MDCT, what is beyond the coronary anatomical assessment?

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Introduction

- Following its introduction in the late 1990s, during the subsequent decade multi-slice computed tomography (MSCT) has rapidly evolved as a modality allowing imaging of the heart.
- Indeed, MSCT coronary angiography may be performed to assess coronary artery stenosis in symptomatic patients with suspected coronary artery disease (CAD) Moreover, MSCT coronary angiography may potentially be useful in guiding coronary interventions and in evaluation of the results of treatment.
- The ability of MDCT to obtain a three-dimensional volumetric dataset of the entire heart and adjacent structures that can be reconstructed at any point in the cardiac cycle makes it a powerful tool for the assessment of cardiac structures.
- This presentation will focus on the evolving applications of MDCT in the assessment of non-coronary structures.

- A large observational study of 4,543 patients who underwent MDCT for assessment of suspected coronary artery disease, demonstrated that 4.4% of patients underwent MSCT for coronary evaluation had structural heart disease unrelated to atherosclerosis, with 25% of these patients having previously undiagnosed abnormalities and 30% of these patients requiring specific treatment.(Lesser JR, et al. Identification of unexpected nonatherosclerotic cardiovascular disease with coronary CT angiography. JACC Cardiovasc Imaging 2009;2(9):1085-92. DOI: 10.1016/j.jcmg.2009.03.022)

- A large number of non-coronary cardiac structures can be studied during a routine MDCT examination. These structures include the cardiac chambers, particularly the left-sided cardiac chambers, the cardiac valves, pulmonary arteries and veins, thoracic aorta and its proximal branches, cardiac veins and pericardium.
- Left ventricular (LV) and left atrial cavities as well as left-sided valves are uniformly opacified in a standard MDCT examination.

Left Ventricle: Evaluation of Perfusion defects and Scar

- An emerging clinical application of MDCT is the ability to evaluate LV myocardial perfusion and detect previous myocardial infarction.
- MDCT stress perfusion imaging is performed after infusion of intravenous adenosine to detect inducible myocardial ischemia, and delayed enhancement imaging is performed 10-15 minutes after the administration of intravenous contrast for further characterization of any myocardial perfusion defect identified at rest, including assessment of myocardial viability.

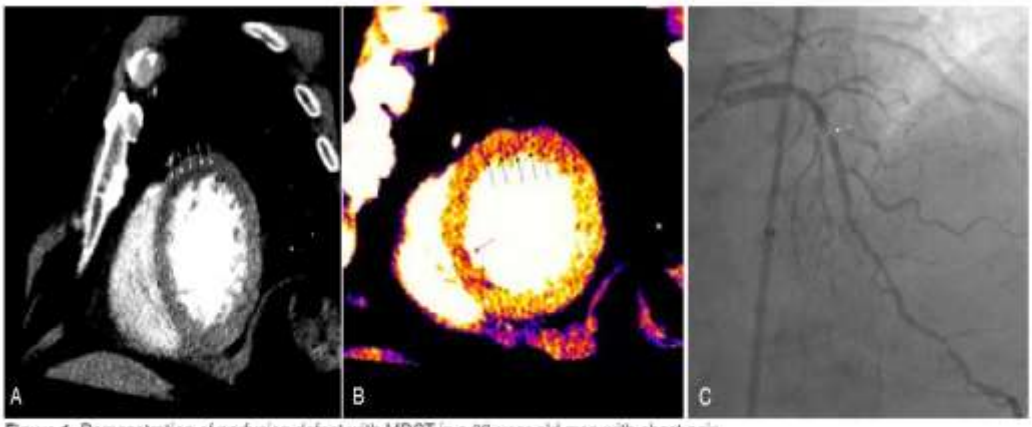


Figure 1. Demonstration of perfusion defect with MDCT in a 68-year-old man with chest pain.
(A) MDCT perfusion axial image illustrates perfusion defect in the mid anterior to mid anterolateral wall (arrows).
(B) Colour mapping also shows this perfusion defect (purple colour) in the mid anterior and anterolateral walls (black arrows) as well as additional perfusion defect in the mid inferoseptal wall (red arrow).
(C) Invasive coronary angiography left anterior oblique cranial view of the left anterior descending coronary artery, with severe stenosis in the mid vessel (arrow) accounting for the perfusion defects.

Right Ventricle (Evaluation of Volume and Function)

- The right ventricle (RV) has a complex trapezoidal shape, and is difficult to assess by current imaging techniques. It appears triangular on a four-chamber view and crescent-shaped on a short-axis view.
- RV to LV short-axis ratio is one measure used to assess RV volume. A ratio of >1 has been found to correlate well with RV dysfunction on echocardiography.
- Other qualitative signs of increased RV volume on MDCT are based on observation of the interventricular septum, similar to echocardiography. As RV volume increases, the interventricular septum may be seen to flatten or bow towards the LV during diastole.

- RV ejection fraction is measured by determining end diastolic and end-systolic RV volumes on contiguous short-axis images.
- Assessment of RV volume and ejection fraction by MDCT has been shown to correlate well with CMR .
- It is important to note that the evaluation of RV by MDCT can be limited by inadequate contrast opacification, resulting in problems with accurate delineation of RV contours.

Study	MDCT System	Patient Number	Reference Modality	Agreement
Raman et al. (11)	16-slice	26	CMR (1.5 Tesla)	κ statistic: 0.88 (range: 0.78 -1.0)
Plumhans et al. (12)	64-slice	38	CMR (1.5 Tesla)	r: 0.99(EDV) r: 0.98 (ESV) r: 0.98 (SV)
Sugeng et al. (13)	16-slice	28	CMR (1.5 Tesla)	r: 0.85(EDV) r: 0.87 (ESV)
Maffei et al. (14)	64-slice	79	CMR (1.5 Tesla)	r: 0.58 (EDV) r: 0.70 (ESV)

Pericardium

- The pericardium is best seen in systole and appears as a bright, linear line with a mean thickness of 1.3-2.5 mm (usually <4 mm).
- MDCT provides excellent delineation of pericardial anatomy and pathology, including the presence of any pericardial effusion, thickening or calcification. It also quantifies pericardial fat volume, a marker of cardiovascular disease and may identify extra-cardiac lesions related to pericardial pathology.
- MDCT attenuation values may aid characterization of the underlying cause of pericardial fluid, with Hounsfield Unit values close to water (0-25 Hounsfield Units) suggesting simple transudates, whereas Hounsfield Unit values >25 suggest an exudate due to malignancy, hemopericardium or purulent exudates

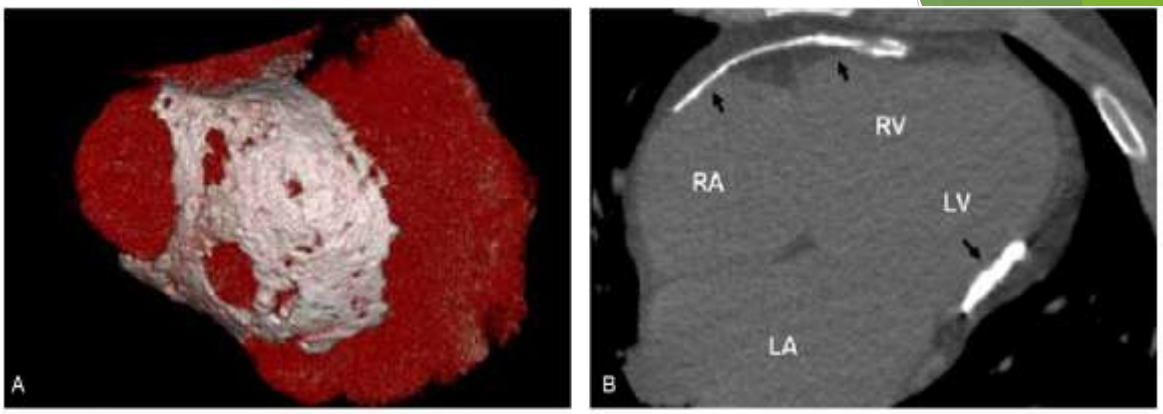
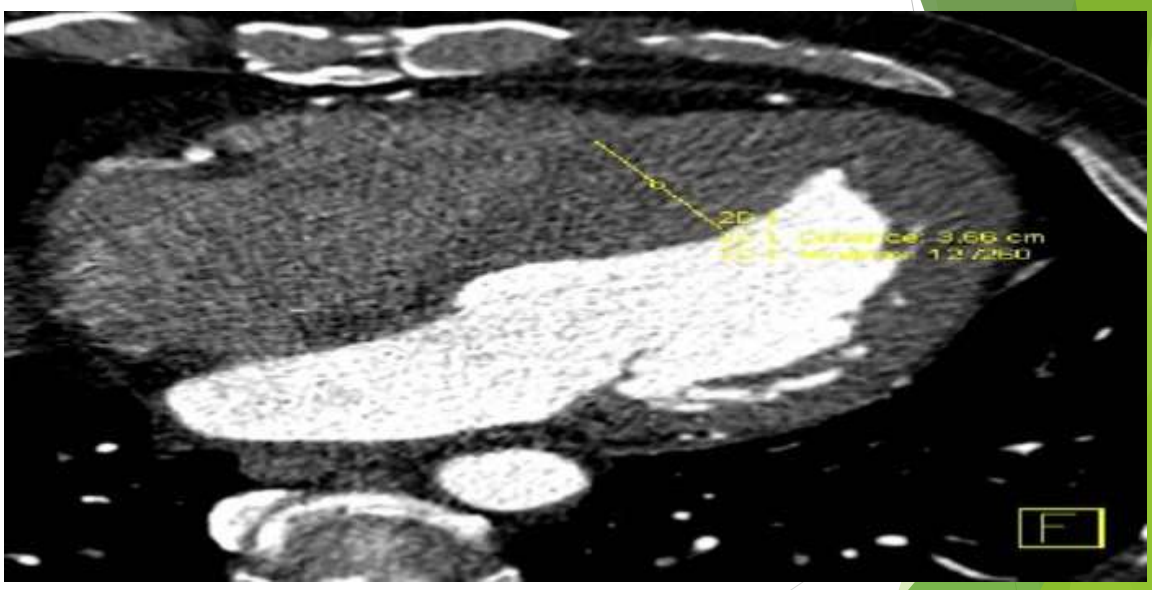


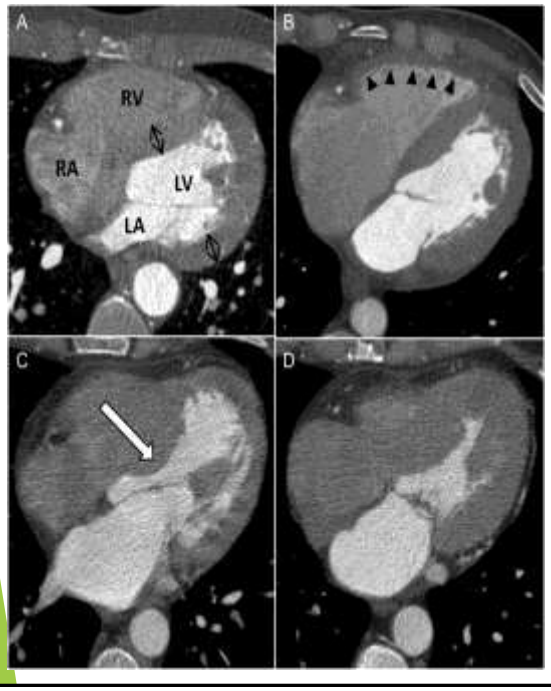
Figure 3.. Extensive pericardial calcification on MDCT in a 41-year-old dyspnoeic man with constrictive physiology on echocardiography.
(A) Three-dimensional volume-rendered image showing extensive circumferential "egg-shell" calcification, with sparing of the left ventricular apex.
(B) Non-contrast multiplanar reformatted four-chamber view demonstrating pericardial calcification (arrows) adjacent to the right atrium, right ventricle and left ventricle with sparing of the apex. LV = left ventricle, RV = right ventricle, LA = left atrium, RA = right atrium.

Cardiomyopathy evaluation

- Echocardiography and CMR are the primary imaging modalities in the assessment of cardiomyopathy.
- MDCT can play a role when echocardiographic images are not diagnostic, or the presence of pacing device and leads present a contraindication to CMR.
- MDCT can provide morphological assessment of the RV, including RV volumes, and the presence of fatty infiltration of the RV and aneurysmal outpouching, to guide the assessment for arrhythmogenic right ventricular cardiomyopathy.

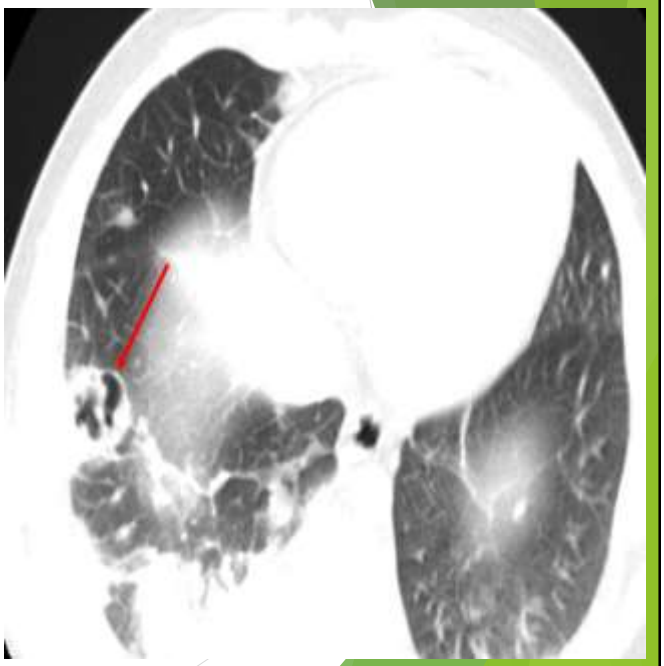
- MDCT can identify changes associated with hypertrophic cardiomyopathy, including the LV wall thickness, and the presence of any aneurysm and the presence of unusual form of HCM (apical type).
- CT coronary angiography may demonstrate the presence of prominent septal perforators that supply the hypertrophied interventricular septum.
- This information could assist in planning for percutaneous transluminal septal myocardial ablation.





Endocarditis evaluation

- While TEE is considered the gold standard imaging method for diagnosis of endocarditis, MDCT can also be used for this purpose with high accuracy.
- In patients with clinically suspected infective endocarditis, MDCT had excellent diagnostic performance in evaluating the presence of vegetations, abscesses and pseudoaneurysms compared to TEE and operative findings.
- MDCT also provides very accurate three-dimensional anatomic information regarding perivalvular extent of abscess and pseudoaneurysms, such as myocardial, pericardial, and coronary sinus involvement, which is helpful in peri-operative surgical planning.
- Therefore, MDCT may be considered as an additional imaging tool in patients with clinically suspected endocarditis after an inconclusive TEE, such as when metallic artifacts hamper the visualization of prosthetic valves.



Intra-cardiac Mass Evaluation

- MDCT can accurately evaluate patients with suspected cardiac masses, particularly cardiac tumors and thrombi.
- While echocardiography is usually the primary imaging modality for assessment of suspected cardiac masses, MDCT is very useful in this setting when limited images are obtained from echocardiography, due to technical reasons.
- MDCT also has benefits over echocardiography including detecting additional lesions, more accurate tissue characterization (including Hounsfield unit attenuation measurements), assessment for the extent of invasion and the evaluation of adjacent structures for additional pathology

Thrombus evaluation

- Intra-cardiac thrombi are most commonly located in the LAA or in the LV apex, visualized as low attenuation contrast filling defects.

- While TEE remains the gold standard for LAA thrombus, MDCT has high sensitivity and negative predictive value for LAA thrombus detection compared to TEE, and is particularly relevant prior to pulmonary vein isolation procedures where MDCT is performed to evaluate pulmonary venous anatomy.

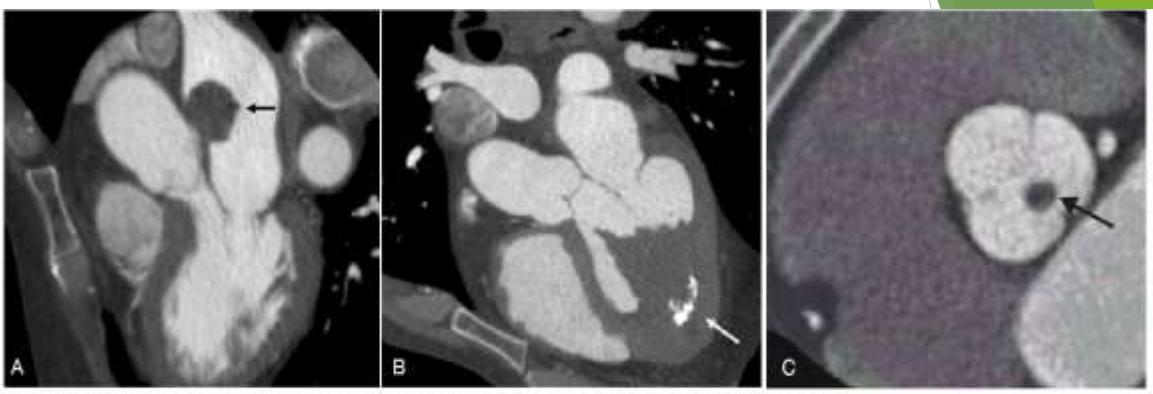


Figure 2. Contrast-enhanced MDCT images showing two common types of intra-cardiac masses.
(A) Four-chamber view showing large, non-enhancing calcified thrombus (arrow) attached to the left ventricular apex and protruding deep into the left ventricular cavity. The presence of calcifications suggests that it is chronic.
(B) Multiplanar reformatted apical three-chamber view demonstrating a well-defined low attenuation mass (arrow) attached to the anterosuperior wall of the left atrium, consistent with an atrial myxoma.
(C) Multiplanar reformatted short-axis view demonstrating a round low attenuation mass (arrow) attached to the commissure between the left and right coronary cusps of the aortic valve, consistent with a fibroelastoma.

Pre-Operative Planning for Re-operative Open Cardiac Surgery

- With the increasing frequency of re-operative open cardiac surgery being performed, MDCT is being increasingly utilized as part of a comprehensive pre-operative planning workup.
- This includes assessment of:
- the distance between the RV and aorta to the chest wall (with <1 cm proximity indicating high risk)
- the relationship of bypass grafts to the sternum, with a particularly high-risk feature being grafts crossing the midline < 1cm anteroposteriorly from the sternum.

- These findings may be associated with severe hemorrhage during resternotomy due to injury of the underlying bypass grafts, RV or aorta, and have been reported to occur in 2-6% of cases of resternotomy, with mortality of up to 37%.
- If high-risk features are identified on MDCT, surgical strategies can be employed to minimize the risk of complications, including non-midline incisions, deep hypothermic circulatory arrest, initiation of peripheral cardiopulmonary bypass and extrathoracic vascular exposure before incision.
- These techniques were recently demonstrated to be associated with a very low 30-day mortality of 2.5%.

Identification of Congenital Heart Disease

- While echocardiography and CMR are the most commonly used modalities in the diagnosis and follow-up of patients with congenital heart disease, MDCT has also been shown to accurately image patients with simple and complex forms of congenital heart disease.
- Advantages include its high spatial resolution that allows evaluation of cardiac chamber volumes and function, aortic arch, great vessels, pulmonary arteries and veins as well as conduits, baffles and surrounding extracardiac structures, such as the lungs, mediastinum, and chest wall.
- In particular, newer wide-detector systems have several advantages over CMR, such as the ability to obtain images in less than a second within a short breathhold without the need for general anaesthesia in children, including in patients with implanted devices.

- Disadvantages include exposure to ionising radiation and potentially nephrotoxic contrast remain important limitations of MDCT, particularly in young patients who require follow-up studies.
- Furthermore, contrast delivery needs to be optimally timed to adequately opacify the structures of interest.

Coronary Anomaly Evaluation

- Coronary anomalies may lead to angina, myocardial infarction or sudden death.
- In a large series of patients undergoing MDCT, coronary anomalies were the most commonly identified cause of nonatherosclerotic structural heart disease.
- In a separate series of young athletes, coronary anomalies were the second most common cause of sudden death due to structural heart disease.

- Due to the three-dimensional nature of the dataset, MDCT accurately detects and defines the anatomic course of coronary anomalies and their relationship to other cardiac and non-cardiac structures.
- Coronary artery anomalies are often classified as either hemodynamically significant or insignificant.
- Hemodynamically significant anomalies are characterized by abnormalities of myocardial perfusion, and include an anomalous origin of either the left main or right coronary artery from the pulmonary artery, an interarterial anomalous course between the pulmonary artery and the aorta of either the right coronary artery arising from the left sinus of Valsalva or the left main arising from the right sinus of Valsalva, and congenital coronary artery fistulae.

- An anomalous origin of a coronary artery from the opposite sinus with an interarterial course is the predominant coronary artery anomaly associated with sudden cardiac death in young athletes with an anomalous left main arising from the right coronary sinus being most common.
- This may require major prophylactic surgery to prevent sudden cardiac death in symptomatic patients or young individuals taking part in regular strenuous exercise.

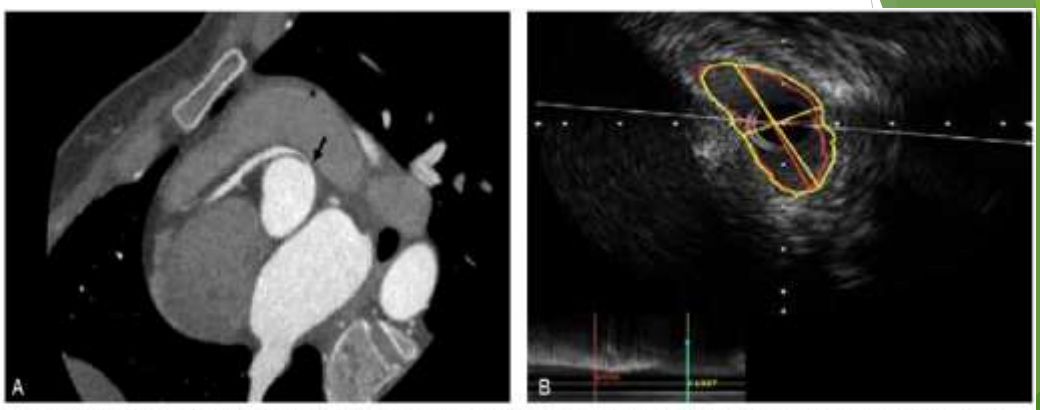
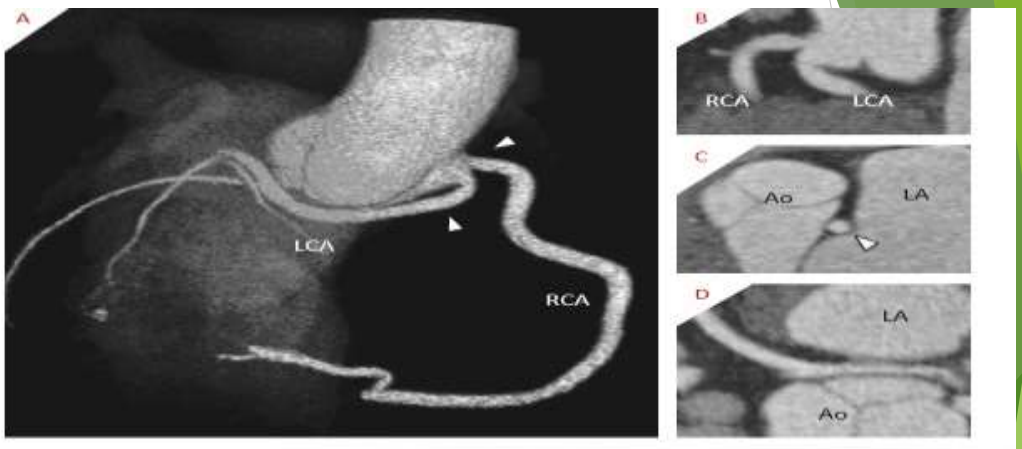


Figure 4. Coronary artery anomaly on contrast-enhanced MDCT with significant narrowing confirmed on intravascular ultrasound (IVUS) in a 40-year-old lady with exertional angina. (
A) Curved multiplanar reconstruction showing right coronary artery (RCA) arising from the left coronary cusp which runs between the aorta and right ventricular outflow tract. Note the "slit-like" appearance of the ostial RCA (arrow), suggesting significant luminal stenosis.
(B) IVUS image (40 MHz Atlantis probe) of the ostial RCA, which confirmed a significant (58%) luminal stenosis.



igure 2. Left coronary artery, originating from the right coronary cusp with a retro-aortic course between aorta and left atrium). (A) A 3D volume rendered reconstruction shows the LCA originating rom the right coronary cusp and a retro-aortic course (arrowheads) towards the left side of the heart. B) a maximum intensity projection image demonstrates the origin of the LCA from the right coronary usp. (C & D) show the course of the LCA between the left atrium and aorta. This particular anomalous coronary artery is considered to be benign.
Ao: Aorta; LA: Left atrium; LCA: Left coronary artery; RCA: Right coronary artery.

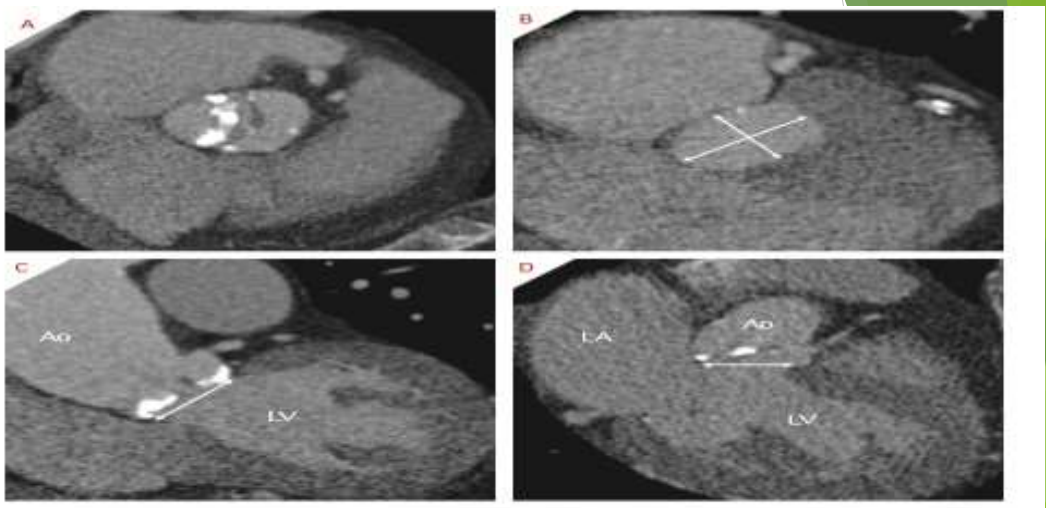
Evaluation of the aortic valve in transcatheter valve replacement

- Transcatheter aortic valve implantation (TAVI) is a novel method to treat symptomatic severe aortic stenosis.
- Accordingly, before the aortic valve implantation, extensive planning of the procedure is mandatory in order to increase the chance of success.
- The assessment of the aortic valve, aorta, and the peripheral vessels is usually performed using two-dimensional transthoracic and trans-oesophageal echocardiography, and angiography.
- Accurate measurement of the aortic annulus is one of the key steps in choosing a proper device. Indeed, undersized device may lead to suboptimal expansion and paravalvular regurgitation, whereas an oversized device may increase the risk of tissue rupture.

- Besides measurement of the aortic annulus, three-dimensional non-invasive imaging by MSCT allows for assessment of extent and location of aortic valve calcification as well as evaluation of the geometry of the aortic root and left ventricular outflow tract.

- Pre-procedural assessment of the aortic root in relation to the body axis with MSCT appears to be useful in prediction of the angle of implantation, this may decrease the need for repeated contrast injections during the TAVI procedure and increase the accuracy of correct valve positioning.

- Moreover, MSCT allows assessment of the peripheral arteries and thoracic aorta and may help identify patients with unfavourable anatomy, such as small lumen diameter, tortuosity, and extensive atherosclerosis.
- characterization of the aortic valve calcification, the assessment of the relationship between the coronary ostia and the aortic leaflets, the information necessary for the valve sizing and planned localization of the implant.



igure 4. Assessment of the aortic valve annulus by multi-slice computed tomography. Oblique ransverse view allows assessment of the degree of calcification of **(A)** the aortic valve (which in this ase is functionally bicuspid), and **(B)** the oval shaped annulus size. The size of the aortic valve annulus s measured in the **(C)** coronal and **(D)**sagittal views, providing an estimation of the eccentricity of the ortic valve annulus.
o: Aorta; LA: Left atrium; LV: Left ventricle.

Evaluation before catheter ablation of atrial fibrillation and device therapy.

- In patients with atrial fibrillation who remain symptomatic under optimal medical therapy, catheter ablation is an effective treatment method.
- MSCT may play a role in patient selection for catheter ablation procedure as well as in the evaluation of the procedural complications.
- MSCT may be used in the assessment of the left atrial size as well as the presence of thrombus as it is a reliable method to measure the left atrial volume.

- Three-dimensional MSCT is a reliable modality in imaging of the pulmonary veins before the catheter ablation of atrial fibrillation as it allows superior accuracy of pulmonary vein assessment as compared to echocardiography.
- In the majority of cases four pulmonary veins are present. Nevertheless, anatomical variants have been described in pulmonary vein anatomy.
- Localization of coronary sinus in CRT-D implantation.

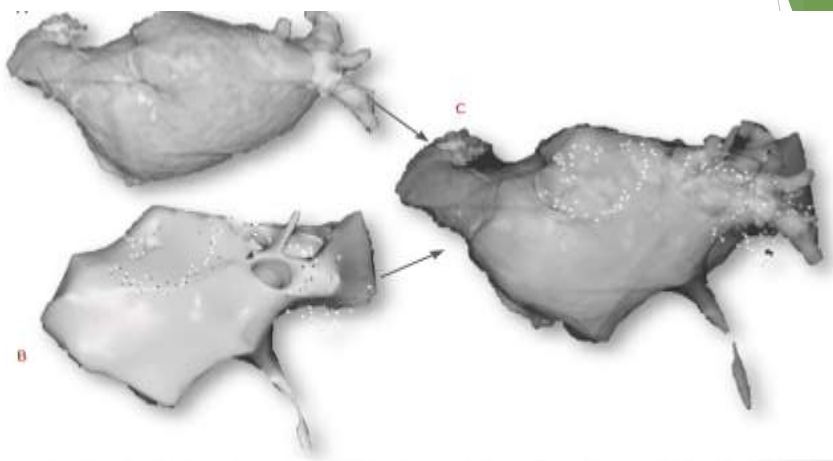


Figure 5. Posterior view of (A) multi-slice computed tomography reconstruction and (B) electro-anatomical mapping image of the left atrium. (C) Fusion of both images is helpful in anatomical orientation during ablation procedures. The white dotted points represent locations where electrical ablation was performed.

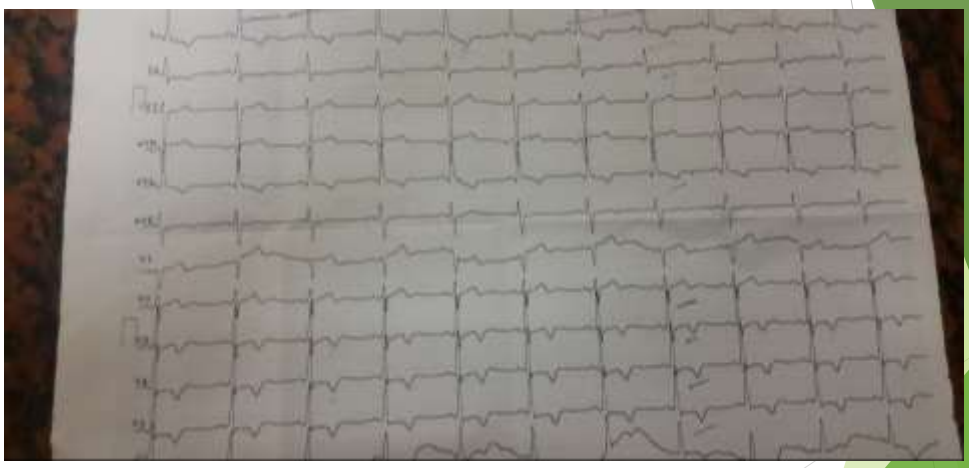
Take Home Message

- In addition to detailed assessment of coronary artery anatomy, MDCT is a powerful non-invasive imaging modality that should be utilized for the comprehensive assessment of non-coronary cardiac structures in all MDCT examinations.
- There are multiple evolving niche clinical applications of MDCT in the assessment of non-coronary cardiac structures.
- Knowledge of these noncoronary applications is important when assessing MDCT studies, as much vital structural heart information could be obtained beyond coronary anatomy.

History:

- Male patient 58years old
- He is hypertensive for 20 years
- No Diabetes Mellitus.
- Smoker
- The patient underwent coronary angio 6 months ago for attack of chest pain which revealed mild CAD and he was advised by medical treatment.
- Presented by dyspnea on moderate exertion.
- ECG : anterior changes.
- Negative Biomarkers.
- The patient was advised to do coronary CT angio and Echcardiography.

ECG :

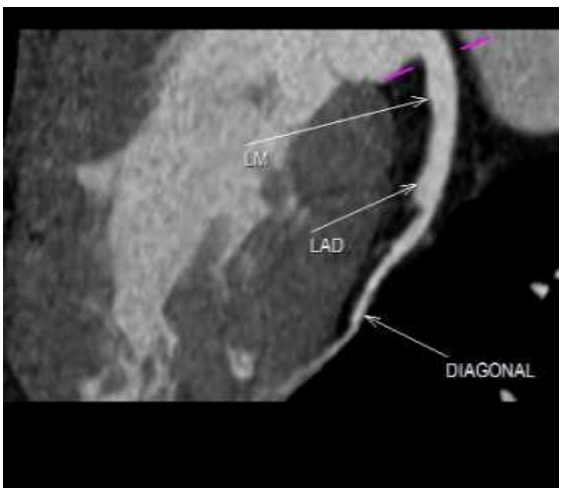


Echo :

- Normal LV dimensions with good overall contractility.
- Grade II diastolic dysfunction.
- Normal mitral and Aortic flow.
- WMA cannot be properly assessed due to poor echogenicity.

MSCT

MSCT



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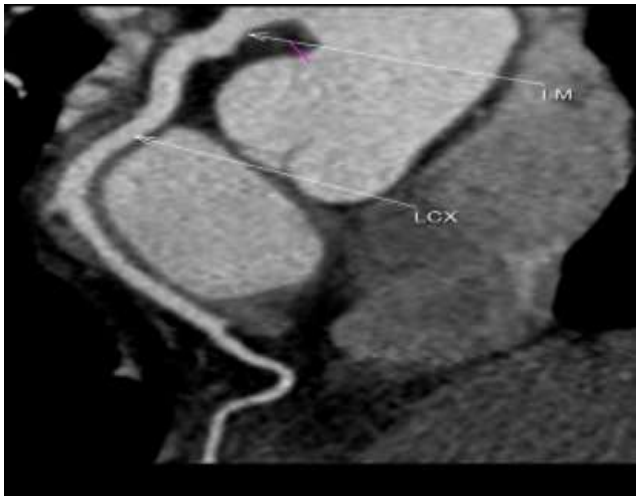

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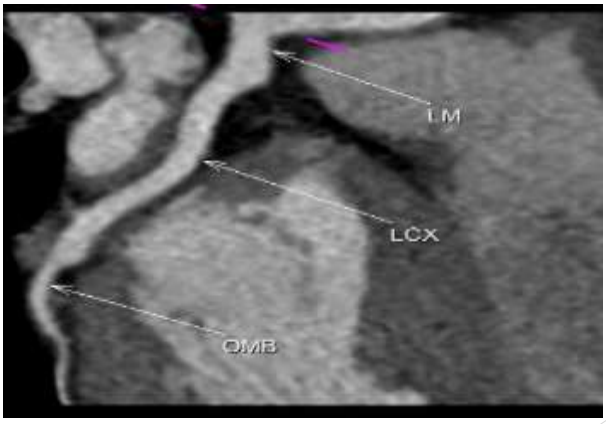

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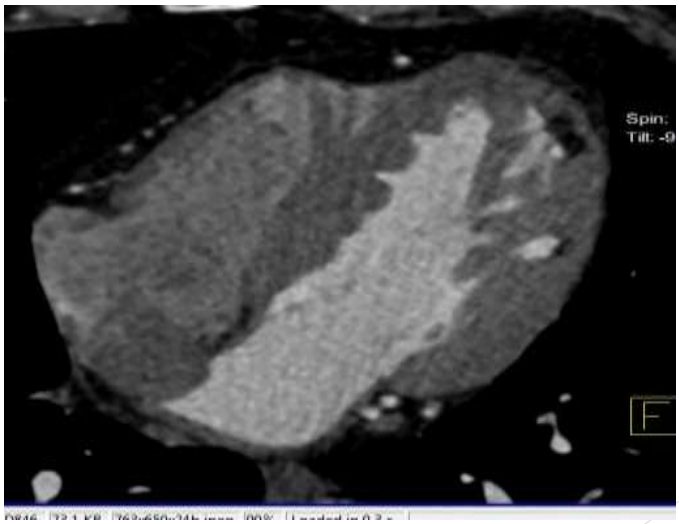

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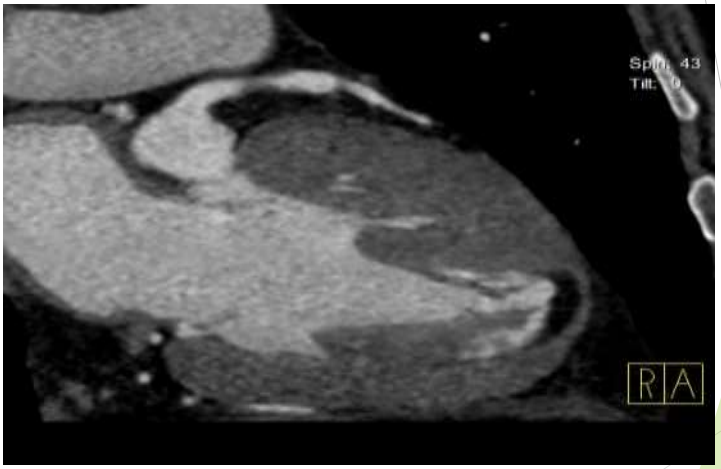

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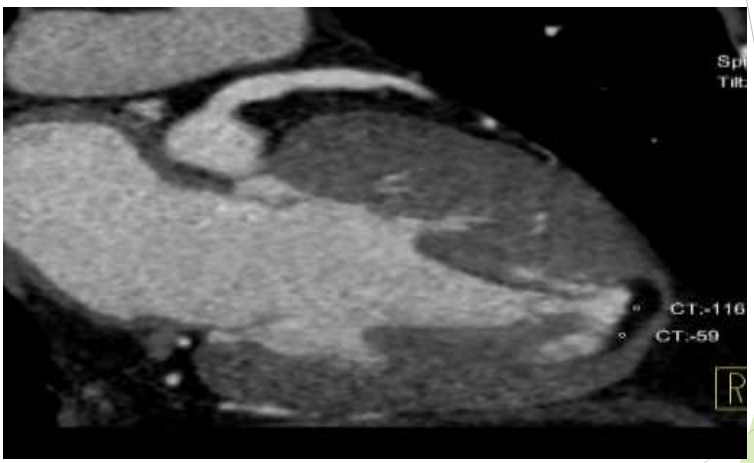

What is the provisional diagnosis?

Needing further investiogations?

Management:

Thank you