Understanding the Coronary Artery Disease Reporting and Data System (CAD-RADS): A Primer for Radiologists

Christopher D. Maroules, MD[1,2]
Muhammad A. Latif, MD[1]
Juan C. Batlle, MD[1]
Constantino S. Pena, MD[1]
Khurram Nasir, MD, MPH[1]
Arthur Agatston, MD[1]
Warren Janowitz, MD[1]
Jack Ziffer, MD, PhD[1]
Suhny Abbara, MD[2]
Ricardo C. Cury, MD[1]

[1]Miami Cardiac and Vascular Institute and Baptist Health of South Florida, Miami, Florida
[2]Department of Radiology, UT Southwestern Medical Center, Dallas, Texas

Baptist Health South Florida

UT Southwestern Medical Center
Radiology

INTRODUCTION

TEACHING POINTS

1. To review evidence supporting coronary CT angiography for the evaluation of acute chest pain and chronic stable chest pain
2. To discuss CAD-RADS assessment categories for patients presenting with acute chest pain
3. To discuss CAD-RADS assessment categories for patients presenting with stable chest
4. To illustrate the imaging appearance of CAD-RADS assessment categories, including modifiers for plaque vulnerability and prior coronary revascularization

- The Coronary Artery Disease Reporting and Data System (CAD-RADS)1 is a standardized reporting system intended for patients undergoing coronary CTA with suspected or known coronary artery disease either in the outpatient, inpatient or emergency department setting.
- CAD-RADS was 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 require continuous update as new data are acquired.
- The purpose of CAD-RADS is to standardize reporting of coronary CTA, linking diagnostic imaging findings with logical next steps in patient management.
- Further, CAD-RADS aims to facilitate improved communication of imaging findings to referring physicians in a clear and consistent fashion with a final assessment and specific course of action. This will offer an important mechanism for peer review and quality assurance, ultimately resulting in improved quality of care.

GENERAL PRINCIPLES

- CAD-RADS classification should be applied on a per-patient basis based on the highest-grade coronary stenosis.
- 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 diame

CAD-RADS reporting and data system for patients presenting with stable chest pain

	Degree of maximal coronary stenosis	Interpretation	Further Investigation	Management
CAD-RADS 0	0% (No plaque or stenosis)	Document 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 Guidelines2, **** ICA – invasive coronary angiography. ICA is recommended for CAD-RADS 4B.

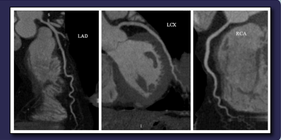
CAD-RADS reporting and data system for patients presenting with acute chest pain (emergency department or hospital setting).

	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.
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

* 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.

CAD RADS CASE EXAMPLES

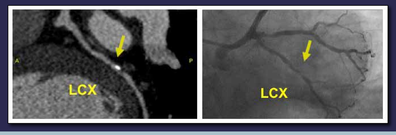
CAD RADS 0.
Example demonstrating normal left main, LAD, LCX and RCA without evidence of plaque or stenosis.



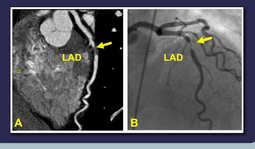
CAD RADS 1.
Example demonstrating minimal calcified plaque in the proximal LAD with minimal luminal narrowing (less than 25% diameter stenosis). The left main, RCA, and LCX coronary arteries were unremarkable.

CAD RADS 2.
Figure on the left: Coronary CT angiography demonstrating predominantly calcified plaque in the proximal LAD with 25-49% diameter stenosis. Figure on the right: Invasive coronary angiography confirming 25-49% stenosis. The left main and RCA coronary arteries were unremarkable (not shown).

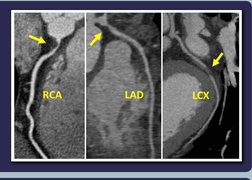
CAD RADS 3.
Example demonstrating predominantly calcified plaque in the mid LCX with 50-69% diameter stenosis. The left main, RCA and LAD demonstrated minimal disease (not shown). Left image – Coronary CT angiography. Right image – Invasive coronary angiography.



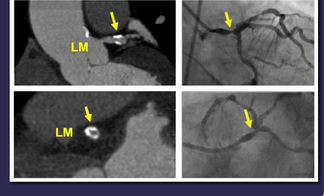
CAD RADS 4A.
Figure A – Coronary CT angiography demonstrating focal non-calcified plaque in the mid LAD (yellow arrow) with 70-99% diameter stenosis. Figure B – Invasive coronary angiography confirming 70-99% stenosis in the mid LAD (yellow arrow). The left main coronary artery and RCA (not shown) were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



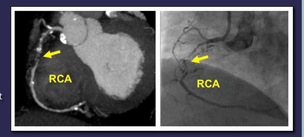
CAD RADS 4B.
Example demonstrating 3 vessel obstructive disease, including proximal RCA plaque resulting in 70-99% stenosis (left), ostial LAD plaque resulting in 70-99% stenosis (middle) and mid LCX plaque resulting in 70-99% stenosis (right).



CAD RADS 4B.
Figure on the left - Coronary CT angiography demonstrating distal left main stenosis with circumferential calcified plaque resulting in > 50% stenosis (arrows). 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).



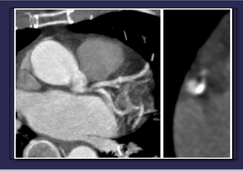
CAD RADS 5.
Left image: Coronary CT angiography demonstrating short total occlusion (100% diameter stenosis) in the proximal RCA (arrow). The obstruction spans a length of 12 mm. There is contrast opacification of the distal RCA and presence of collateral vessels, supporting chronic total occlusion. Right image: Invasive coronary angiography confirming the total occlusion (100%) in the proximal RCA with bridging collaterals supplying the distal RCA.



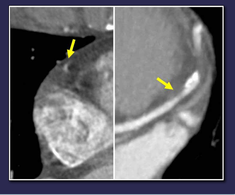
Non-Diagnostic Segments – CAD-RADS N should be used if the study is non-diagnostic or includes coronary segments that are non-evaluable. Additional or alternative evaluation may be required and since a significant stenosis cannot be excluded.

- This information should be included in the report.
- 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 (this 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 (0%), 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 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.



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.



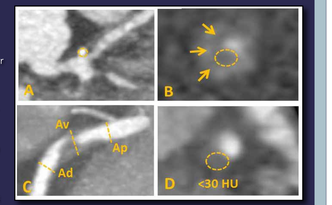
CAD-RADS MODIFIERS
If more than one modifier is present, the symbol "/" (slash) should follow each modifier in the following order:
i. First: modifier S (stent)
ii. Second: modifier G (graft)
iii. Third: modifier V (vulnerability)

Vulnerable Plaque (V):
If a coronary plaque demonstrates two or more high-risk (vulnerable) features by coronary CTA, the modifier "V" (vulnerability) in CAD-RADS should be used. High-risk features include: low attenuation plaque (less than 30 Hounsfield Units), positive remodeling, spotty calcification, and the napkin ring sign.3

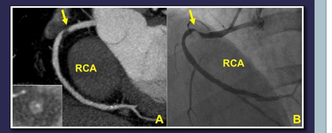
Coronary Stent (S):
Indicates presence of coronary stent. The addition of the letter "S" after CAD RADS will indicate that the patient has at least one coronary stent. For example, if a patient has a patent stent in the proximal left anterior descending coronary artery (LAD) with no significant in-stent restenosis or occlusion and demonstrates mild non-obstructive disease (25-49%) in the left circumflex artery (LCX) and right coronary artery (RCA), then the case would be classified as: CAD-RADS 2/S.

Bypass Graft (G):
Indicates presence of a coronary-artery by-pass 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. The bypassed coronary artery segments are not evaluated for purposed of CAD-RADS designation.

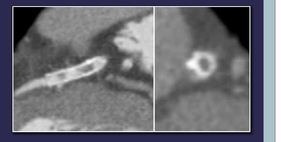
Vulnerable plaque. (V)
These include a) **spotty calcium**, defined as punctate calcium within a plaque measuring less than 3 mm in all dimensions; b) **napkin ring sign**, defined as central low attenuation plaque with a peripheral rim of higher CT attenuation (arrows); c) **positive remodeling**, defined 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.



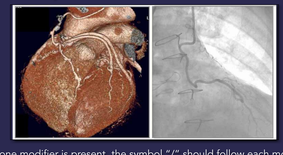
Example: CAD RADS 4A/V.
Example demonstrating focal non-calcified plaque in the proximal RCA with 70-99% diameter stenosis. The plaque demonstrates three high-risk features, including positive remodeling, central low attenuation (<30 HU) and napkin ring sign, thus coding with the modifier "V". The patient 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).



Example: 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."

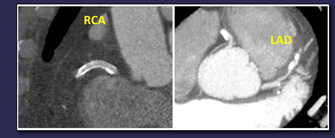


MODIFIER G.
Example demonstrating normal coronary bypass grafts. Left image – Coronary CT Angiography demonstrating patent left internal mammary artery to the LAD and patent saphenous vein grafts to the ramus intermedius branch and second obtuse marginal branch. There were no stenosis throughout the grafts (0%). Right image – Invasive coronary angiography demonstrating patent LIMA to the LAD. The grafts and the native coronary artery segments distal to and including the anastomosis should be evaluated for CAD-RADS coding.



NOTE: If more than one modifier is present, the symbol "/" should follow each modifier in the following order:
i. First: S (stent)
ii. Second: G (graft)
iii. Third: V (vulnerability)

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.



CONCLUSIONS

- The main goal of CAD-RADS is to create a standardized reporting language for coronary CTA, and to improve communication of results to referring physicians, including a final assessment and specific management recommendation.
- CAD-RADS will provide the framework for standardized education, research, peer-review, quality assurance, ultimately resulting in improved 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: [ ]

REFERENCES

1. Cury RC, Abbara S, Achenbach S, et al. CAD-RADS(TM) 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 Imaging (NASCI). Endorsed by the American College of Cardiology. Journal of cardiovascular computed tomography 2016;10:269-81.
2. Fihn SD, Gardin JM, Abrams J, et al. 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the diagnosis and management of patients with stable ischemic heart disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. Journal of the American College of Cardiology 2012;60:e44-e164.
3. Maurovich-Horvat P, Ferencik M, Voros S, Merkely B, Hoffmann U. Comprehensive plaque assessment by coronary CT angiography. Nature reviews Cardiology 2014;11:390-402.

DISCLAIMER