Uses of Cardiac CT in the Primary Care Settings

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MedNet21

Outline

- CAC: coronary artery calcification
  - Explain how to perform CAC scan
  - Discuss Role of CAC in the 2018 cholesterol treatment guidelines
  - Explain advantages of the use of CAC in primary prevention
- CCTA: Coronary Computed Tomography Angiography
  - Explain how to perform CCTA scan
  - Appropriate Uses of coronary CT angiography in the view of the most recent 2021 multisociety chest pain guideline
  - Discuss appropriate selection of stress test modality vs CCTA

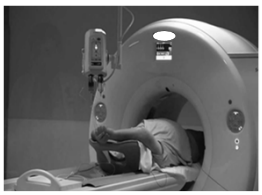
Pathogenesis of Coronary Calcification

- Atheroma is formed by the focal retention of lipoprotein in the subintimal layer.
- Circulating monocytes enter the tissues and differentiate into macrophages and ingest lipoprotein forming foam cells.
- Inflammatory cytokines are produced by macrophages and foam cells which stimulate inflammation and the differentiation of pericytes & smooth muscle cell to osteoblast like cells.
- This results in microcalcification which then merge together to form marcorcalcification.

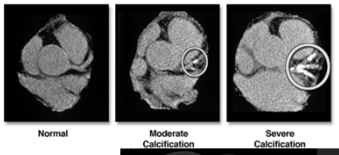
How to Perform Calcium score scan

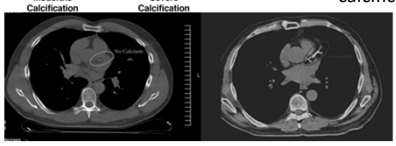
- Lying flat
- ECG monitoring and gating
- Able to hold breath for 3-6 sec.
- Total time in the scanner 5-10 minutes
- Radiation 0.5-2 mSv
- Cost $100-200

- No IV line
- No Beta blocker
- No IV contrast
- No Oral contrast
- No nitroglycerin
- No 4-8 hr fasting



Coronary Artery Calcification





- Any chest CT can detect coronary calcification

CAC vs Risk Factors Burden

CAC score is a very strong and independent of all cause mortality.

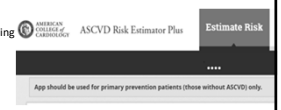
CAC predicted all cause mortality beyond traditional risk factors.

For example, the risk of mortality is higher in patients with CAC score of >400 and no Risk factor than that in patients with >=3 risk factors and zero CAC score.

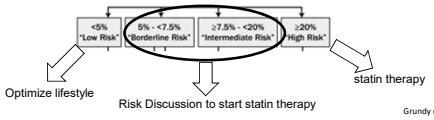
Interplay of Coronary Artery Calcification and Traditional Risk Factors for the Prediction of All-Cause Mortality in Asymptomatic Individuals. Nasir et al. (*Circ Cardiovasc Imaging*. 2012; 5:467-473).

2018 Guidelines on the Management of Blood Cholesterol

1. Assess 10-year risk of Major adverse cardiovascular events (MACE) using the ACC ASCVD risk calculator in asymptomatic individuals https://tools.acc.org/ascvd-risk-estimator plus/#!/calculate/estimate/

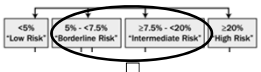


2. CAC is useful in those with 10-year risk is 7.5-20% (intermediate)



Grundy et al JACC 2019 Jun 25;73(24):3168-3209.

2018 Guidelines on the Management of Blood Cholesterol



Risk Discussion to start statin therapy

- Level of risk
- Patient preference
- Potential for side effect.
- Patient values (prevention vs taking medications regularly)

If risk discussion is uncertain,

If CAC > 100 or >=75th percentile --→ initiate Statin
If CAC 1-99-→ favor statin especially if age > 55
If CAC =zero→ no statin except smoker or diabetes

Grundy et al JACC 2019 Jun 25;73(24):3168-3209.

Advantages of CAC use

- The use of ASCVD risk calculator results in significant overestimate and underestimation of risk in about 50% of those with 5-20% risk. CAC use improves accuracy of risk estimation. Greenland P et al; JACC 2017: (72) (4):434-47
- CAC scan resulted in a 2-fold increase in the odds of increasing exercise or making dietary changes among individuals found to have any CAC versus those with no CAC. JAAC Img 2017;10:933-42
- CAC scan resulted in 2- to 3-fold increase in the odds for initiating aspirin, lipid-lowering medication, and antihypertensives. JAAC Img 2017;10:933-42
- CAC represents the results of lifelong exposure to risk factors and genetic factors
- CAC= zero is a powerful negative risk predictor that is associated with low risk of MACE and mortality. J Am Coll Cardiol Img 2016;9:900-9) (EHJ (2014) 35,2232-2241).

Clinical Case #1.

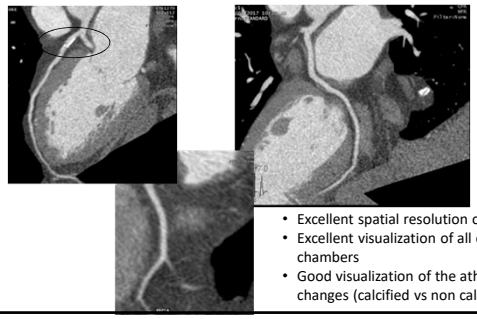
55 yo asymptomatic woman with no hx of HTN or DM

- Brother had a PCI for 99% stenosis at age 49, one month prior
- Father had PCI at age of 60. , 2 other sisters healthy but slightly "high cholesterol"
- BMI 33, Bp 130/70. Lipid panel: Tchol: 206, HDL 61, TG 96, LDL 126
- Asymptomatic, exercise sporadically 1-2 a week on 20 minutes on her home treadmill
- He is concerned about his CV risk, but unsure if he would take regular medications

10-y CVD risk by PCE is 7.6%

CAC score is 150
Which is at the 85th percentile for age, gender and race

Coronary CT angiography (CCTA)



- Excellent spatial resolution of 1-2 mm
- Excellent visualization of all cardiac chambers
- Good visualization of the atherosclerotic changes (calcified vs non calcified plaque)

How to Perform Coronary CTA

- Lying flat
- ECG monitoring
- Heart rate control, ideally 50- 60 BPM
- NPO for 4-8 hours.
- Able to hold breath for 3-6 seconds
- Iodinated contrast 60-110 ml
- Total time in the scanner 15-30 minutes
- Radiation 4-8 mSv

CCTA vs Cath

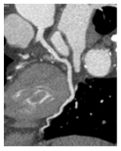
Invasive coronary angiography (also known as heart catheterization) has been considered as the standard for the diagnosis of coronary artery disease because it provide direct anatomical visualization of the coronary arteries.

Stress tests (various forms) do not directly detect anatomical atherosclerosis, but rather they detects the late effect which is ischemia caused by advanced atherosclerosis with stenosis >50-70%

Coronary CT angiography provides anatomical evaluation of the coronary arteries non invasively.

The early time of development of CCTA, studies shows accuracy of CCTA in comparison with invasive coronary angiography.

A meta-analysis in 2011, that included 28 studies and more than 3,674 patients, showed overall, CCTA sensitivity of 98% and specificity of 82%. And NPV of 99% which make CCTA an excellent test to rule out significant CAD in low-intermediate risk patients.



Coronary CT angiography (CCTA)

Heart catheterization (invasive coronary angiography)

BMC cardiovascular disorders 2011,11;32

PROMISE Trial

- The Trial randomly assigned 10,003 symptomatic patients were randomly assigned to
  - strategy of initial anatomical testing with the use of coronary computed tomographic angiography (CTA)
  - or to functional testing (exercise electrocardiography, nuclear stress testing, or stress echocardiography).
- The Event rate were low and similar in both groups. Of 3.3 % in the CTA group and 3% in the functional group.

N Engl J Med 2015;372:1291-300.

Outcomes of Anatomical versus Functional Testing for Coronary Artery Disease

- **It is a tie.**
- **CCTA is a good/safe option for work up of CAD**
- **PROMISE trial did not stipulate medical therapy for non-obstructive CAD, ie stenosis <50-70%**

Prognostic Value of Noninvasive Cardiovascular Testing in Patients With Stable Chest Pain

Insights From the PROMISE Trial (Prospective Multicenter Imaging Study for Evaluation of Chest Pain)

PROMISE trial re-analysis

	Events	Total number of events over study period of 26 months	
Non obstructive CCTA	74	137	54%
Normal functional test	75	132	57%

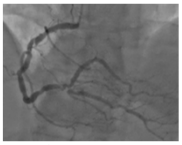
- In the trial, 54% of the events in the CTA group, happened in those with non obstructive disease .
- 57% of the events in the stress test group, had a normal stress test.

More than half of the events (MI, death) happened in patients who had no ischemia on stress testing and no obstructive stenosis on CCTA

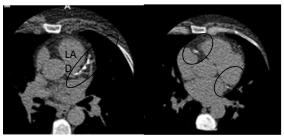
Hoffman U et al. Circulation. 2017:135:2320-2332

Coronary Atherosclerosis is a Diffuse Multifocal disease.

Therapies targeting a local stenosis/plaque that is stable will not change the overall outcome of the disease.



Invasive coronary angiogram showing the right coronary artery with multifocal disease



Coronary calcium scan showing the multifocal nature of atherosclerosis.

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Coronary CT Angiography and 5-Year Risk of Myocardial Infarction

The SCOT-HEART Investigators*

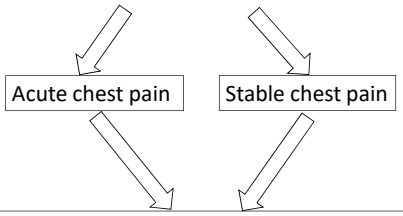
- Prospective, open-label, parallel-group, multicenter trial in Scotland
- Patients (n=4,146) randomly assigned to standard of care or cardiac CT arm
- The primary end point was Non fatal MI and death from coronary heart disease at 5 years.
- Cardiac CT resulted in 41% relative risk reduction compared to standard care over 5 years.
- Cardiac CTA group, also had higher rate of preventive therapies and more anti anginal therapy.
- NO difference in cath rate or revascularization rates.

CCTA vs standard care

41% relative risk reduction And 1.6 % absolute risk reduction over 5 years.

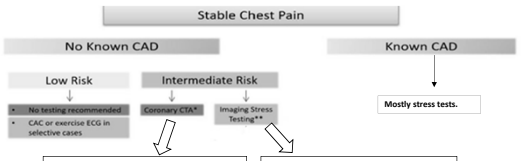
N Engl J Med 2018;379:924-33.

ACC/AHA 2021: Chest pain Guidelines



Key question #1: What is the patient risk level and how to assess it ?
Key question #2: Does the patient have a prior history of CAD?

Diagnostic Evaluation for Stable Chest Pain



Criteria that favor CCTA use:
- Age <65 years
- Good local expertise
- Normal renal function.
- Aorta assessment
- Coronary anomalies assessment.
- Prior inconclusive stress tests

Criteria that favor stress tests use:
- Age <70years
- Good local expertise in stress tests
- Impaired renal function.
- Known severe coronary calcification
- Prior inconclusive CCTA

What Type of test or Stress Test Should I order?

Exercise vs Pharmacological stress test	Exercise always is preferred
Reduced LVEF	Cardiology referral , Likely need cath or CCTA
Prior CAD , prior PCI, prior CABG	Consider referral to Cardiology, or stress testing
LBBB or Ventricular paced rhythm	CCTA vs Pharmacological SPECT
Uncontrolled hypertension	Pharmacological SPECT, exercise testing or dobutamine echo are not optimal
Persistent symptoms despite prior negative stress test	CCTA

CCTA: coronary CT angiography

What Type of test or Stress Test Should I order?

Inconclusive or indeterminate SPECT or stress echo	**CCTA**
Young or low risk patient	**CCTA vs Exercise ECG vs no testing**
Age <65 and no hx of CAD with chest pain	**CCTA**
Asymptomatic patient	**NO stress testing, but can consider CAC score**
High 10-y ASCVD score, but refuses statin	**CAC score**
Low ASCVD 10-y risk, but risk enhancers	**CAC score**

CCTA: coronary CT angiography

Take Home Message

- CAC scan is a very useful tool to detect early atherosclerosis especially in
  - The majority of subjects who are intermediate risk with 10-year risk of 7.5-20% who are hesitant about statin
  - Elderly who have no or very low risk factors
  - Young individuals with strong Fhx of premature CAD
- Coronary CTA is appropriate first test for evaluation of stable chest pain patients who are intermediate risk and have no prior hx of CAD , especially if <65 years.
- Stress testing (nuclear, echo, MRI) is more appropriate for those with a history of CAD, PCI or CABG or for those with >75 years.
- Exercise stress testing is more informative than pharmacologic stress testing.
- Non-obstructive coronary artery disease is not benign
- Coronary artery calcification is coronary artery disease
- CCTA use is associated with 41% risk reduction compared to stress testing in stable patients with chest pain.

Cardiac Imaging Indications

Focus on Cardiovascular Magnetic Resonance

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Outline

- Cardiovascular magnetic resonance (CMR) techniques
- Guidelines
- Common CMR indications

Cardiovascular Magnetic Resonance

- CMR → magnetic field and radiofrequency waves used to generate images with high spatial resolution and excellent contrast.
- Newer gadolinium agents being used in chronic kidney disease.
- Many devices are now MR conditional (can undergo CMR in specific environment and under specific conditions).
- Please contact the CMR lab if you have any questions about whether CMR is the right test for your patient.

CMR Imaging Techniques

- Cine imaging
- Blood flow quantification (phase contrast imaging)
- Myocardial perfusion (stress)
- Angiography
- Tissue characterization
  - Late gadolinium enhancement
  - T1 mapping
  - T2 mapping

Cine Imaging

- Gold standard for LV and RV structure and function
- Accurate even without ECG gating or breath holding
- Detailed analysis of wall motion and strain
- Evaluate the heart from any angle

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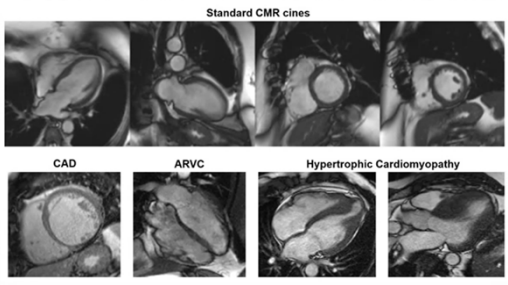
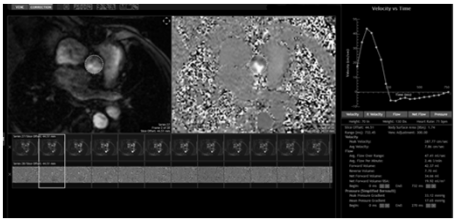
Video 1 - Standard CMR cines



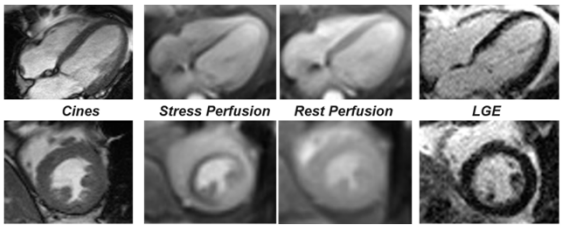
Phase contrast imaging

- Quantitative assessment of blood flow
- Excellent for valvular and shunt evaluation



Myocardial perfusion imaging

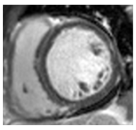
- Qualitative and quantitative myocardial blood flow evaluation during stress testing



Angiography

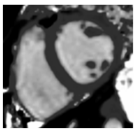
- Vascular evaluation without radiation!
- Can be performed with or without gadolinium contrast.
- Most commonly used to follow aortic dilation and congenital heart disease anomalies.

Myocardial fibrosis imaging



Late gadolinium enhancement

- Replacement fibrosis, focal scar
- Relative differences in T1 signal between enhancing bright scar and normal myocardium

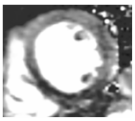


T1 mapping

- Interstitial fibrosis
- Direct measure of T1 signal of tissue
- Extracellular volume fraction (ECV): measure of extracellular space in myocardium

Myocardial edema / inflammation

- **T2 mapping** identifies myocardial edema / inflammation (histologically validated)



- **Many clinical applications**
  - Myocardial infarction
  - Myocarditis
  - Inflammatory cardiomyopathies (sarcoidosis, lupus, etc)
  - Takotsubo cardiomyopathy
  - Transplant rejection

Higgins CB et al. AJC 1983; 52.
Giri S et al. JCMR 2009: 56.
Friedrich, MG. Nat. Rev. Cardiol 2010;7:292-296.

Guidelines & Appropriate Use Criteria

https://scmr.org/page/guidelines

Common CMR Indications

- **Chest pain**
  - Coronary artery disease
  - Myocarditis
  - Pericarditis
  - Takotsubo
- **Arrhythmias**
  - Structural abnormalities
  - Cardiomyopathy
  - Evaluate fibrosis burden
- **Heart failure / cardiomyopathy**
  - Ischemic
  - Non-ischemic
  - Infiltrative
  - Arrhythmogenic
- **Valvular disease**
- **Mass / thrombus**
- **Congenital heart disease**
- **Cardio-oncology**

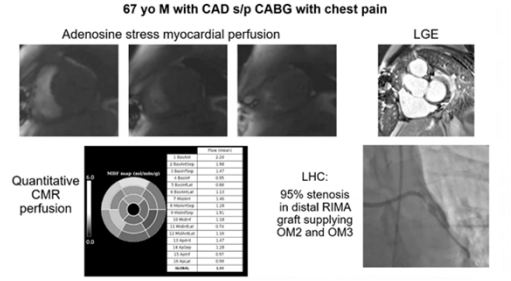
"SCMR Position Paper (2020) on clinical indications for CMR." Leiner T, et al. JCMR 2020; 22.

CAD – Stress Testing

- CMR → comprehensive evaluation of structure, function, stress testing, and scar / infarct burden.
- Identify ischemic myocardium with stress myocardial perfusion imaging to guide revascularization.
- Head-to-head trials endorse stress CMR as one of the most accurate modalities in evaluating the symptomatic CAD patient.[1]

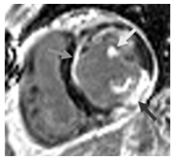
1. Leiner T, et al. JCMR 2020; 22.

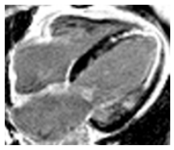
Video 2 - 67 yo M with CAD s/p CABG with chest pain



CAD - Viability

- CMR identifies infarction extent and related complications
- Extent of myocardial damage by LGE is inversely related to the likelihood of functional recovery with revascularization. [1]

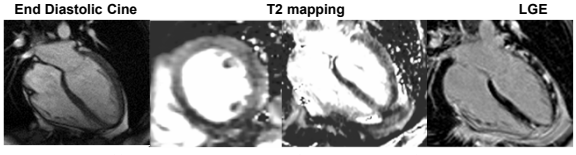




1. Kim RJ, et al. N Engl J Med 2000; 343:1445-1453

Myocarditis

- CMR is the key diagnostic tool in myocarditis with established imaging criteria.[1]
- Utilized for diagnosis and prognostication.[2]
- Case: 20 yo M with chest pain and troponin elevation



1. Ferreira VM, et al. JACC 2018; 72.
2. Obrien AT … Zareba KM. JCMR 2022: 24.

Dilated Cardiomyopathy

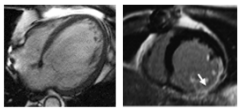
- Accurate evaluation of ventricular structure and function.


LVEF 22%
LVEDVI 150 ml/m2

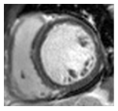

LVEF 44%
LVEDVI 98 ml/m2


LVEF 49%
LVEDVI 98 ml/m2

- Distinguish between ischemic and non-ischemic Cardiomyopathy.



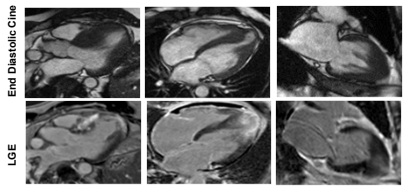
- Fibrosis burden is highly prognostic of Sudden Cardiac Death.



1. Leiner T, et al. JCMR 2020; 22.

Hypertrophic Cardiomyopathy (HCM)

- CMR is essential for HCM diagnosis[1]
  - Visualize hypertrophy, structural abnormalities (apical aneurysm, mitral valve motion, left ventricular outflow obstruction), fibrosis burden
- Fibrosis burden is a key prognostic factor for adverse cardiac events. [1]

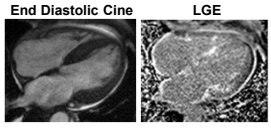


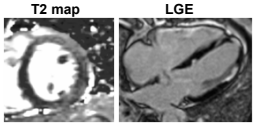
1. Leiner T, et al. JCMR 2020; 22.

Infiltrative cardiomyopathies[1]

Amyloidosis
- Evaluate for cardiac involvement in AL / ATTR.
- LGE and T1 mapping are key for diagnosis and prognosis.
- Significantly elevated ECV.

Sarcoidosis
- Cardiac involvement is associated with poor outcomes.
- CMR evaluates myocardial infiltration (LGE) and inflammation (T2 mapping).





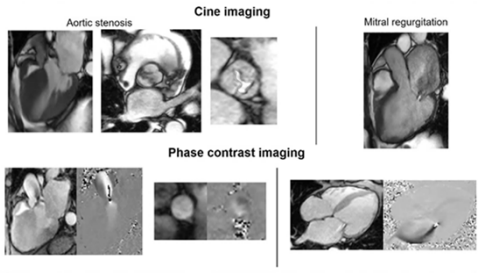
1. Leiner T, et al. JCMR 2020; 22.

Valvular disease

CMR enhances valve assessment

- Regurgitation, stenosis, prosthetic valve function in unlimited imaging planes
- Detailed imaging of valve anatomy
- Reproducible volumes/function
- Flow and velocity quantification
- Associated pathology (amyloidosis, aortopathy, fibrosis)

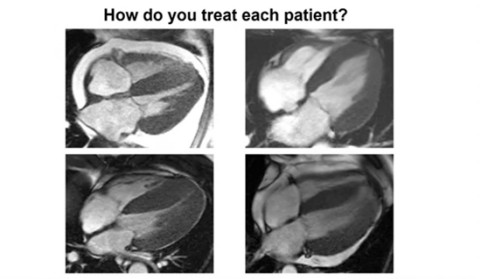
Video 3 - Cine imaging



Other Common CMR Indications

- **Pericardial disease**
  - Evaluate for pericarditis and constriction
- **Congenital heart disease**
  - Anatomy, function, shunt assessment
- **Vascular assessment / Aortic imaging**
- **Cardio-oncology**
  - Monitoring cardiotoxicity, mass/thrombus evaluation

Video 4 - How do you treat each patient?



Precise and accurate diagnosis is key!