among others. CCTA has lower radiation exposure when compared to SPECT, but obviously has more radiation when compared to exercise treadmill test or stress echocardiogram. The remaining and perhaps the most difficult challenges to overcome are the limited availability of experienced CCTA readers to provide sufficient coverage and improve collaboration among different specialties in order to enhance patient care.

Table 1 - SCCT grading scale for stenosis severity:

Stenosis

0% - No visible stenosis
1-24% - Minimal stenosis
25-49% - Mild stenosis
50-69% - Moderate stenosis
70-99% - Severe stenosis
100% - Occluded

* All vessels greater than 1.5mm in diameter should be graded for stenosis severity and CAD-RADS classification will apply for these vessels. Conversely, CAD-RADS will not apply for smaller vessels (<1.5mm in diameter).

* CAD-RADS classification should be applied on a per-patient basis for the highest-grade stenosis.

Table 2. CAD-RADS Reporting and Data System for patients presenting with stable chest pain.

	Degree of maximal coronary stenosis	Interpretation	Further Cardiac Investigation	Management
CAD-RADS 0	0% (No plaque or stenosis)	Documented absence of CAD*	None	- Reassurance. Consider other non- atherosclerotic causes of chest pain
CAD-RADS 1	1- 24% - Minimal stenosis or plaque with no stenosis**	Minimal non-obstructive CAD	None	- Consider preventive therapy and risk factors modification per guideline-directed care***
CAD-RADS 2	25- 49% - Mild stenosis	Mild non-obstructive CAD	None	- Consider preventive therapy and risk factors modification per guideline-directed care***
CAD-RADS 3	50-69% stenosis	Moderate stenosis	Consider functional assessment	- Consider symptom-guided anti-ischemic and preventive pharmacotherapy as well as risk factors modification per guideline-directed care*** - Other treatments should be considered per guideline-directed care***
CAD-RADS 4	A - 70-99% stenosis or B - Left main >50% or 3- vessel obstructive disease	Severe stenosis	A: Consider ICA**** or functional assessment B: ICA is recommended	- Consider symptom-guided anti-ischemic and preventive pharmacotherapy as well as risk factors modification per guideline-directed care*** - Other treatments (including options of revascularization) should be considered per guideline-directed care***
CAD-RADS 5	100% (total occlusion)	Total coronary occlusion	Consider ICA or functional/ viability assessment	- Consider symptom-guided anti-ischemic and preventive pharmacotherapy as well as risk factors modification per guideline-directed care*** - Other treatments (including options of revascularization) should be considered per guideline-directed care***
CAD-RADS N	Non-diagnostic study	Obstructive CAD cannot be excluded	Additional or alternative evaluation may be needed	

CAD-RADS classification should be applied on a per-patient basis for the highest-grade stenosis

* CAD – coronary artery disease

** CAD-RADS 1 – This category should also include the presence of plaque with positive remodeling and no evidence of stenosis

*** Guideline-directed care per ACC Stable Ischemic Heart Disease Guidelines (Fihn et al. JACC 2012)

**** ICA – invasive coronary angiography. ICA is recommended for CAD-RADS 4B.

MODIFIERS: If more than one modifier is present, the symbol “/” (slash) should follow each modifier in the following order:

- i. First: modifier **S (stent)**
- ii. Second: modifier **G (graft)**
- iii. Third: modifier **V (vulnerability)**

Table 3. CAD-RADS Reporting and Data System for patients presenting with acute chest pain (emergency department or hospital setting). Adopted and modified from management recommendations based on *SCCT Guidelines for Evaluation of patients presenting with acute chest pain to the emergency department* (13).

	Degree of maximal coronary stenosis	Interpretation	Management
CAD-RADS 0	0%	ACS* highly unlikely	- No further evaluation of ACS is required. Consider other etiologies.
CAD-RADS 1	1- 24%**	ACS highly unlikely	- Consider evaluation of non-ACS etiology. - Consider referral for out-patient follow-up for preventive management of coronary atherosclerosis and risk factors modification.
CAD-RADS 2	25- 49% ***	ACS unlikely	- Consider evaluation of non-ACS etiology. - Consider referral for out-patient follow-up for preventive management of coronary atherosclerosis and risk factors modification. - If clinical suspicion of ACS is high or if high-risk plaque features are noted in the stenosis, consider hospital admission with cardiology consultation.
CAD-RADS 3	50-69%	ACS possible	- Consider hospital admission with cardiology consultation, functional testing and/or ICA**** for evaluation and management. - Recommendation for anti-ischemic and preventive management should be considered as well as risk factor modifications. Other treatments should be considered if presence of hemodynamic significant lesion.
CAD-RADS 4	A - 70-99% or B - Left main >50% or 3-vessel obstructive disease	ACS likely	- Consider hospital admission with cardiology consultation and further evaluation with ICA and revascularization is appropriate. - Recommendation for anti-ischemic and preventive management should be considered as well as risk factor modifications.
CAD-RADS 5	100% (Total occlusion)	ACS very likely	- Consider expedited ICA on a timely basis and revascularization if appropriate. - Recommendation for anti-ischemic and preventive management should be considered as well as risk factor modifications.
CAD-RADS N	Non-diagnostic study	ACS cannot be excluded	Additional or alternative evaluation for ACS is needed

CAD-RADS classification should be applied on a per-patient basis for the highest-grade stenosis

* ACS – acute coronary syndrome

** CAD-RADS 1 – This category should also include the presence of plaque with positive remodeling and no evidence of stenosis

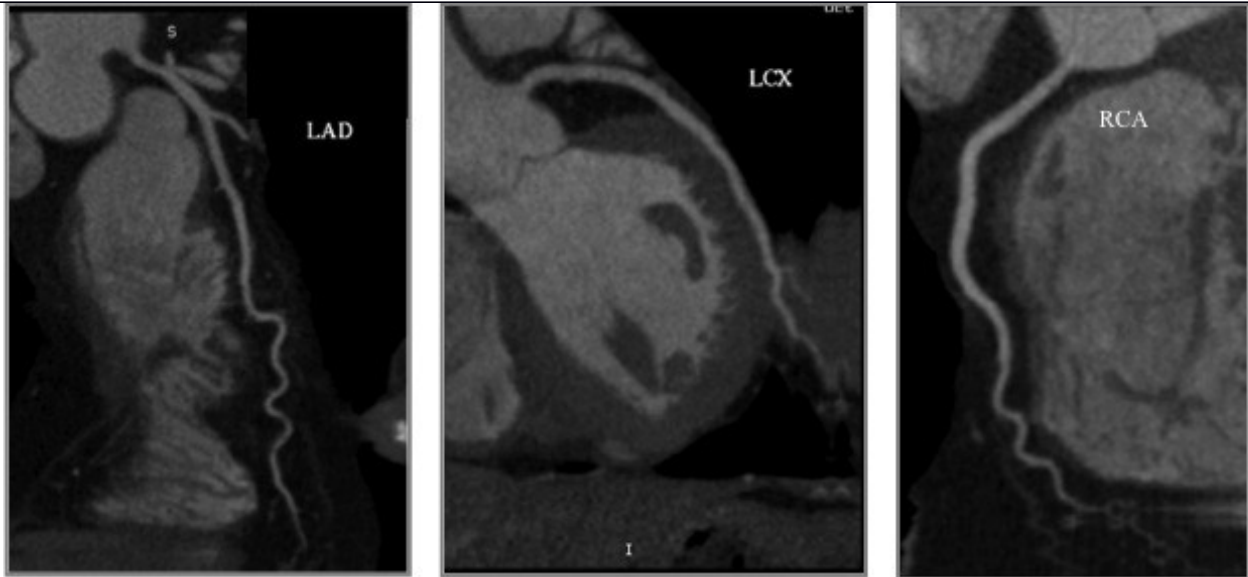
*** CAD-RADS 2 - **Modifier 2/V** can be used to indicate vulnerable/ high-risk plaque (see below)

**** ICA – invasive coronary angiography.

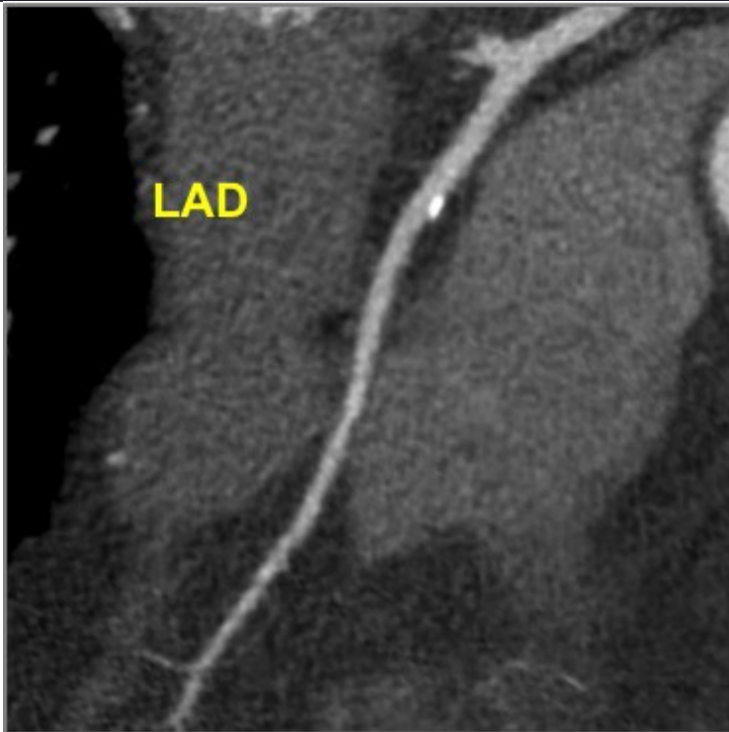
MODIFIERS: If more than one modifier is present, the symbol “/” (slash) should follow each modifier in the following order:

- i. First: modifier **S (stent)**
- ii. Second: modifier **G (graft)**
- iii. Third: modifier **V (vulnerability)**

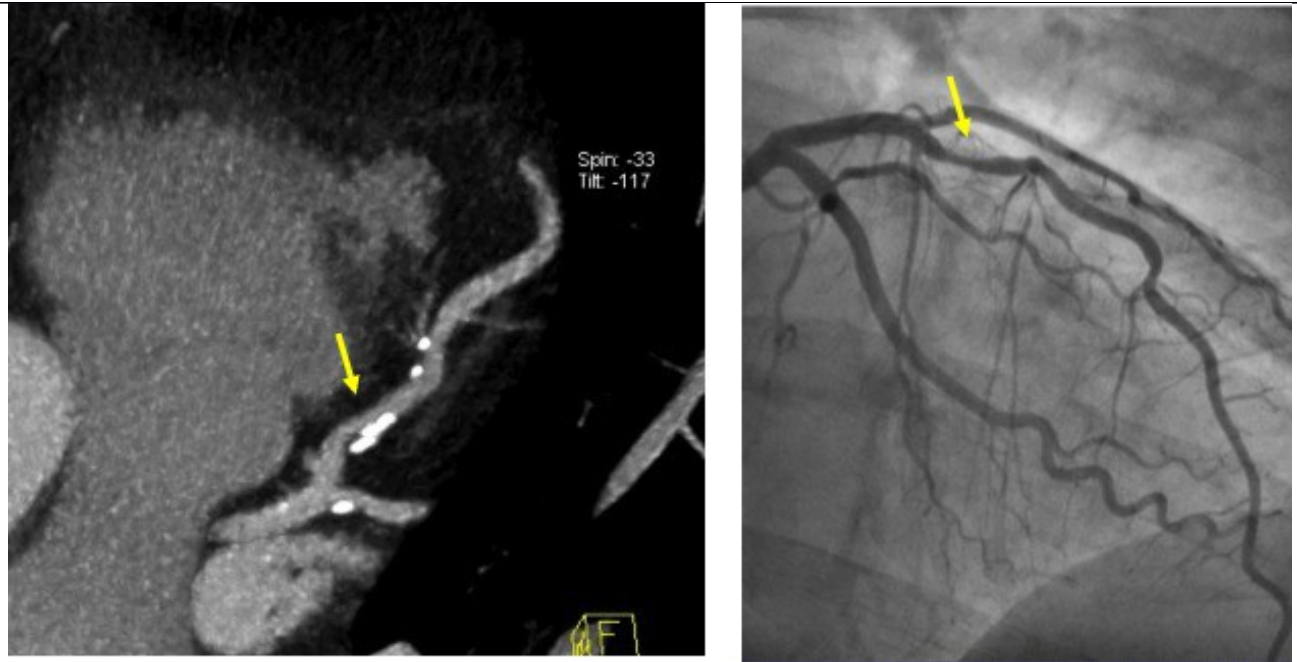
CAD RADS Categories



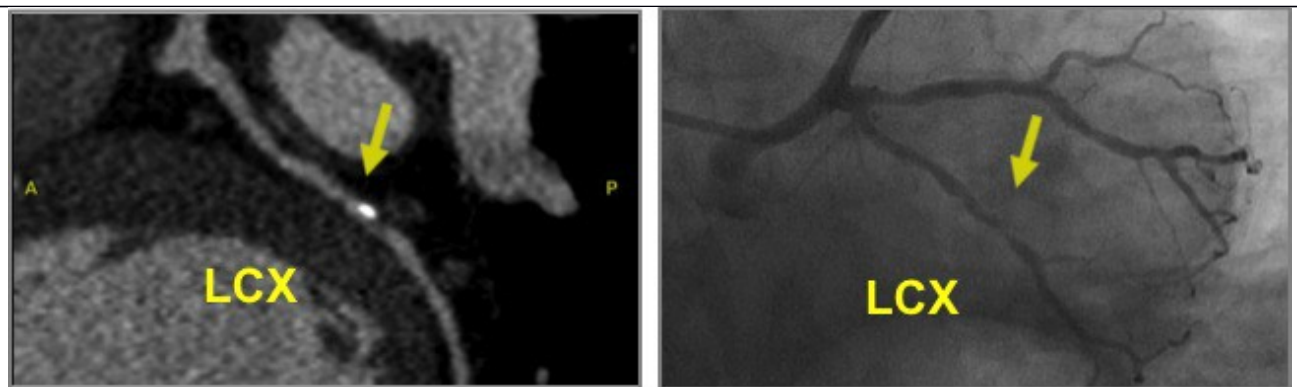
CAD RADS 0. Example demonstrating normal left main, LAD, LCX and RCA without evidence of plaque or stenosis.



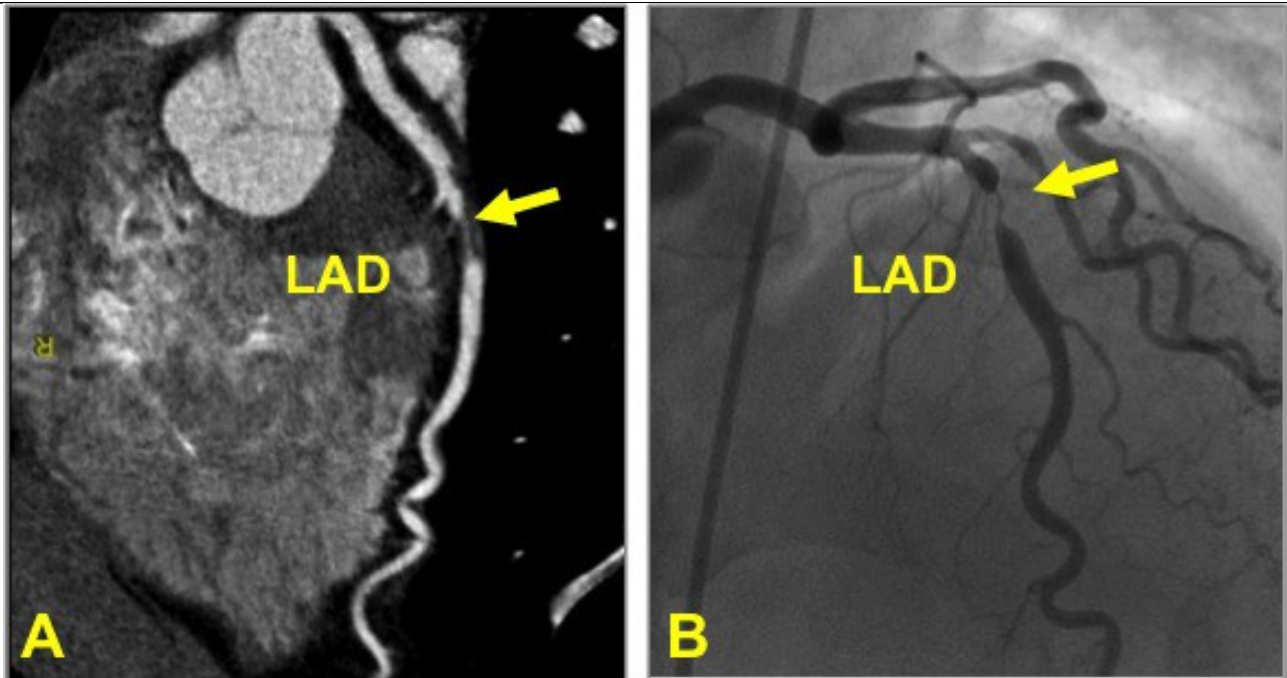
CAD RADS 1. Example demonstrating minimal calcified plaque in the proximal LAD with minimal luminal narrowing (less than 25% diameter stenosis). The left main, RCA, and LCX coronary arteries were unremarkable.



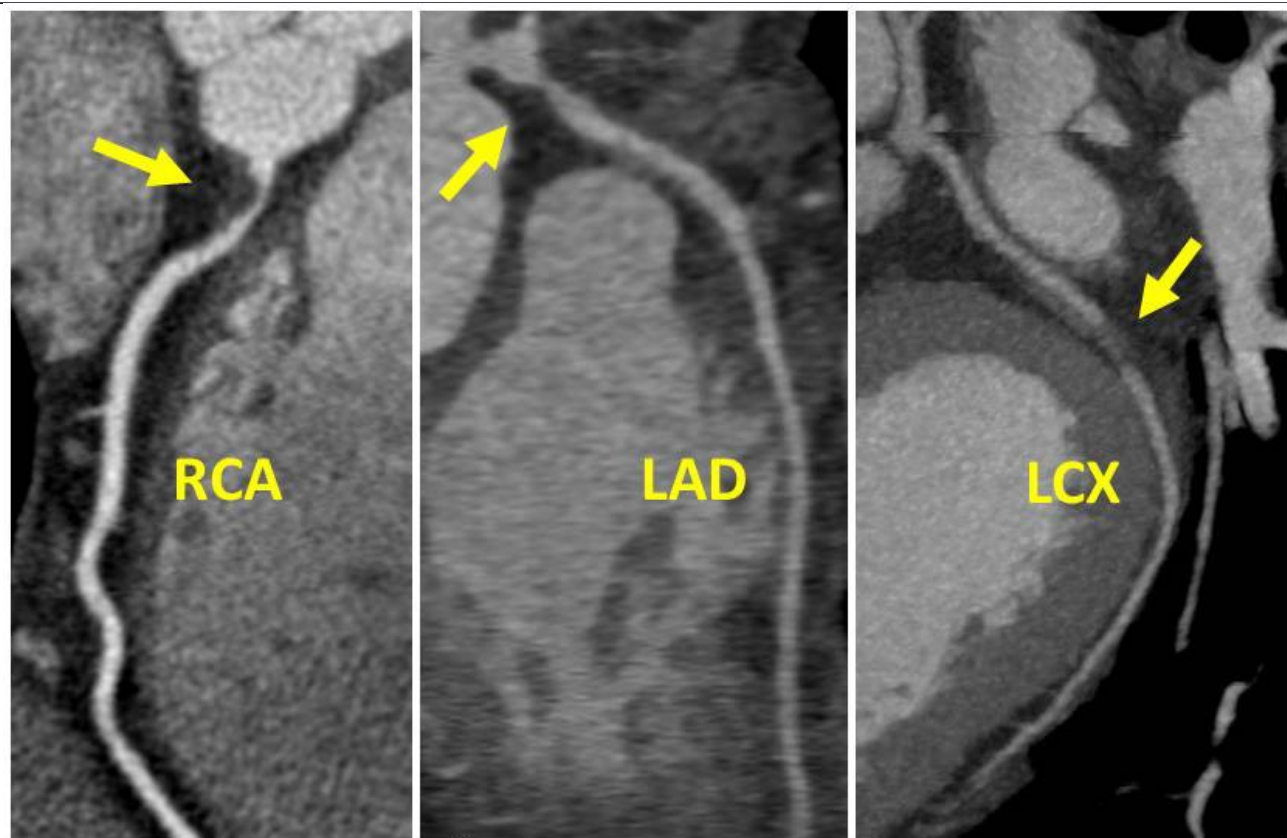
CAD RADS 2. Figure on the left: Coronary CT Angiography demonstrating predominant calcified plaque in the proximal LAD with 25-49% diameter stenosis. Additional calcified plaques are noted in the mid LAD and proximal LCX were associated with minimal luminal narrowing (less than 25% diameter stenosis). Figure on the right: Invasive coronary angiography confirming 25-49% stenosis. The left main and RCA coronary arteries were unremarkable (*not shown*).



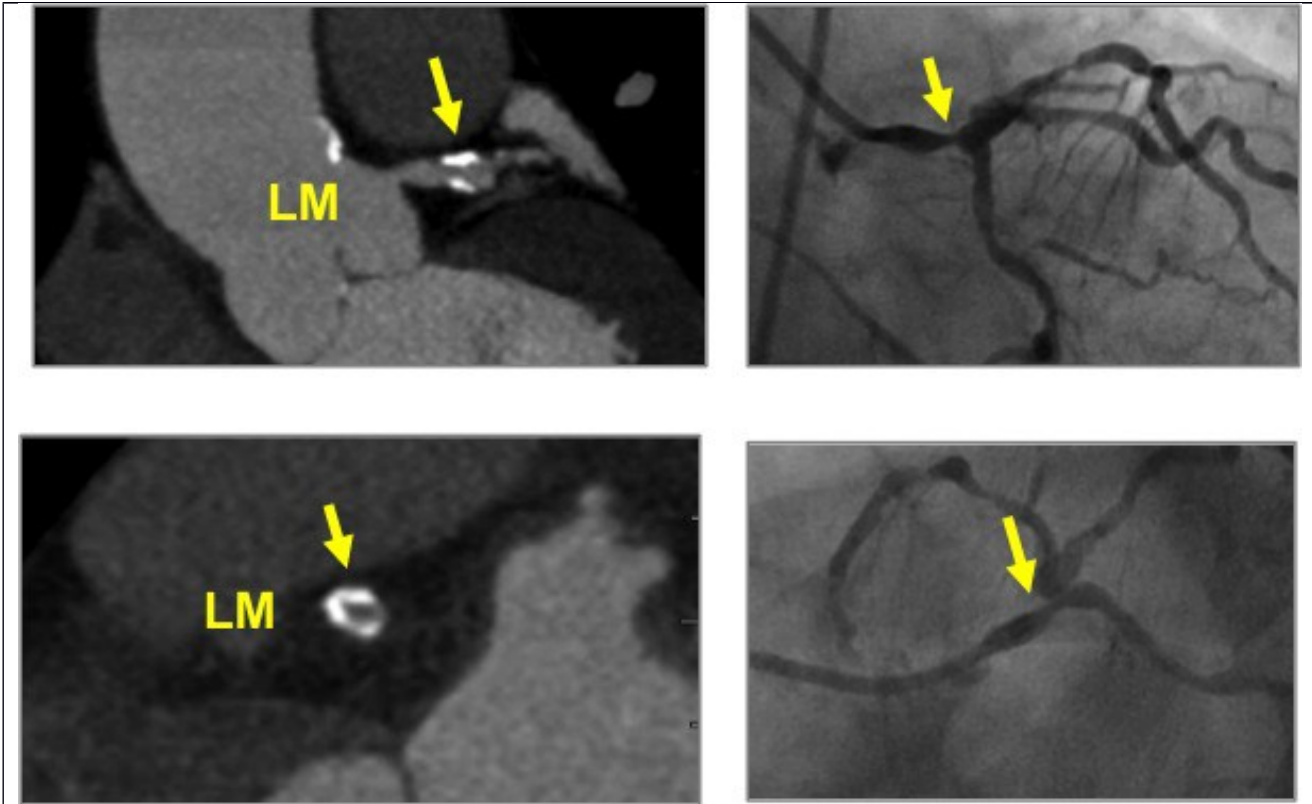
CAD RADS 3. Example demonstrating predominantly calcified plaque in the mid LCX with 50-69% diameter stenosis. The left main, RCA and LAD demonstrated minimal disease (*not shown*). Left image – Coronary CT angiography. Right image – Invasive coronary angiography.



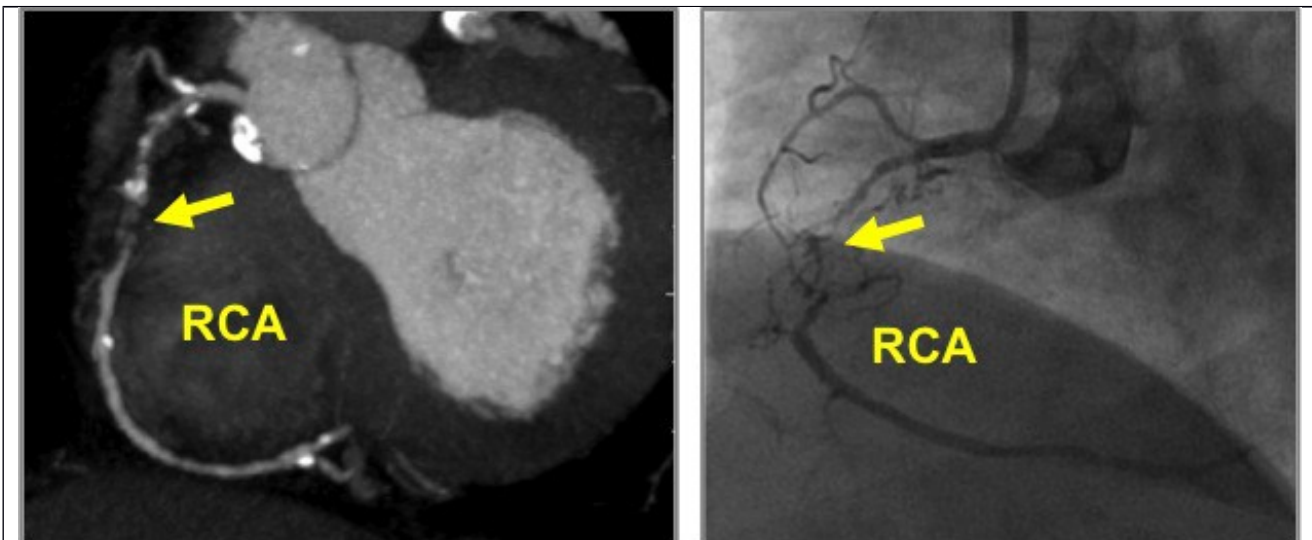
CAD RADS 4A. Figure A – Coronary CT Angiography demonstrating focal non-calcified plaque in the mid LAD (yellow arrow) with 70-99% diameter stenosis. Figure B – Invasive coronary angiography confirming 70-99% stenosis in the mid LAD (yellow arrow). The patient also had minimal stenosis in the LCX with less than 25% diameter stenosis (*not shown*). The left main coronary artery and RCA (*not shown*) were unremarkable.



CAD RADS 4B. Example demonstrating 3 vessel obstructive disease, including proximal RCA plaque resulting in 70-99% stenosis (*left*), ostial LAD plaque resulting in 70-99% stenosis (*middle*) and mid LCX plaque resulting in 70-99% stenosis (*right*).



CAD RADS 4B. *Figure on the left* - Coronary CT Angiography demonstrating distal left main stenosis with circumferential calcified plaque resulting in > 50% stenosis (arrows). *Upper left panel* – oblique longitudinal plane of the left main coronary artery. *Lower left panel* – cross-sectional slice of the distal left main coronary artery. *Figures on the right* - Invasive coronary angiography confirming focal severe stenosis in the distal left main coronary artery. Severe stenosis (70-99%) was also demonstrated in the mid LAD (shown only in the invasive angiogram in the above images).



CAD RADS 5. *Left image:* Coronary CT Angiography demonstrating short total occlusion (100% diameter stenosis) in the proximal RCA (arrow). The obstruction spans a length of 12 mm. There is contrast opacification of the distal RCA and presence of collateral vessels, supporting chronic total occlusion. The patient also had non-obstructive atherosclerosis in the LAD and LCX (*not shown*). *Right image:* Invasive coronary angiography confirming the total occlusion (100%) in the proximal RCA with bridging collaterals supplying the distal RCA.

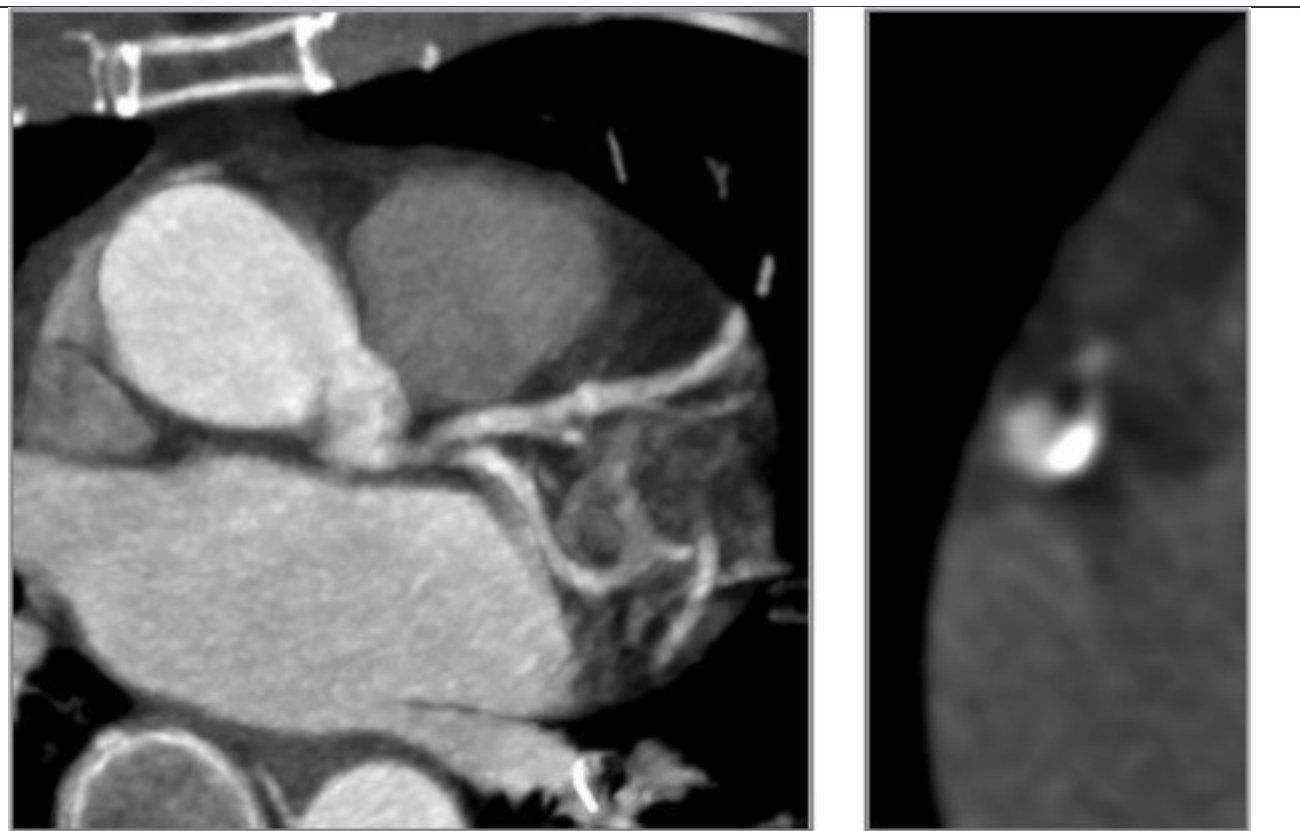
MODIFIERS:

I. CAD-RADS N (Non-diagnostic) – CAD-RADS N should be used if the study is non-diagnostic or includes segments that are non-evaluable. Additional or alternative evaluation may be required since a significant stenosis cannot be excluded.

Non-diagnostic studies can be related to two main reasons:

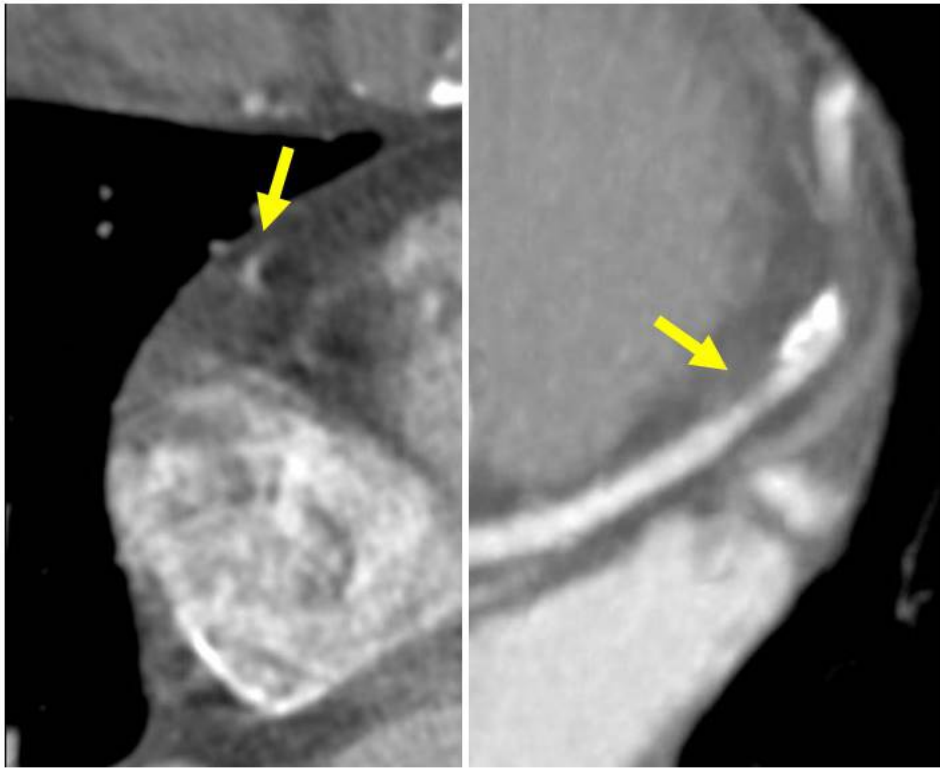
- i- Technical factors: The study is non-diagnostic due to technical limitations during scan acquisition such as: incorrect timing of contrast, slab or misalignment artifacts, motion artifacts, imaging that does not include the entire coronary artery tree,, etc...
- ii- Anatomic factors: The study is non-diagnostic due to patient-related issues, such as: large body mass index, calcified plaque leading to blooming artifact, metal artifact, stents, etc...

This information should be included in the report.



CAD RADS N. Left figure demonstrating motion artifacts obscuring the left main, LAD and LCX arteries, which renders these segments non-diagnostic. Right figure demonstrating motion artifacts in the mid RCA.

II. CAD-RADS N (Non-diagnostic) - If the study is non-diagnostic and a stenosis is present in a diagnostic segment, the highest stenosis should be graded in addition to the letter N if the CAD-RADS is greater than 3 (i.e. applies only for CAD-RADS 3, 4 and 5). For example, for a patient with moderate stenosis (50-69%) in one segment and a non-diagnostic area in another segment, the study should be graded as **CAD-RADS 3/N and not CAD-RADS N**, as further evaluation is needed and patient recommendations for anti-ischemic and preventive management is recommended. However, for a patient with no stenosis (zero), minimal (1-24%) or mild stenosis (25-49%) **CAD-RADS N** should be used as further evaluation to exclude obstructive coronary artery disease is still needed.

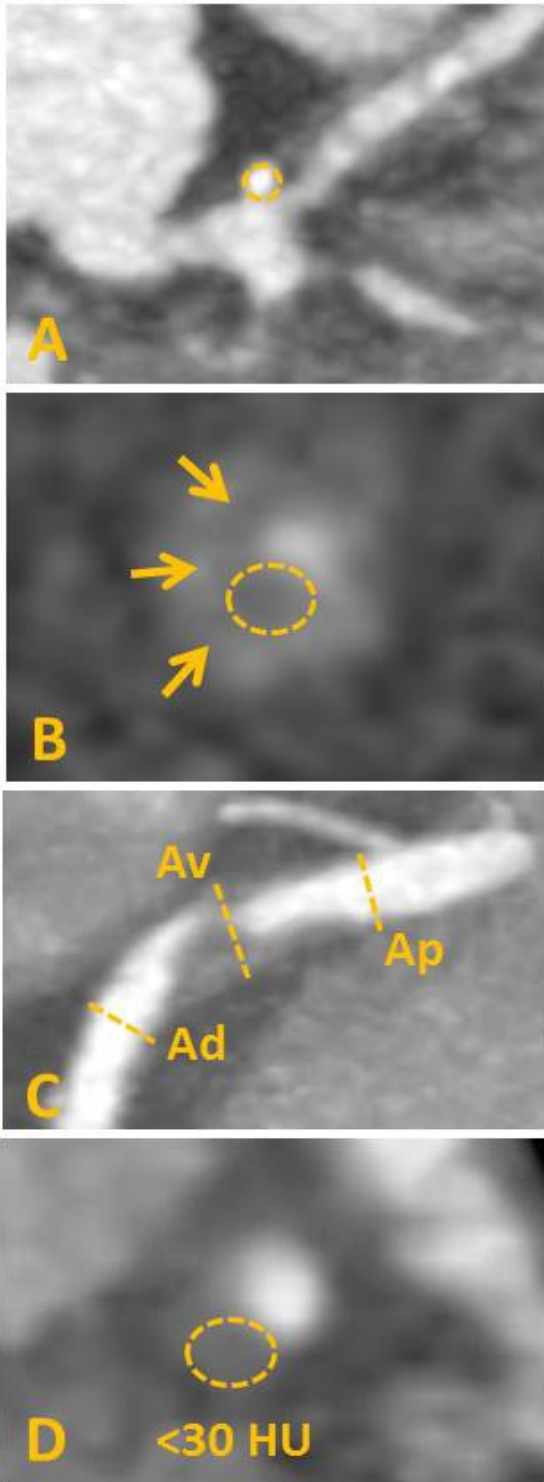


CAD RADS 3/N. Example demonstrating motion artifact obscuring the mid RCA (*left, arrow*), which renders this segment non-diagnostic. There is also stenosis of the mid LAD with 50-69% luminal narrowing (*right, arrow*), qualifying this lesion as CAD RADS 3. The left main and LCX were unremarkable (*not shown*). Although the mid RCA segment is non-diagnostic, the presence of obstructive disease within the LAD should be coded as CAD RADS 3/N. If the LAD lesion was mild (less than 50% diameter stenosis), and no other plaques were identified, the patient would be coded as CAD RADS N.

III. Presence of high-risk plaque features:

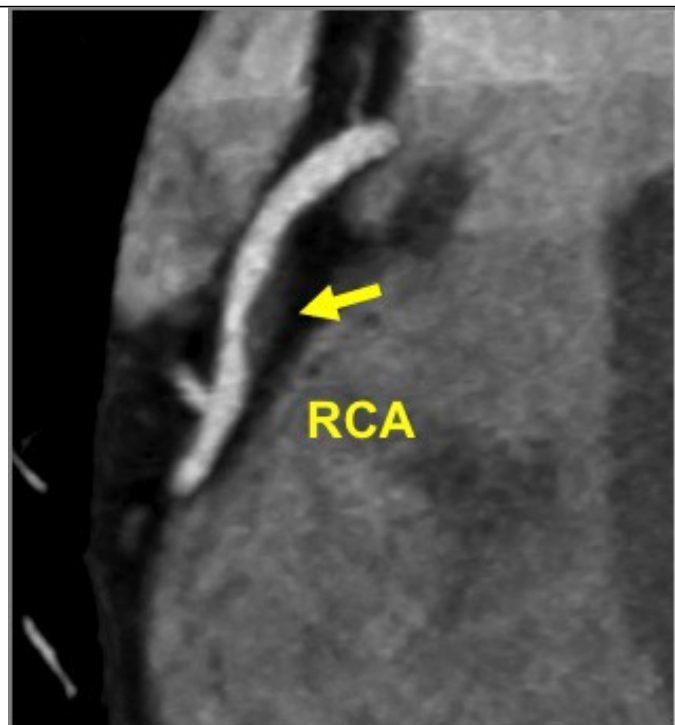
Vulnerable plaque is a recent paradigm describing a subset of atherosclerotic plaques that are at higher risk for plaque rupture and inciting acute coronary syndrome (ACS). The concept of vulnerable plaque has received increasing attention over recent years as a promising strategy to improve coronary risk stratification beyond diameter stenosis. Specific morphologic and physiologic features of vulnerable plaque including a large lipid rich necrotic core, thin fibrous cap, endothelial denudation, active inflammation, or a combination of these features. Data from recent CCTA studies have further described vulnerable plaque characteristics that are independently associated with ACS, including positive remodeling, low-attenuation plaque, spotty calcification, and the napkin-ring sign (25). Further, using prospective data from the ROMICAT II trial, Puchner et al.(26) demonstrated the presence of vulnerable plaque on CCTA was independently and incrementally associated with ACS beyond $\geq 50\%$ diameter stenosis and clinical predictors.

If a coronary plaque demonstrates two or more high-risk features by CCTA, the modifier "V" (vulnerability) in CAD-RADS should be used. As noted above, high-risk features include: low attenuation plaque (less than 30 Hounsfield Units), positive remodeling, spotty calcification, and the napkin ring sign (see Figure).



High risk plaque features on CCTA. These include a) Spotty calcium, defined as punctate calcium within a plaque measuring less than 3 mm in all dimensions; b) Napkin ring sign, defined as central low attenuation plaque with a peripheral rim of higher CT attenuation (*arrows*); c) Positive remodeling, defined as the ratio of outer vessel diameter at the site of plaque divided by the average outer diameter of the proximal and distal vessel greater than 1.1, or $Av/[(Ap + Ad)/2] > 1.1$; and d) Low attenuation plaque, defined as non-calcified plaque with internal attenuation less than 30 HU. Please note that a combination of two or more high risk features is necessary to designate the plaque as high-risk for CAD RADS.

CAD RADS 2/IV should be used for a patient with diameter stenosis between 25-49% and demonstrating plaque with two or more high-risk features (large non-calcified plaque, positive remodeling, spotty calcification, low HU values and napkin ring sign). The features should be described, particularly in patients presenting to the emergency department with acute chest pain. There is not enough published data to guide the management of such patients. However, clinical and laboratory correlation and close observation is recommended. Consider hospital admission in high risk clinical settings. If the patient is discharged, short-term clinical follow-up within a week is suggested in the outpatient setting with a cardiologist or primary care physician.



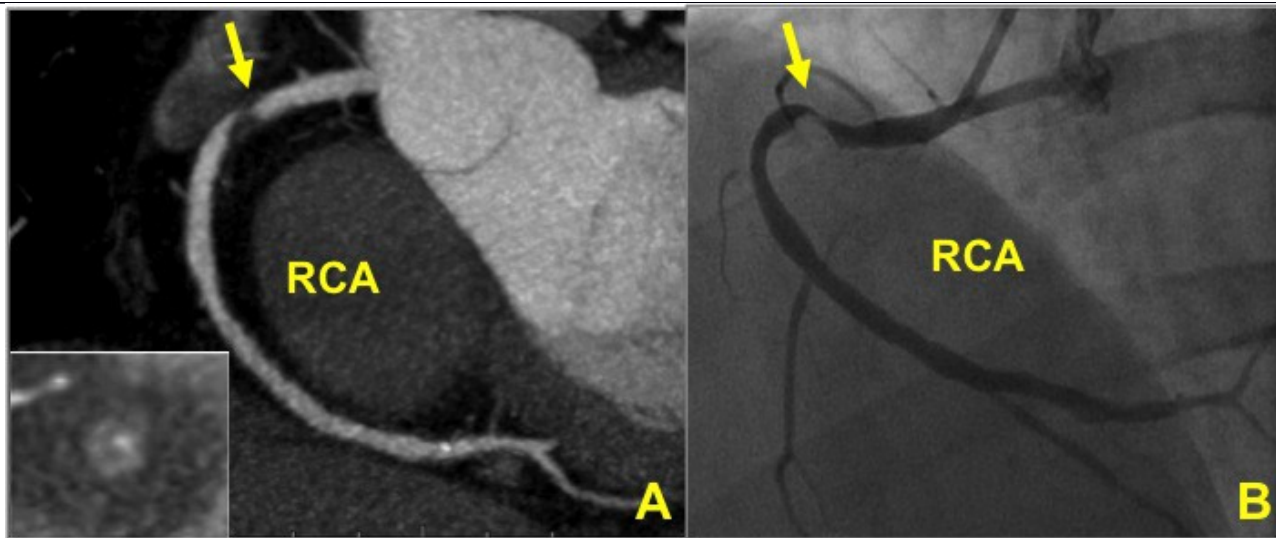
CAD RADS 2/IV. Example demonstrating focal non-calcified plaque in the mid RCA with 25-49% diameter stenosis. The plaque demonstrates two high risk features, including low attenuation (<30 HU) and positive remodeling, thus coding with the modifier “V.” The patient also had nonobstructive plaque in the LAD and LCX resulting in 25-49% diameter stenosis in both vessels (*not shown*). The left main coronary artery was unremarkable (*not shown*).

Studies coded with CAD-RADS 3/IV (the presence of high risk plaque with 50-69% diameter stenosis, excluding left main lesions) should prompt consideration for more aggressive management than studies coded with CAD-RADS 3, particularly in patients presenting to the emergency department with acute chest pain. This includes consideration for further testing with ICA instead of non-invasive functional testing. However, management decisions should ultimately be made on an individual basis taking into consideration supporting clinical and laboratory data.

IV. CAD RADS 4 – If a left main coronary artery stenosis greater than 50% is suspected or the examination demonstrates three-vessel obstructive disease, then further evaluation with ICA is recommended. To ensure this is tracked, **CAD RADS 4** is sub-divided into A and B.

CAD RADS 4A – Single vessel or two-vessels demonstrating severe stenosis (70-99%).

CAD RADS 4B - This indicates presence of left main stenosis greater than 50% or triple vessel occlusive disease. Further evaluation with ICA is recommended.



CAD RADS 4A/V. Example demonstrating focal non-calcified plaque in the proximal RCA with 70-99% diameter stenosis. The plaque demonstrates three high-risk features, including positive remodeling, central low attenuation (<30 HU) and napkin ring sign, thus indicating coding with the modifier “V”. The patient also had mild stenosis in the LAD and LCX resulting in 25-49% diameter stenosis in each vessel (*not shown*). The left main coronary artery was unremarkable (*not shown*).

V. CAD RADS 5 – Consideration for coronary occlusion

Does this coronary occlusion demonstrate acute or chronic imaging features? What is the length of the occlusion? Are collateral vessels present? Does it demonstrate calcified plaques at the entry site of the occlusion? Subtotal vs total occlusion? This information should be included in the report.



CAD RADS 5. Two examples of cases coded as CAD RADS 5. *Case A:* Patient with focal noncalcified plaque in the proximal RCA (*arrow*) resulting in short total occlusion (100% diameter stenosis). The obstruction spans a length of 8 mm. There is contrast opacification of the distal RCA and absence of collateral vessels, supporting acute/subacute subtotal occlusion. The patient also had non-obstructive atherosclerosis in the RCA and LCX (*not shown*). *Case B:* Patient with a total occlusion of the proximal LCX and absence of distal contrast opacification (*arrow*). A small focus of “orphan” calcium along the distal LCX supports the diagnosis of chronic total occlusion.

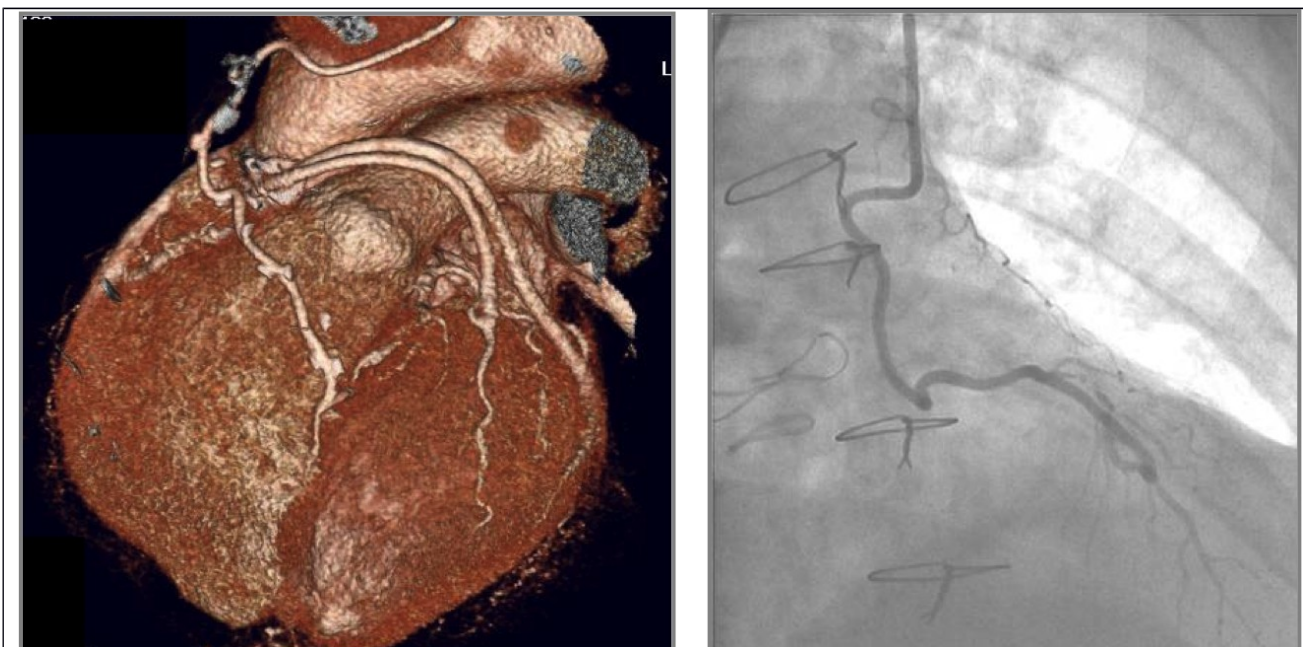
VI. Presence of prior revascularization: Patients undergoing coronary CT angiography with prior revascularization should be sub-classified with the following modifiers:

- i- **S = Stent:** Indicates presence of coronary stent. The addition of the letter “S” after CAD RADS will indicate that the patient has at least one coronary stent. For example, if a patient has a patent stent in the proximal left anterior descending coronary artery (LAD) with no significant in-stent restenosis or occlusion and demonstrates mild non-obstructive disease (25-49%) in the left circumflex artery (LCX) and right coronary artery (RCA), the case would be classified as: **CAD-RADS 2/S**. Another example: if the patient demonstrates significant in-stent restenosis of the proximal LAD stent, then the case would be classified as: **CAD-RADS 4A/S**. If there is a patent stent in the LAD and a new severe stenosis in the RCA, then the case would be classified as **CAD-RADS 4A/S**. CAD-RADS of 4 indicates the highest stenosis score and the modifier S indicates the presence of a stent. If the stent is occluded, then **CAD-RADS 5/S** would be the proper classification. Finally, if a stent is non-evaluable, then the case would be classified as **CAD-RADS N/S** if there is no other stenosis greater than 50% in the coronary tree. Note: CAD-RADS was created to guide management recommendations, so it does not matter if it is the stent that is demonstrated to have a severe stenosis or if it is a new non-stented vessel; rather, what matters is that the patient has a severe stenosis and needs further work-up.



CAD RADS 4A/S. Example demonstrating proximal LAD stent with in stent restenosis resulting in significant luminal narrowing (70-99% stenosis). Non-obstructive plaque was also identified in the RCA and LCX (*not shown*). Grading of in stent restenosis should follow the grading of normal coronary arteries (0% stenosis, 1-24% stenosis, 25-49% stenosis, 50-69% stenosis, 70-99% stenosis, and >99% stenosis). In this case, high grade in-stent restenosis designates a CAD RADS 4 lesion, which would be followed by the stent modifier “S.”

- ii- **G = Graft:** Indicates presence of coronary-artery by-pass graft. The addition of the letter “G” after CAD RADS indicates that the patient has at least one coronary artery bypass graft. For example, if a patient has a patent left internal mammary artery (LIMA) graft to LAD, with patent distal anastomosis and patent run-off vessel with no significant stenosis or occlusion and demonstrates non-obstructive disease (25-49%) in the LCX and RCA, and expected proximal LAD severe stenosis, then the case would be classified as: **CAD-RADS 2/G**. Interpretation is that the patient has a patent graft and distal runoff and expected proximal LAD stenosis, but no further investigation is needed. The focus of CAD-RADS is on management. Another example: if the patient demonstrates total occlusion of the saphenous vein graft (SVG) to the RCA, and patent LIMA to LAD and SVG to LCX, then the case would be classified as: **CAD-RADS 5/G**. The interpretation is that a total occlusion is present and further investigation and/or management may be required.



MODIFIER G. Example demonstrating normal coronary bypass grafts. *Left image* – Coronary CT Angiography demonstrating patent left internal mammary artery to the LAD and patent saphenous vein grafts to the ramus intermedius branch and second obtuse marginal branch. There were no stenoses or luminal narrowing throughout the grafts (0% stenosis). The left main and RCA were also unremarkable (*not shown*). *Right image* – Invasive coronary angiography demonstrating patent LIMA to the LAD. When evaluating CCTA cases of bypass grafts, the native coronary artery segments *proximal* to the graft anastomoses should not be evaluated for purposes of CAD RADS coding. Only the grafts and the native coronary artery segments *distal* to and *including* the anastomosis should be evaluated for CAD RADS coding.

VII. Presence of other cardiac or extra-cardiac findings: Patients undergoing coronary CTA may demonstrate other significant, potentially significant or non-significant cardiac or extra-cardiac findings. CAD-RADS is intended to focus solely on the classification of coronary artery stenosis and further management. The CAD-RADS Steering Committee acknowledges that other cardiac and extra-cardiac findings should be reported in coronary CT angiography studies. Specific follow-up and recommendations should be reported depending on the pathology. It is beyond the scope of this document to provide recommendations for other cardiac or extra-cardiac findings.

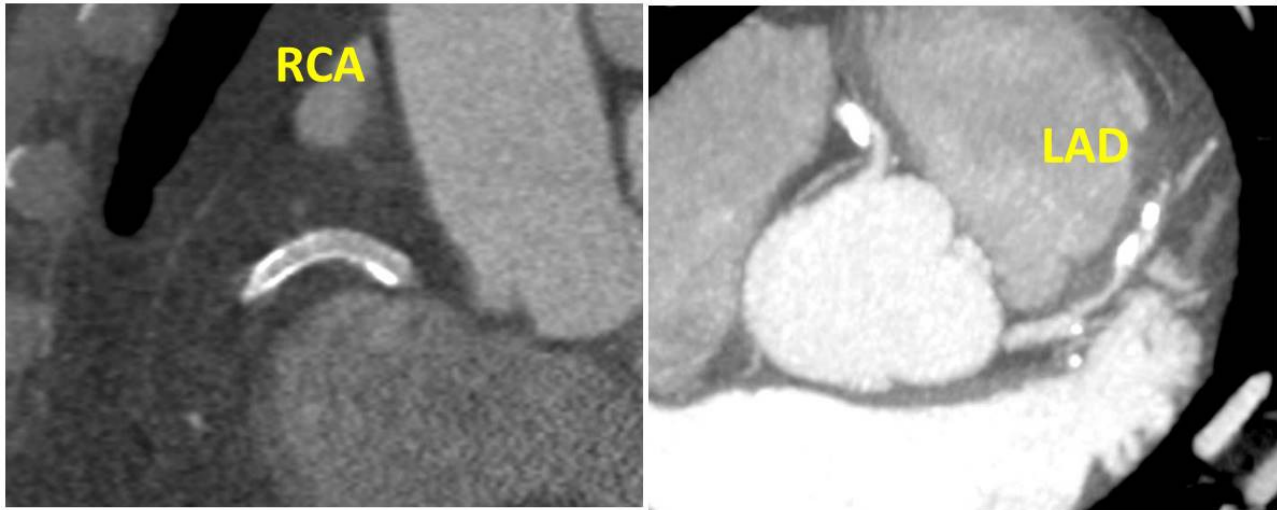
NOTE: If more than one modifier is present, the symbol “/” (slash) should follow each modifier in the following order:

- i. First: modifiers **S (stent)**
- ii. Second: modifier **G (graft)**
- iii. Third: modifier **V (vulnerability)**

For example:

- i. Non-interpretable coronary stent without evidence of other obstructive coronary disease: **Modifier S = CAD RADS N/S**
- ii. Presence of stent and a new moderate stenosis showing a plaque with high-risk features: **Modifier S/V = CAD-RADS 3/S/V**
- iii. Presence of stent, grafts and non-evaluable segments due to metal artifacts: **Modifier S/G = CAD-RADS N/S/G**
- iv. Presence of patent LIMA to the LAD and expected occluded proximal LAD. Mild non-obstructive stenosis in the RCA and LCX. **Modifier G = CAD-RADS 2/G.**

- v. For a patient with severe stenosis (70-99%) in one segment and a non-diagnostic area in another segment, the study should be graded as **CAD-RADS 4/N**.



CAD RADS 3/S/V. Example demonstrating a patent stent in the proximal RCA (0% stenosis) with high-risk plaque in the proximal LAD resulting in 50-69% luminal narrowing. The LCX was unremarkable (*not shown*). In isolation, the proximal LAD lesion would be coded CAD RADS 3/V. However, since CAD RADS is coded on a per-patient basis, and a RCA stent is present, this patient would be coded as CAD RADS 3/S/V.

Management of patients with known CAD

The management recommendations with regard to patients with previously known CAD deserve special consideration. The great strength of coronary CTA relies on its extremely high sensitivity and negative predictive value. This allows the rapid division of patients into the majority, who have little or no disease, and those with plaques that may or may not have functional consequences. The positive predictive value of coronary CTA is significantly lower, and most research studies have recommended functional testing of intermediate grade lesions. Most patients with previously known CAD will include plaques that fall into this category, unless the coronary CTA findings demonstrate that the original diagnosis was erroneous or a critical lesion is so obvious that immediate action is required. Additionally, patients with stents have reduced accuracy for diagnosis of in-stent stenosis compared to native arteries, particularly stents smaller than 3mm in diameter, and often have other lesions that are likely to require functional analysis.

Thus, caution should be used regarding the use of coronary CTA in patients with previously known CAD, as it will not demonstrate the functional consequences of the multiple plaques that are likely to be found in typical CAD patients, and thus may merely be a precursor to further testing.

DISCUSSION

The use of Coronary CT Angiography to assess patients with stable chest pain in the outpatient setting or acute chest pain presenting to the Emergency Department has been extensively validated and now the main hurdles are how to decrease variation in reporting and effectively implement in clinical practice. Major guidelines are incorporating the use of Coronary CT Angiography as appropriate for assessing low to intermediate risk patients presenting with chest pain. The main goal of the CAD-RADS classification system is to propose a reporting structure that allows consistency in final assessment categories with accompanying management recommendations. This is important not only to communicate and guide referring clinicians in proper patient management and next steps in patient care, but also to serve as a framework for data collection and auditing.

Healthcare is rapidly changing and proper use of resources is imperative. The development of CAD-RADS will allow optimal tracking for accurate communication of results and management recommendations. This will also allow reliable and reproducible data collection, storage and retrieval for future research trials and audits. CAD-RADS is intended to be a tool that imagers can use to communicate with clinicians to convey concise and orderly findings in understandable and standardized language. CAD-RADS is also intended to be a living document that undergoes continued development to provide up-to-date, evidence based standard terminology and recommendations. Similar to other larger registries, such as, the National Radiology Data Registry (NRDR) and National Cardiovascular Data Registry (NCDR), CAD-RADS can provide the framework for standardize collection of Coronary CT Angiography reports across multiple sites for quality improvement and benchmarking. Moreover, it can provide the framework for collecting outcome data in each of several sub-categories, such as:

- 1- Follow-up of disposition of patients with positive Coronary CT Angiography results;
- 2- Rate of downstream testing;
- 3- Correlation with ICA;
- 4- Rate of revascularization (percutaneous coronary intervention and coronary artery by-pass graft surgery)
- 5- Major adverse cardiac events, including cardiovascular death and myocardial infarct.

Therefore, it is strongly encouraged that every Coronary CT Angiography study includes the CAD-RADS classification or similar language for a final assessment. This practice will also be important for consistent and rational evaluation of Coronary CT Angiography findings and will facilitate resident and fellowship training in Cardiac Imaging. Residency and Fellowship trainees should be required to use the CAD-RADS terminology, assessment categories and management recommendations.

Similar to Bi-RADS, peer-reviewed Radiology and Cardiology journals in the future may also find the CAD-RADS terminology useful for assessment and sub-classification of Coronary CT Angiography results, which in turn will further propel the wide use of CAD-RADS nationally and internationally.

Finally, standardization in reports and management recommendations will not only improve the clarity of communication and comprehension of imaging results by all members of the clinical care team, but also will improve communication between humans and computer-based systems. This will allow the development of decision support technologies and serve as the basis for developing artificial intelligence algorithms.

CONCLUSION

In conclusion, CAD-RADS has been developed from scientific data, expert guidance from leaders in cardiac imaging and a multi-disciplinary effort involving Radiology and Cardiology Societies (SCCT, NASCI, ACR and ACC). It is meant to be an evolving document that will undergo continuous update as new data are acquired. The main goal of CAD-RADS is to create report standardization terminology for coronary CTA results, and to improve communication of results to referring physicians in a clear and consistent fashion with a final assessment and recommendation for a specific course of action. This will provide the framework to standardize education, research, peer-review, quality assurance and ultimately result in improvement to quality of care. Finally, compiling imaging data in a standardized manner will allow linking imaging findings with specific treatments and better access to data regarding the impact on patient outcomes.

Figure: Sample standardized reporting template for CCTA incorporating CAD RADS coding.

EXAM: CORONARY CT ANGIOGRAPHY WITH CALCIUM SCORE

CLINICAL HISTORY: []

COMPARISON: []

TECHNIQUE: Using a [scanner type], a preliminary scout study was obtained, followed by coronary artery calcium protocol. Following administration of intravenous contrast, [0.5] mm collimated images were obtained through the coronary arteries. Data were transferred off-line for 3D reconstructions and multi-planar imaging.

ACQUISITION: [Prospective; Retrospective>] ECG triggering was used. Heart rate at the time of acquisition was approximately [] bpm.

MEDICATIONS: [100mg of oral metoprolol was administered prior to scanning]. [0.4mg sublingual nitroglycerine was administered immediately prior to scanning].

TECHNICAL QUALITY: [excellent, with no artifacts; good, with minor artifact but good diagnostic quality; acceptable, with moderate artifacts; poor/suboptimal, with severe artifacts]

FINDINGS:

The total calcium score is zero indicating absence of calcified plaques in the coronary tree.

The coronary arteries arise in normal position. There is ____ (right/ left/ co) coronary artery dominance.

Left main: The left main coronary artery is a ____ (short/ medium/ large) size vessel and (bifurcates in LAD and LCX / or trifurcates in LAD, LCX and RI). It is patent with no evidence of plaque or stenosis.

LAD: The left anterior descending artery is patent with no evidence of plaque or stenosis. It gives off ____ patent diagonal branches.

LCX: The left circumflex artery is patent with no evidence of plaque or stenosis. It gives off ____ patent obtuse marginal branches.

RCA: The right coronary artery is patent with no evidence of plaque or stenosis. It gives off a patent posterior descending artery and a patent posterior left ventricular branch.

Cardiac valves: There is no thickening or calcifications in the aortic and mitral valves.

Pericardium: The pericardial contour is preserved with no effusion, thickening or calcifications.

Extra-cardiac findings: There is no significant extra-cardiac findings in the available limited views of the lungs and mediastinum.

IMPRESSION:

1- Total calcium score of zero.

2- No evidence of coronary stenosis or plaque by Coronary CT Angiography.

CAD RADS [0] Management recommendation: Reassurance. Consider other non-atherosclerotic causes of chest pain

Other: []

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