UNITED IMAGING

RSNA 2022 Edition

Issue Highlights

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Coronary CT angiogram – An evolving valuable diagnostic tool

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1. Introduction

Ischemic cardiovascular disease has evolved to become the leading cause of morbidity. Despite effective treatments like statins and other preventive efforts, it has led to the loss of useful life years and global mortality. Cardiovascular disease is no longer confined to the developed world; it is also a problem for developing nations. Despite receiving the best possible care from modern interventional and pharmacologic therapies, 10% of acute coronary syndrome patients experience recurrent episodes during the first year (1).

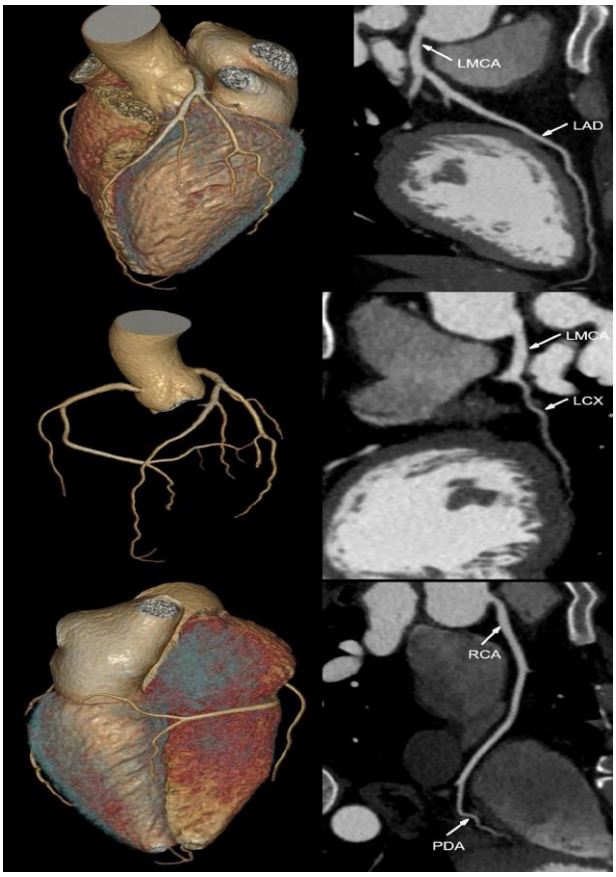

Figure 1. Curved and 3D reconstructions in a 32-year-old man who is a smoker with dyslipidaemia and comes with acute onset chest pain and a normal ECG, reveals a normal coronary arterial tree ruling out an acute coronary event. Scanning was performed on a uCT® 780 (United Imaging Healthcare, Shanghai, China) 160 slice CT scanner.

The CT Coronary Angiogram (CTCA) is the most advanced diagnostic armamentarium of tests for detecting and monitoring coronary artery disease. Patients with stable and unstable anginal symptoms benefit greatly from CTCA, which has a 99% sensitivity and 97% negative predictive value (2) for severe coronary artery disease (CAD) detection, shown in Figure 1.

The National Institute for Health and Care Excellence (NICE) provides independent evidence-based guidance for England's National Health Service. Its 2016 updated guideline for the assessment and diagnosis of recent onset chest pain or discomfort of suspected cardiac origin recommends CCTA as the first-line investigation for all patients with angina (or non-anginal pain but an abnormal electrocardiogram) and no prior CAD, with second-line functional imaging if the CCTA is equivocal (3) as shown in the Figure 2.

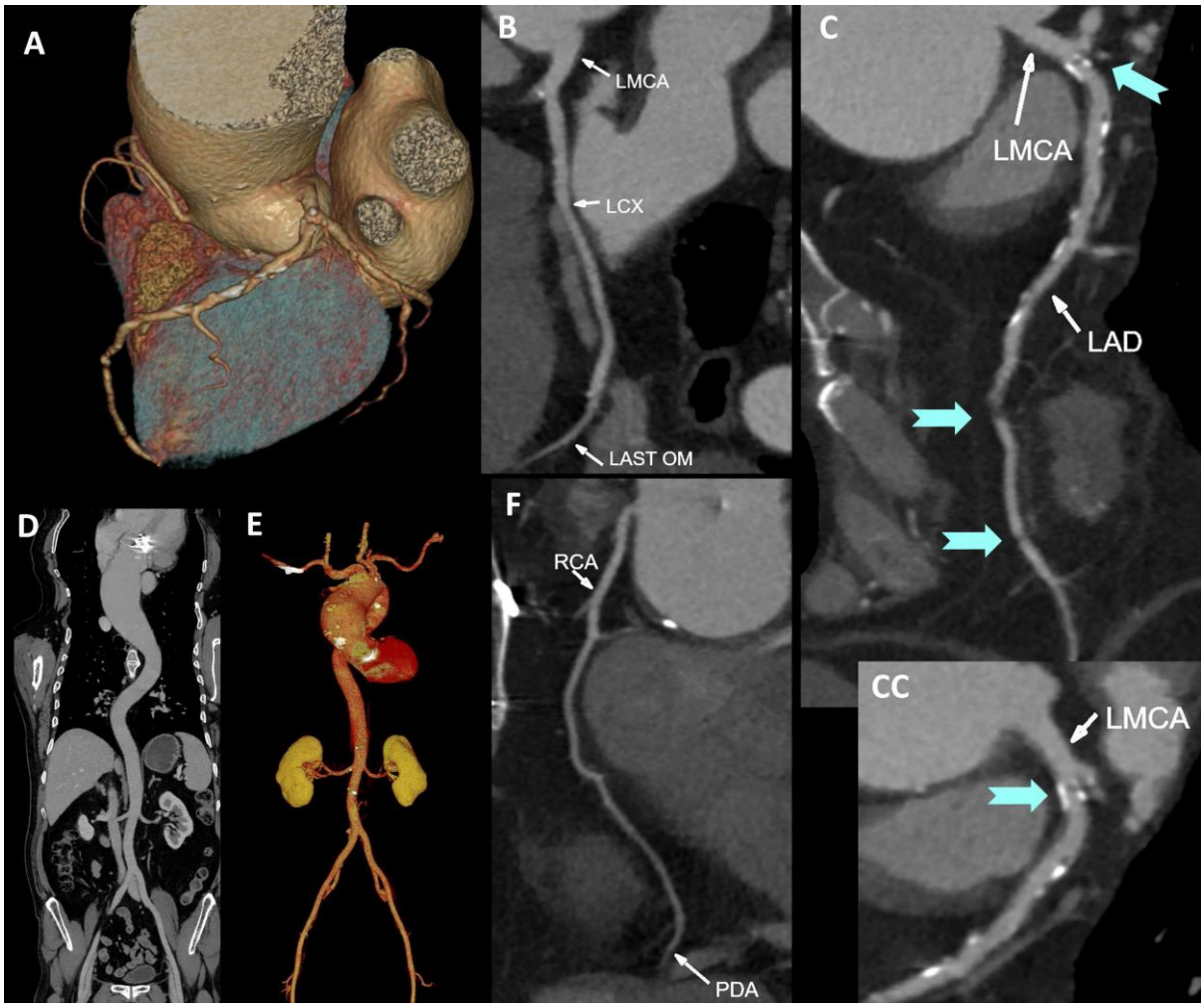

Figure 2. A 63-year-old man with an aortic valve replacement done 10 years ago and no prior coronary artery disease comes with recent onset chest pain. The Echocardiogram showed a normal left ventricular function but a dilated ascending aorta. The ECG showed no new changes. CTCA reveals no stenosis in the left circumflex (LCx) artery and right coronary artery (RCA) (panels B and F). However, left anterior descending (LAD) shows a 90% ostial as well as two short more than 90% stenosis in the distal segments marked by arrows (panels C and CC). The venous phase run through the chest and abdomen after the CTCA with no additional intravenous contrast shows a dilated ascending aorta with no dissection, dilatation or stenosis in the rest of the aorta (Panels D and E). The patient was scanned on a uCT 780 (United Imaging Healthcare, Shanghai, China) 160 slice cardiac CT scanner.

The SCOT-Heart Investigators trial was an open-label, multicenter, parallel-group trial that followed 4146 patients with stable chest pain for 3 to 7 years. The study showed that adding CCTA to standard care in patients with stable chest pain resulted in a significantly reduced rate of CAD or nonfatal MI at five years than standard care alone, without increasing the rate of coronary angiography or coronary revascularization (4) (Figure 3).

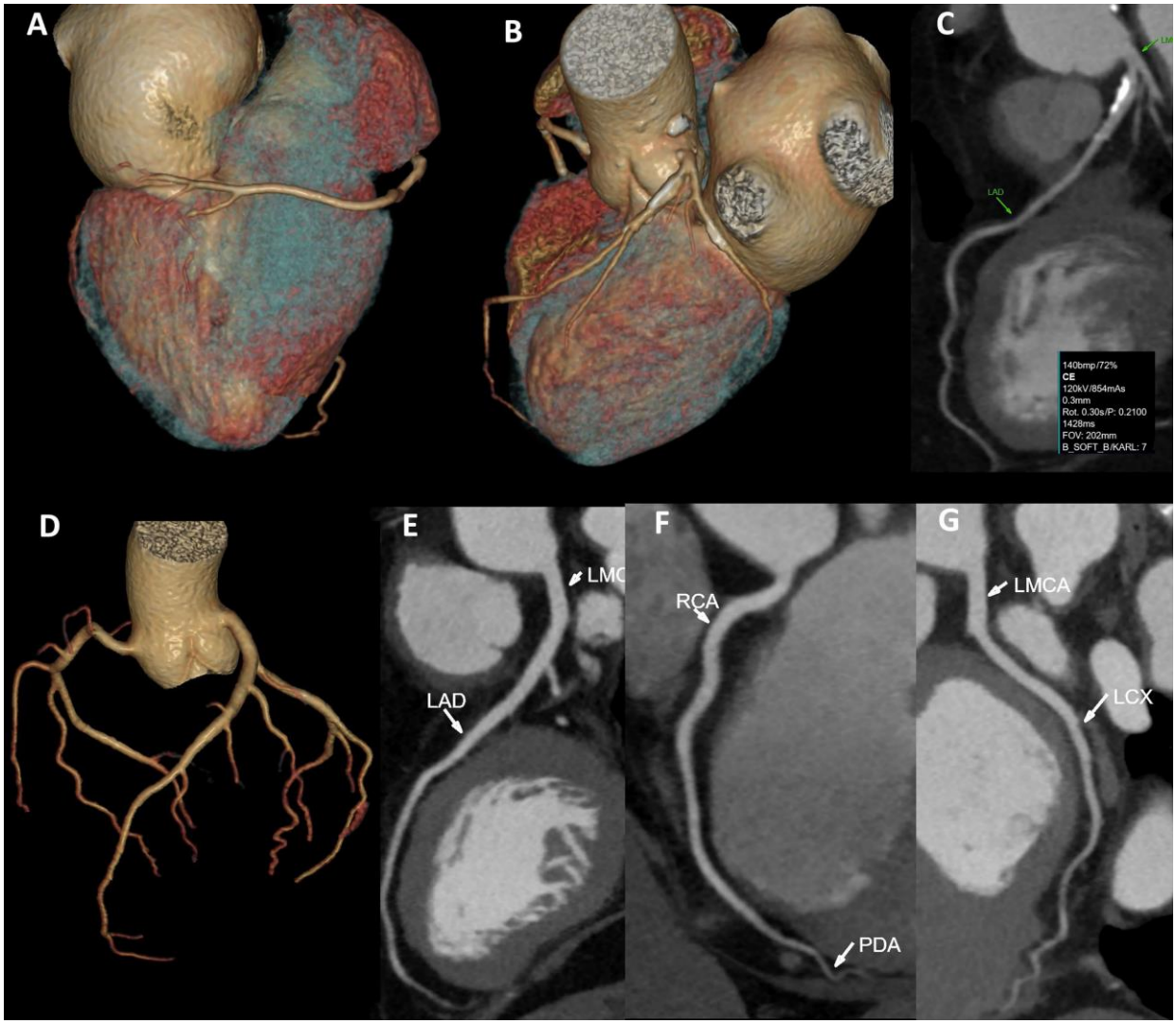

Figure 3. Panels A, B and C show CTCA in a 40-year-old lady with palpitations and chest pain. She was scanned on a uCT 780 (United Imaging Healthcare, Shanghai, China) 160 slice cardiac CT scanner. ECG and Echocardiogram were normal. Despite a high heart rate of 140 beats/minute, the image quality we obtain was excellent. A mild to moderate stenosis was seen by calcified plaques in proximal LAD and LCx. She was managed medically. Panels D, E, F and G show a normal CTCA in a 49-year-old woman without any risk factors for coronary artery disease but with recurrent chest pain and an abnormal ECG with a borderline positive treadmill test. Chest pain from cardiac cause was ruled out.

2. Recent improvements in CTCA hardware and software

The clinical value of CTCA has continued to increase because of considerable developments in CT technology, software, and machine learning in recent years. Increasing gantry rotational rates enables imaging that was not achievable with older machine models. Iterative reconstruction techniques with improved temporal resolution for patients with high heart rate have been utilized to drastically lower the radiation dose to the patient without affecting the image quality. High, near-isotropic spatial resolution is also required for coronary artery imaging. The accuracy of CTCA is improved by using the advanced detector features a thin 0.5 mm element size that can fundamentally improve the spatial resolution. And the detector has a coverage of 4–16 cm in z direction which enables simultaneously acquiring imaging data of the entire heart in a single breath-hold. Such developments are underway and will undoubtedly increase the use of CTCA. (5) (Figure 4)

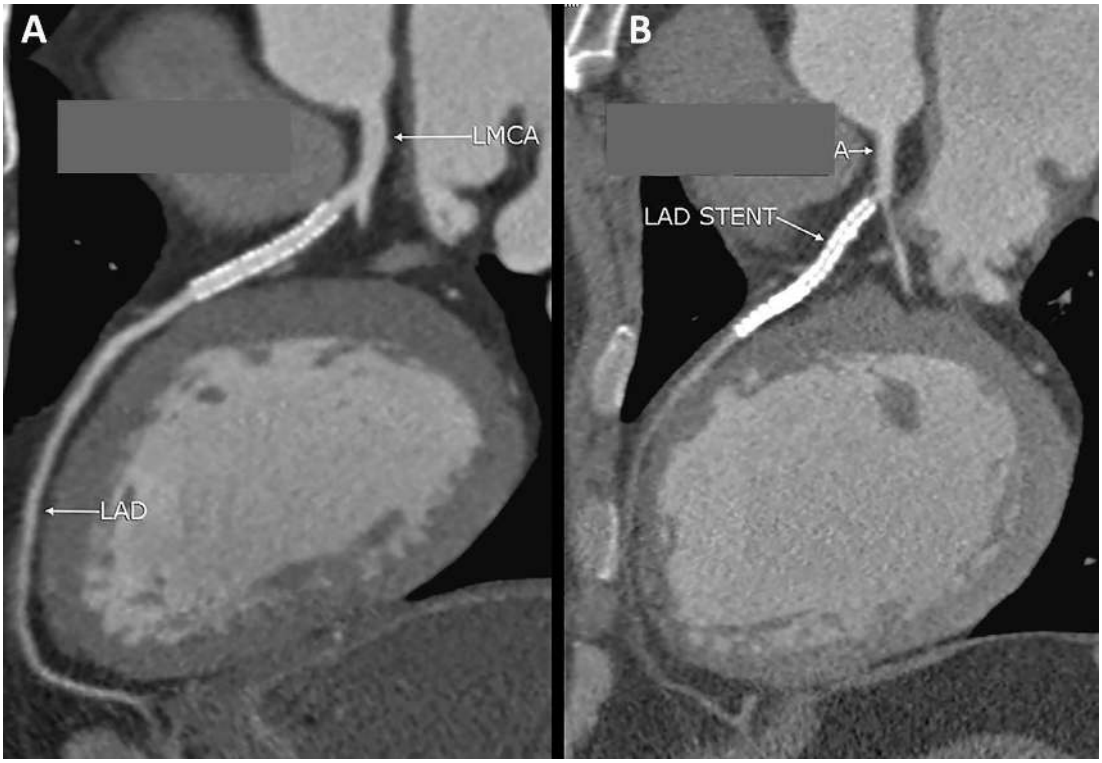

Figure 4. The LAD stent imaged in a higher version machine, the uCT 780 (United Imaging Healthcare, Shanghai, China) 160 slice cardiac CT scanner. Panel A shows remarkable clarity of the in-stent lumen as compared to the lower version machine study performed a few years earlier shown in Panel B.

3. The usefulness of coronary artery calcium scoring (CACS)

CACS is widely accessible, less complicated to operate (e.g., not depending on heart rate), does not need contrast, is less costly, and provides highly reproducible results. Although this test has been available for the past 20 years, there has recently been increased interest in its possible use of CACS in patients with low-risk symptomatic and the clinical importance of non-calcified plaque and stenosis in the absence of calcium. It has been shown that only 1 to 2% of symptomatic patients with CACS zero have potentially obstructive CAD, and only 0.4% of these patients have >70% stenosis. None of these patients will need coronary revascularization or have a bad prognosis within two years. (6) Patients with low and intermediate risk of CAD who appear with chest discomfort and have a normal Electrocardiogram, normal cardiac biomarkers, and a CACS of zero may be considered for early discharge without further screening in the emergency department (7).

CACS has been shown to continue improving discrimination and risk revaluation for major CAD and CVD in community-dwelling people who do not exhibit symptoms, even when Framingham risk factors are considered. It correctly reclassified two-thirds of the people in the Framingham Heart Study who were in the intermediate-risk group. Of those, 77% were moved down to low risk, and 23% were moved up to high risk (8). The ability to identify asymptomatic occult CAD in community residents who appear to be at low risk based on the Framingham risk scoring and to prevent CAD progression and incidents is a crucial addition of CACS.

4. CTCA value in the emergency room (ER)

Patients with low to intermediate-risk chest discomfort have found CTCA to be helpful in the ER. Those individuals without visible plaque can be discharged from the hospital immediately and securely. After a negative 6-hour troponin level, patients with non-obstructive plaque and mild to moderate stenosis can be discharged, whereas patients who have severe stenosis must be hospitalized to the hospital for further care (Figure 5). It has been determined that there are no fatalities or incidences of acute coronary syndrome

during the follow-up period. It has been demonstrated that patients without a CTCA have a greater rate of chest pain-related rehospitalization. The average stay period is similarly shorter for patients having a CTCA (9).

5. CTCA usefulness for percutaneous coronary interventions (PCI)

More than 2cm long, over severely angulated segments, heavily calcified, across ostia or bifurcations, with uneven surfaces and adherent thrombi, past tortuous segments, or completely blocked coronary artery lesions are considered complicated and have limited effectiveness following stenting (10). Therefore, it is essential to recognize these lesions. Brett M. Wertman et al. (11) revealed that CTCA was able to recognize Type C complex lesions well, which was related with increased contrast use and procedure duration during PCI. (Figure 6)

CTCA can differentiate angiographic TIMI grade 3 (normal) flow from TIMI grade 2 (sluggish) flow in patients with acute MI by comparing the contrast density at the distal end of the thrombolyzed artery with that proximal to the stenotic lesion. For TIMI 3, the ratio of CTCA number distal to CTCA number proximal should be greater than 0.54. CTCA can be used to check on coronary reperfusion after thrombolysis without any invasive procedure.

6. Plaque composition on CTCA and risk prediction

Due to the high resolution of CTCA images, the atheroma's composition can be depicted in exquisite detail. (Figure 7) Instead of exclusively soft plaques, we discovered that mixed plaques with soft and calcific portions are substantially more likely to rupture (13). It is now established that plaque morphology influences primary prevention, predictors of ischemia, and prognosis. Plaque composition, namely calcified vs soft and/or mixed plaques, as well as the presence of soft or mixed plaques, have been proven to be the highest predictor of events as a likely measure of plaque vulnerability, regardless of lesion severity. (Figure 8) (14, 15). The complete coronary tree is visible, and the overall plaque load and extent of diseased segments are assessed.

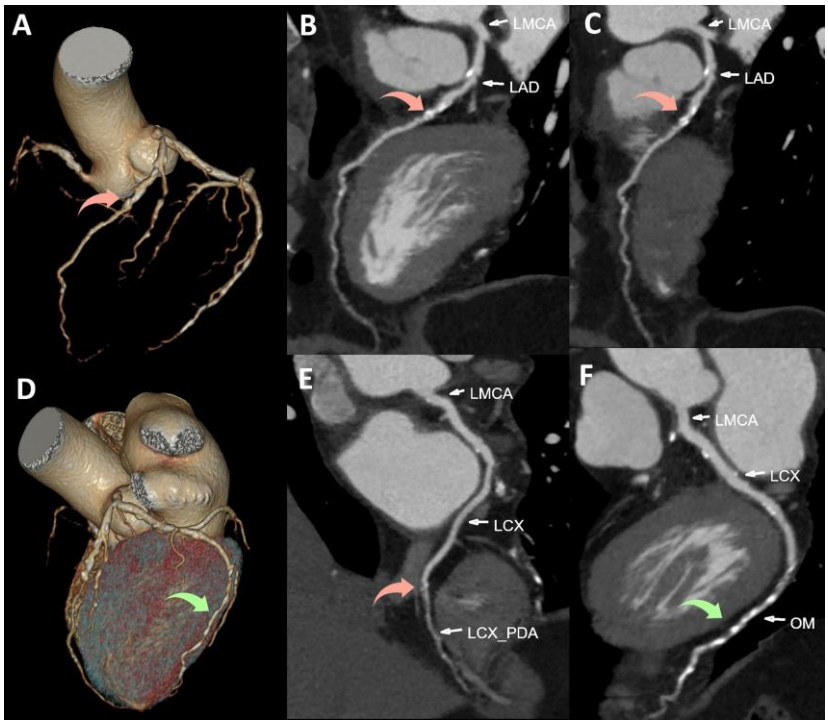

Figure 5. A 57-year-old man presented to the emergency room with chest discomfort. The ECG, echocardiogram and cardiac biomarkers were negative. However, CTCA revealed significant calcified plaque burden in the coronary arteries. Panels A, B and C show calcified mid LAD plaque causing more than 80% stenosis (pink arrow). Panels D and F show diffuse distal disease of the major OM branch (green arrow). Panel E shows a significant stenosis at the LCx- (posterior descending artery) PDA ostium (pink arrow). The patient was treated with a three vessel CABG with grafts to LAD, Diagonal and the LCx – PDA.

7. Plaque regression assessment by CTCA

The detection of early CAD on CTCA would be useless if it could not be resolved with medication. Several multicenter, randomized lipid-lowering trials utilizing both invasive catheter angiography (ICA) and clinical assessment, on the other hand, found a minimal change (1 to 3%) in luminal diameter on ICA. Nonetheless, these same studies found a 25% to 75% reduction in severe occurrences, such as myocardial infarction (16,17).

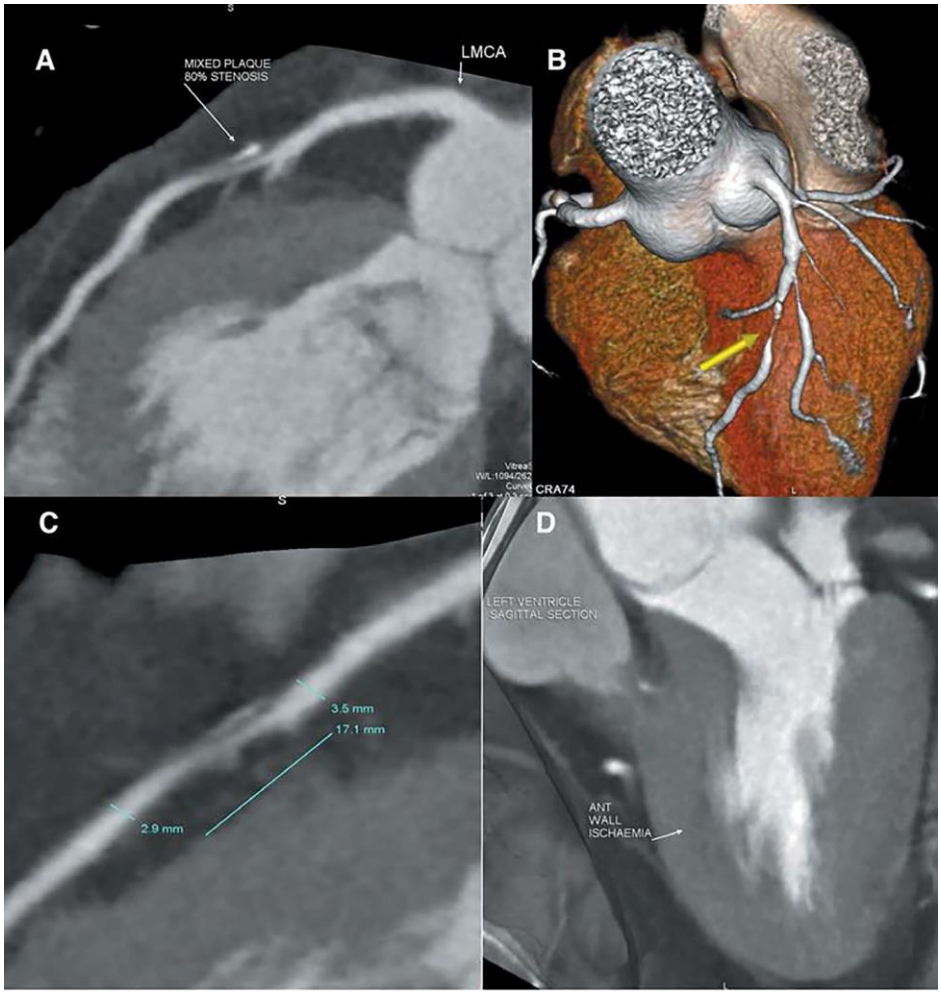

Figure 6. Panel A shows a curved reconstruction with a mixed plaque in the mid LAD. The 3D image gives the relation of the stenotic segment to side branches as well as the curvature of the artery in panel B. The lesion length and vessel diameter can be measured in Panel C. Panel D shows the myocardium in the 2 chamber long axis view revealing a dark area in the sub-endocardium of the anterior wall representing a perfusion defect at rest. Patient was scanned on a uCT 780 (United Imaging Healthcare, Shanghai, China) 160 slice cardiac CT scanner.

This shows that the benefits of lowering lipids come from stabilizing lipid-rich plaques, not from changes in the size of the ICA lumen. CTCA is able to accurately measure the diminution in plaque size. Even at modest doses, the administration of statins may cause significant changes in the CTCA plaque shape, an absolute reduction in plaque volume without a discernible change in lumen size, and variations in lipid profile that are not statistically meaningful. This shows that plaque morphological changes may emerge early on, even with only modest alterations to the lipid profile, as a result of statin therapy (18).

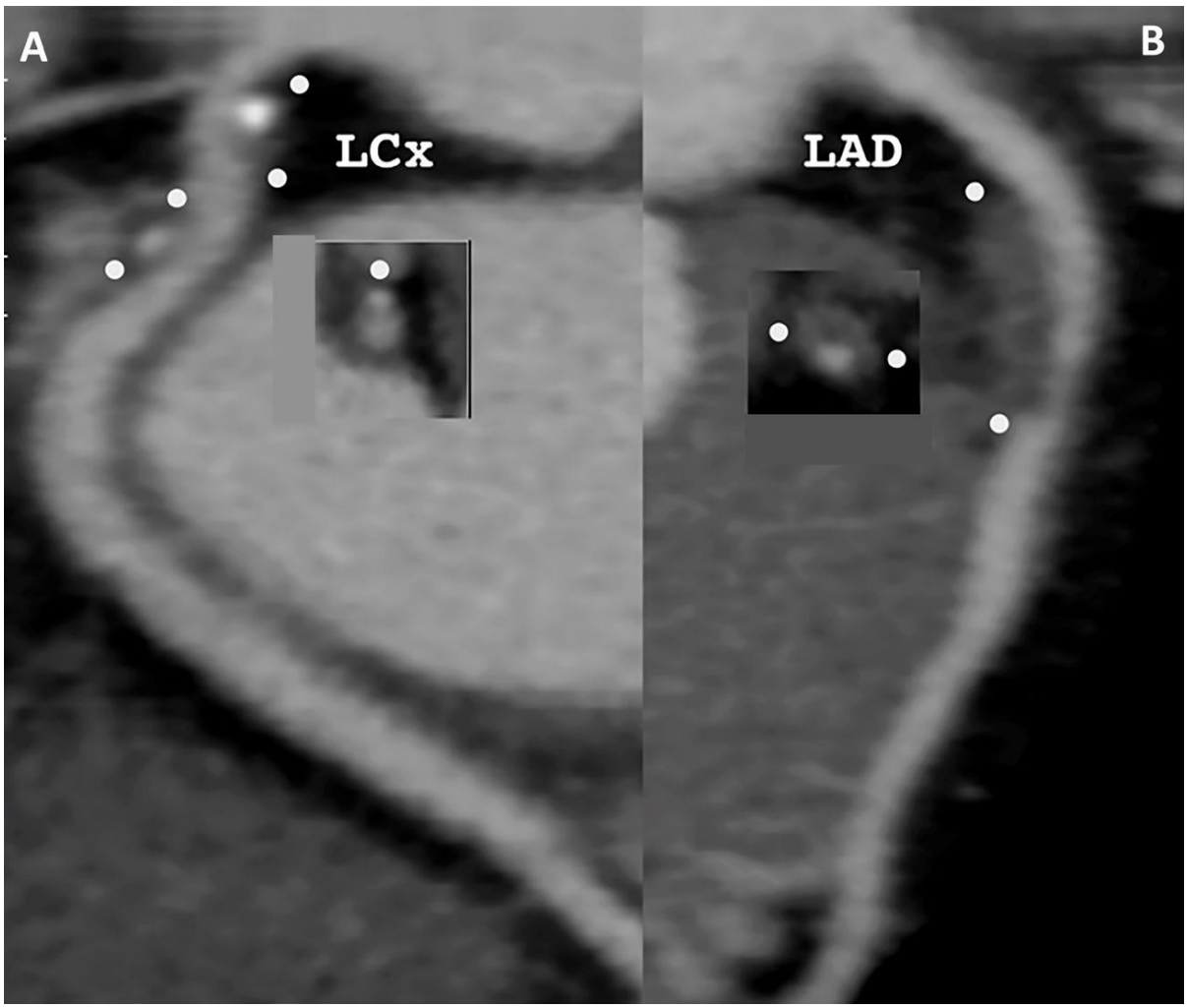

Figure 7. Panel A shows two eccentric mixed plaques marked by white dots in the proximal LCx artery with a soft component and a small, calcified nodule. Inset shows the cross section of one of the plaques. Panel B shows a thick eccentric soft plaque with no calcified component marked by white dots in the proximal LAD artery. Inset shows the plaque in cross section.

8. Stress myocardial CT perfusion (CTP)

CTP contains anatomic as well as physiological information (i.e., myocardial perfusion). The viability of stress myocardial CTP has been shown in multiple single-center studies. In addition, it has been demonstrated that a combination CCTA/CTP strategy increases the diagnostic accuracy for detecting hemodynamically severe stenosis compared to CTCA individually. Stress and reversible myocardial perfusion deficits detected by CTP utilizing a visual semi-quantitative technique and a visually guided software-based method are comparable to those assessed by SPECT (19,20).

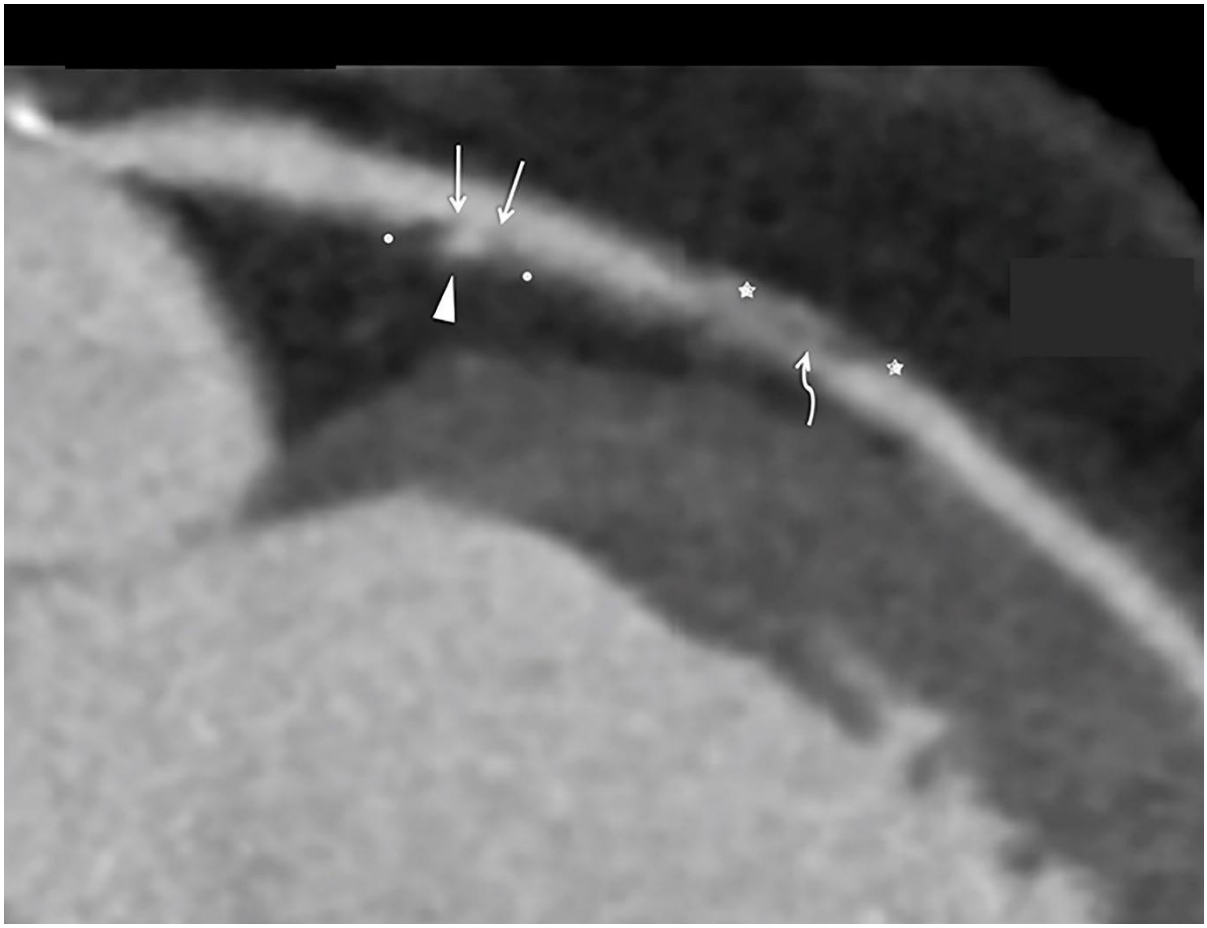

Figure 8. An eccentric ruptured plaque is seen along the inferior wall of the LAD marked by white dots. The straight arrows show the central ulceration on the plaque luminal surface. The arrowhead marks the cavity within the plaque filled with intraluminal contrast. Another plaque is seen marked by stars in the anterior wall of the LAD. This shows an ulceration along the inferior shoulder (curved arrow). Patient was scanned on a uCT 780 (United Imaging Healthcare, Shanghai, China) 160 slice cardiac CT scanner.

9. CT fractional flow reserve (CT-FFR)

CT- FFR predicts the functional relevance of coronary artery lesions using computational fluid dynamics. The strongest indicator of a positive CT-derived FFR, according to the Assessing Diagnostic Value of Non-invasive FFRCT in Coronary Care (ADVANCE) Registry, is stenosis greater than 70%. However, the ADVANCE Registry, like invasive FFR studies, demonstrates that there is a gap between morphological assessment of coronary stenosis and the physiological consequences of such lesions. 28.4% of severe lesions were found to have no functional significance. Similar to this, there is a positive CT- FFR rate of 20.8% in patients with non-obstructive coronary structure (stenosis grade 30-49%) (21).

10. Coronary Bypass Graft (CABG) imaging on CTCA

CTCA is quite reliable for determining graft patency after CABG. In a 3D picture, it shows every graft together. Studying the native arteries in relation to the failed grafts enables a therapeutic strategy to determine whether a PCI is warranted. In our study, we discovered that regardless of the number of years following CABG, 72% of all grafts, including LIMA, SVG, RIMA, and LRA, failed when placed on coronary arteries with less than 75% stenosis as opposed to 22.8% of grafts failing when positioned on coronary arteries with more than 75% stenosis ($p < 0.0001$) (Figure 9) (22).

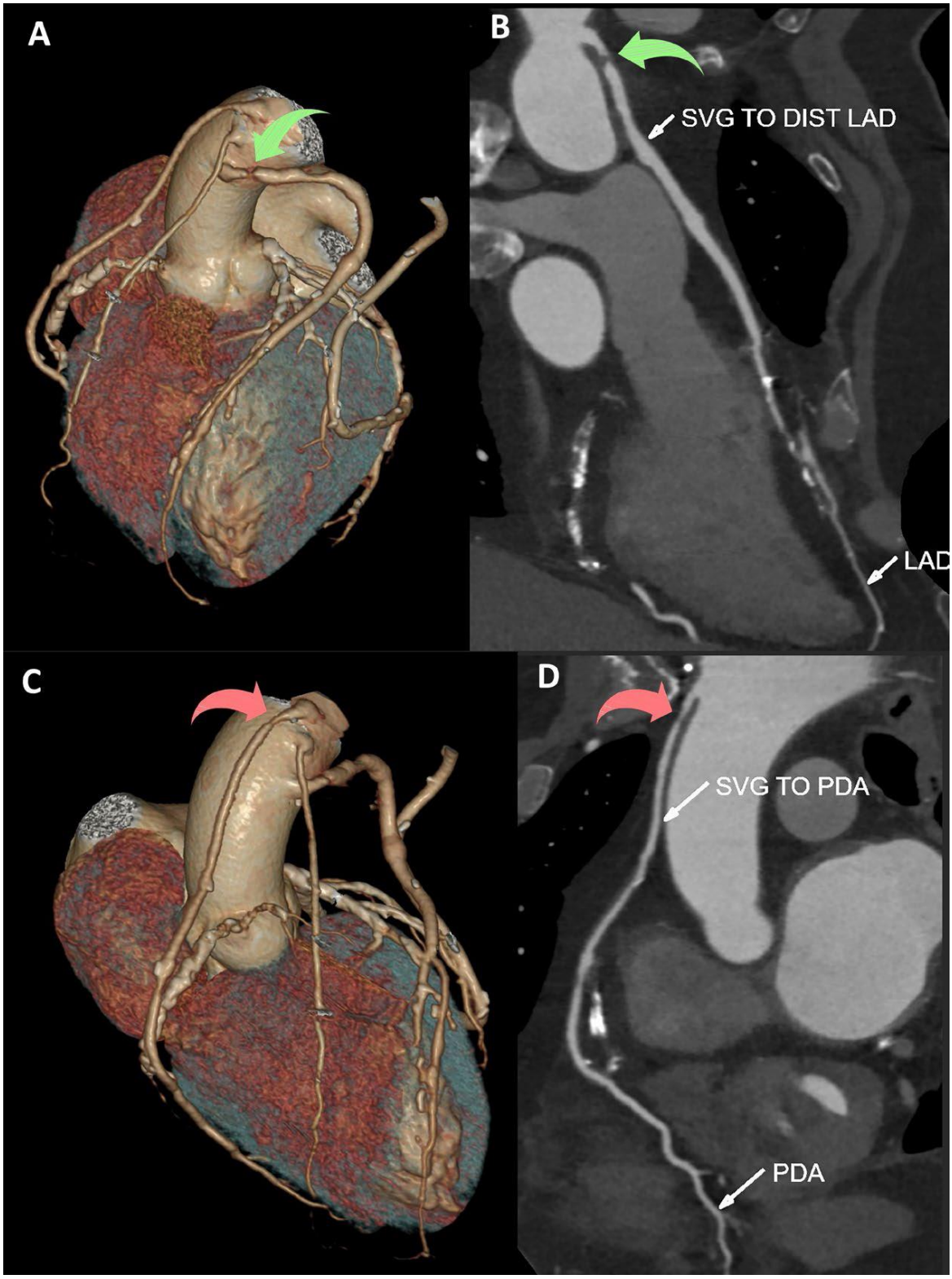

Figure 9. A 67-year-old man 6 years post CABG comes with recurrence of angina. Sequential LIMA to Diagonal and Obtuse marginal as well as saphenous vein grafts (SVG) to LAD, right ventricular branch and right PDA are patent. However, short critical stenosis is seen in the proximal segment of the SVG to LAD (green curved arrow) as well as the SVG to PDA (orange arrow). These were successfully stented. Patient was scanned on a uCT 780 (United Imaging Healthcare, Shanghai, China) 160 slice cardiac CT scanner.

11. Conclusion

In the modern era, CCTA has developed into an ideal test that can accurately and consistently image the true severity of coronary artery stenosis, a detailed representation of the atheroma causing this, the downstream impact on the myocardium, and functionality of the heart with minimum contrast dose and radiation in a short time with no patient discomfort.

CTCA demonstrates that the existence of soft and mixed plaques can result in higher major cardiovascular events score than a clinical risk model, regardless of the severity of the lesion. CTCA can be utilized in the emergency unit to check the coronary arteries and determine who needs to be hospitalized for an acute cardiac problem quickly and noninvasively. For patients who do not experience a cardiac incident, it is confidently concluded that a secure and early discharge is appropriate. By demonstrating a decrease in plaque volume, CTCA could be able to show a meaningful effect at lower statin doses.

It has been demonstrated that CACS improves risk categorization and discrimination for significant CAD and CVD irrespective of Framingham risk variables in asymptomatic community-dwelling individuals. CT-FFR, in conjunction with CTCA, could become the optimum test for assessing the functional relevance of a stenosis and guiding therapies.

12. Image/Figure Courtesy

All images are the courtesy of Advantage Imaging and Research Institute, Mylapore, Chennai, India.

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