Cardiac CT: Your chest pain patient CAN be discharged from the Emergency Department

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No financial disclosures relevant to this talk

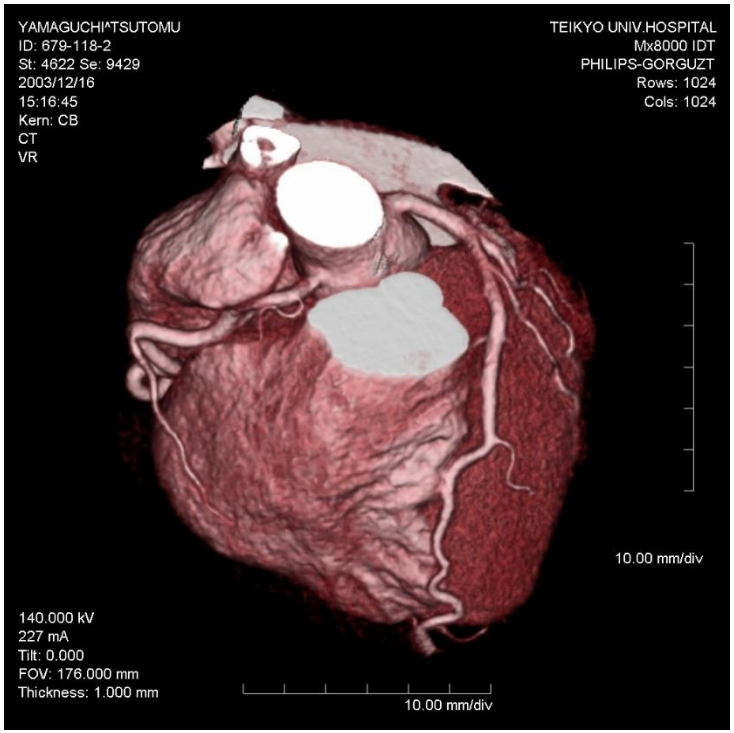
Objectives

Discuss the indications for Cardiac CT

Discuss the advantages of Cardiac CT

Discuss the disadvantages of Cardiac CT

Cardiac CTA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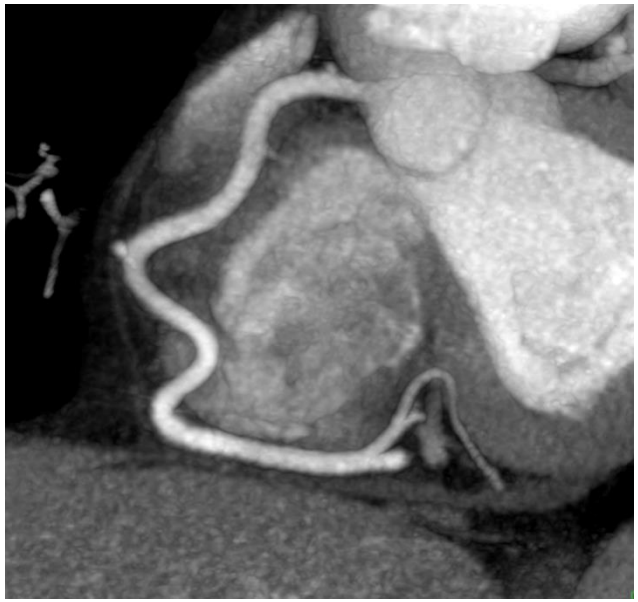

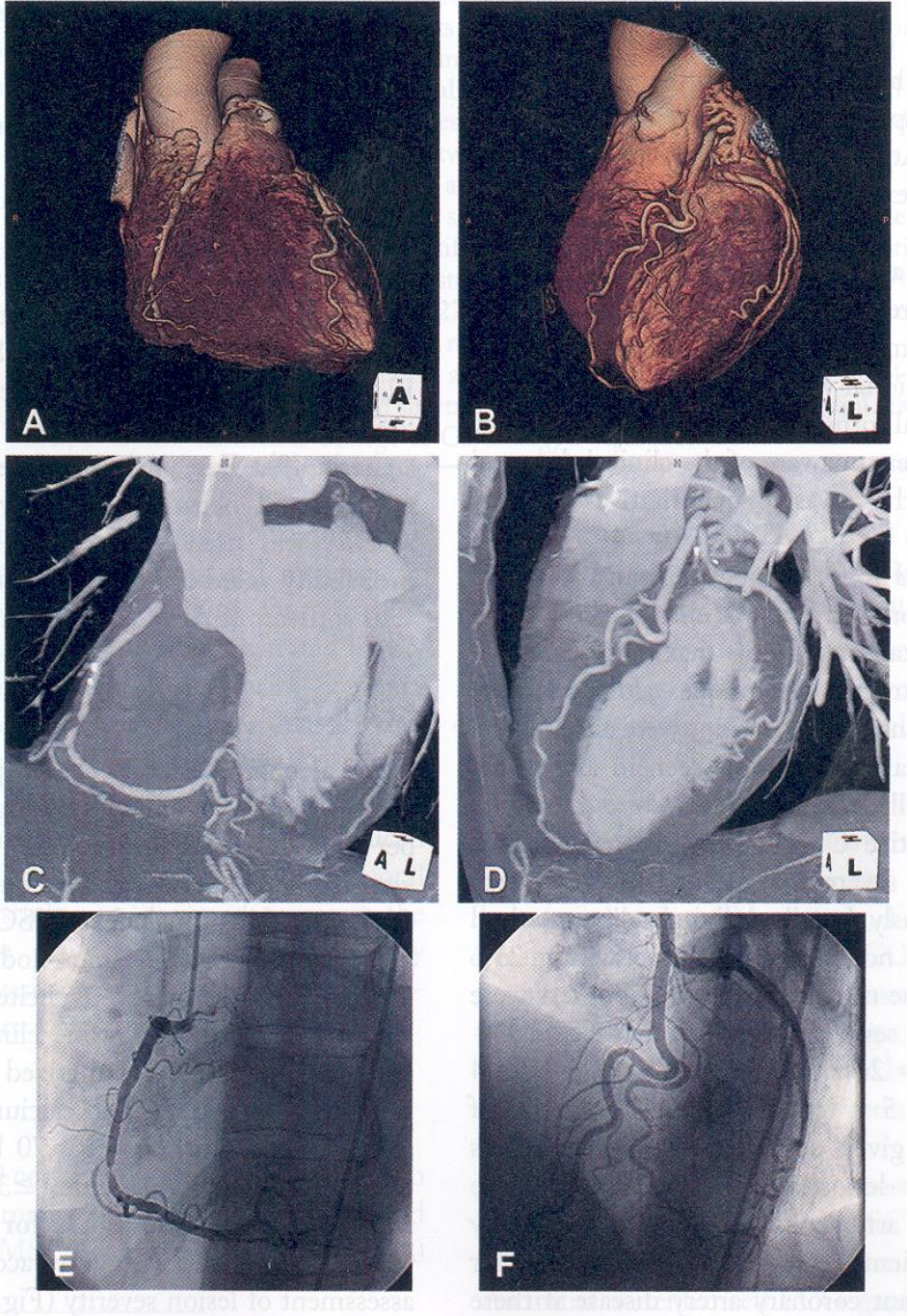
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Excellent Identification of Blockage

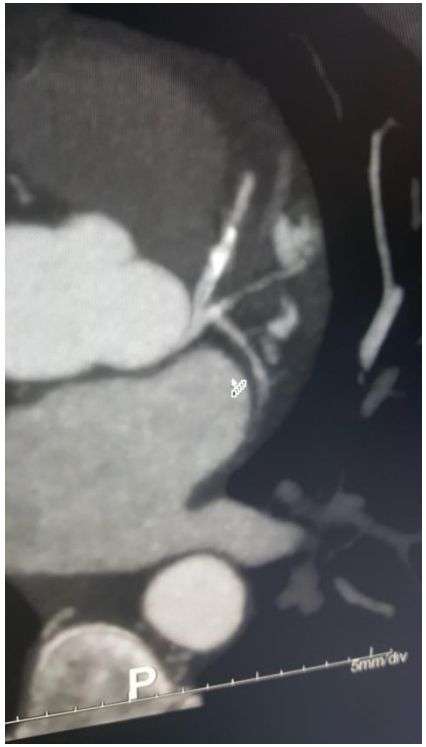
Coronary CT Angiogram-a Healthy Driven paradigm

- Screening for CAD and primary and secondary preventive clinical management have made a significant impact on decreasing cardiac morbidity and mortality
- Between 2000 and 2010, the American Heart Association reported a 30% decline in cardiovascular mortality per 100,000 people, decreasing from 0.34% to 0.24%
- **Early detection** has played an integral role in reduction in mortality by application of proven treatment modalities for both short term and long term risk reduction
- Advantages of coronary CTA include:
  - Non-invasive
  - Efficiency in diagnosis
  - Low cost when compared to the entire cost of treatment for a patient with chest pain
  - Do not need to wait for cardiac panel as it is not provocative
  - Not limited by uncertainties of balanced ischemia

320 Slice CT

- Presumed Disadvantages
  - Radiation?
  - Cost?
  - Contrast exposure in renal insufficient patients
  - Functional significance

- Advantages of our Cardiac CT Program
  - Part of ER management of chest pain patients
  - CT scan read by Cardiologists with extensive experience in image interpretation and correlation
  - Image of the entire heart during one phase
  - Uses a stationary table scanning approach - heart is “frozen” at a particular time
  - Heart scan happens in less than half a second - full body scan in 3 seconds
  - Dose reduction strategies have dramatically reduced radiation exposure while maintaining diagnostic image quality
  - 1/3 to 1/5 the radiation dose in comparison to the other CT programs and marked reduction in radiation in comparison to myocardial perfusion imaging



Balanced ischemia on stress test

Small vessel disease

Pericardial abscess as cause of chest pain

Patient selection

BMI over 40 generally not good candidates for CTA however there may be some patients whose body mass is distributed outside of the chest into the abdomen and lower extremities

In morbidly obese patients the mA and contrast administration rate can be increased to improve imaging

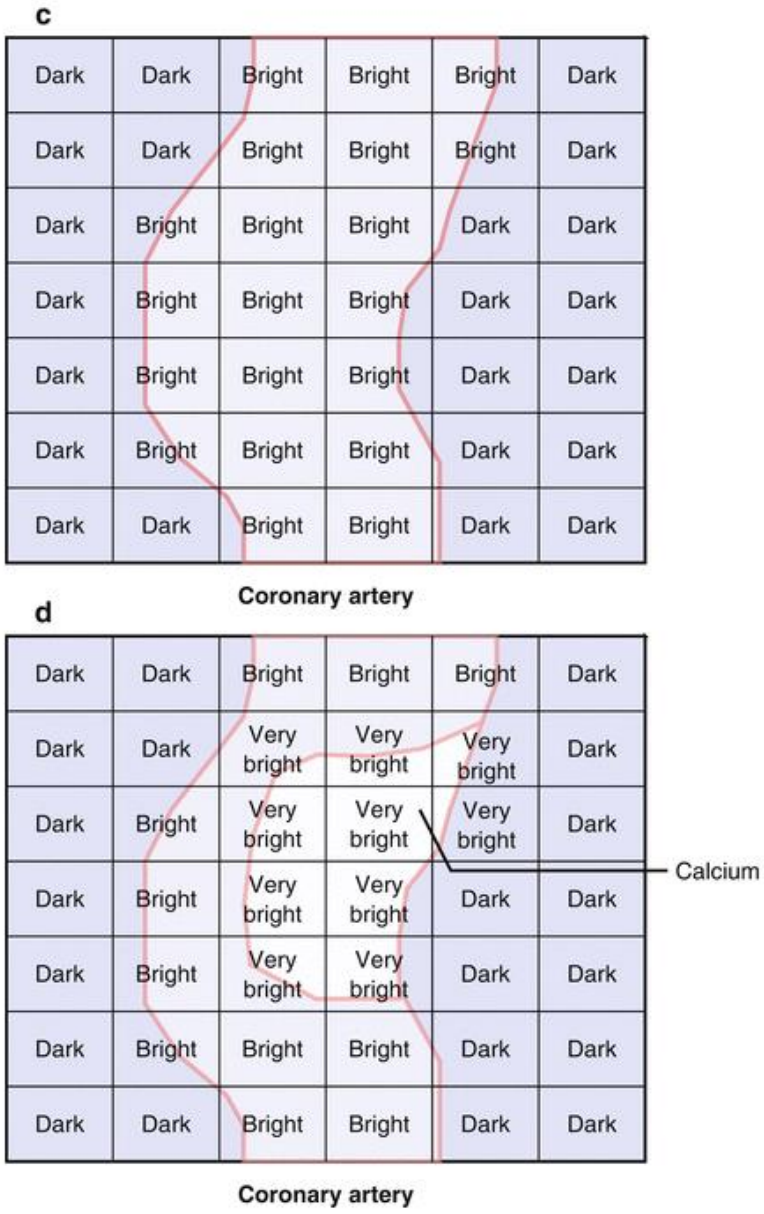
Patients with diminished cardiac output(not always EF) will have decreased iodine flux and decreased image quality

Patients with high calcium score will have blooming artifact

Blooming artifact

Partial volume averaging averages the edges of calcium that are smaller than the resolution of the scanner

Therefore the voxel is larger than calcium in the area and additional voxels are averaged into the edges of calcium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Calcium
Coronary artery

If the calcium completely obstructs the lumen there is a 50% chance of obstructive lesion

If any lumen can be seen there is a 2% chance

There are no guidelines as to what level of calcium precludes visualization

Absolute calcium score do not necessarily exclude visualization of the lumen

Arrhythmias

Patients with excessive ectopy are not good candidates

Patients with slow heart rates are good candidates

Atrial fibrillation patients can be imaged if their heart rates are slow

Bypass grafts and stents

Bypass grafts can be visualized well by CTA

However, native coronary arteries may not be well visualized in these same patients as heavily calcific coronary arteries are seen in these patients as these native vessels degenerate quicker

Similarly stents < 3 mm are not well seen due to blooming artifacts

Patient prep

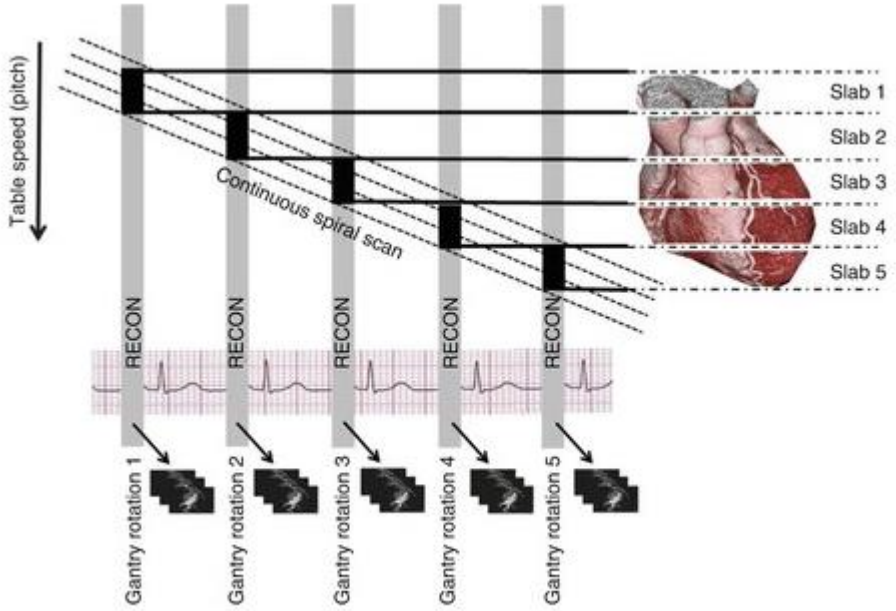
Oral beta blocker is essential in controlling heart rate

A dose of 100 mg metoprolol prior to test if HR 70-80 and 50 mg if HR 60-70 is given preferably night before and morning of scan

Avoid Levitra, Cialis, Viagra 48 hours prior to exam if NTG is used

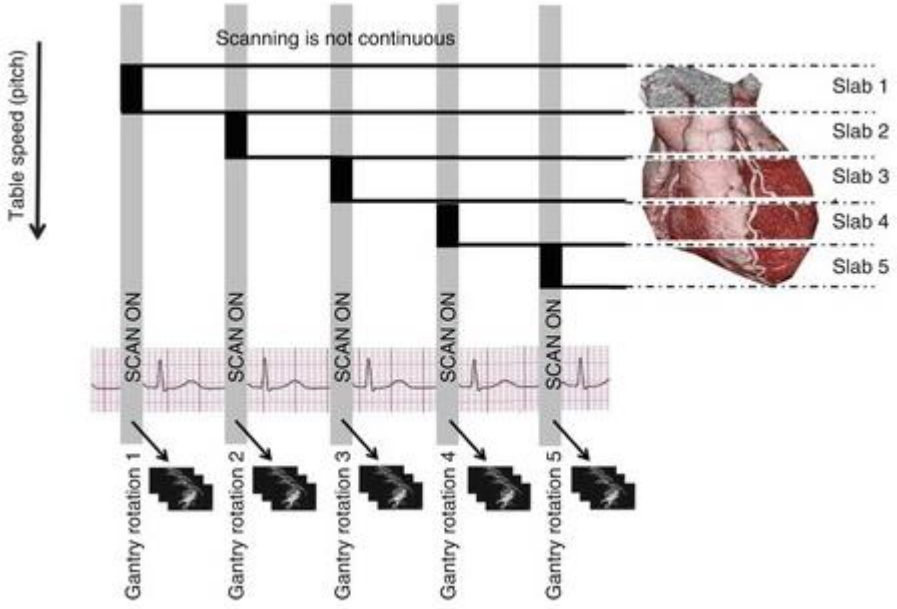
Avoid test if Cr > 1.5 or GFR < 60

Scanning technique



Retrospective scan: Advantage is image are recontructed throughout the cardiac cycle at the expense of significant radiation but may be used for patients with high heart rates

Prospective scanning

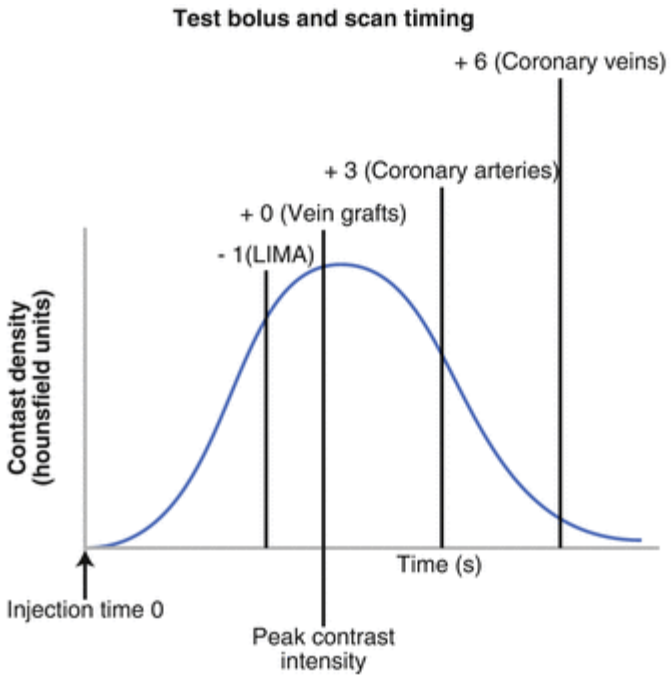


Advantage is markedly lowered radiation
Elmhurst scanner can obtain the entire heart in a single gantry rotation

Radiation dose reduction

- Prospective gating
- Reducing tube current from Kv from 120 to 100 reduces radiation by 30%
- For patients above BMI of 30 120 Kv may be used
- For patients < 60 kg 80 Kv may be used
- Dose modulation during phases of the cardiac cycle less likely to be utilized

Contrast bolus timing



Processing

Image data reconstruction

Cardiac phase selection for optimal interval

In some instances the RCA may be best seen in systole

Filters

Voxel is a 3 dimensional pixel and the smallest unit of measure

Inherent inaccuracy of CT to designate a particular X ray beam to a particular voxel is not possible at 100%

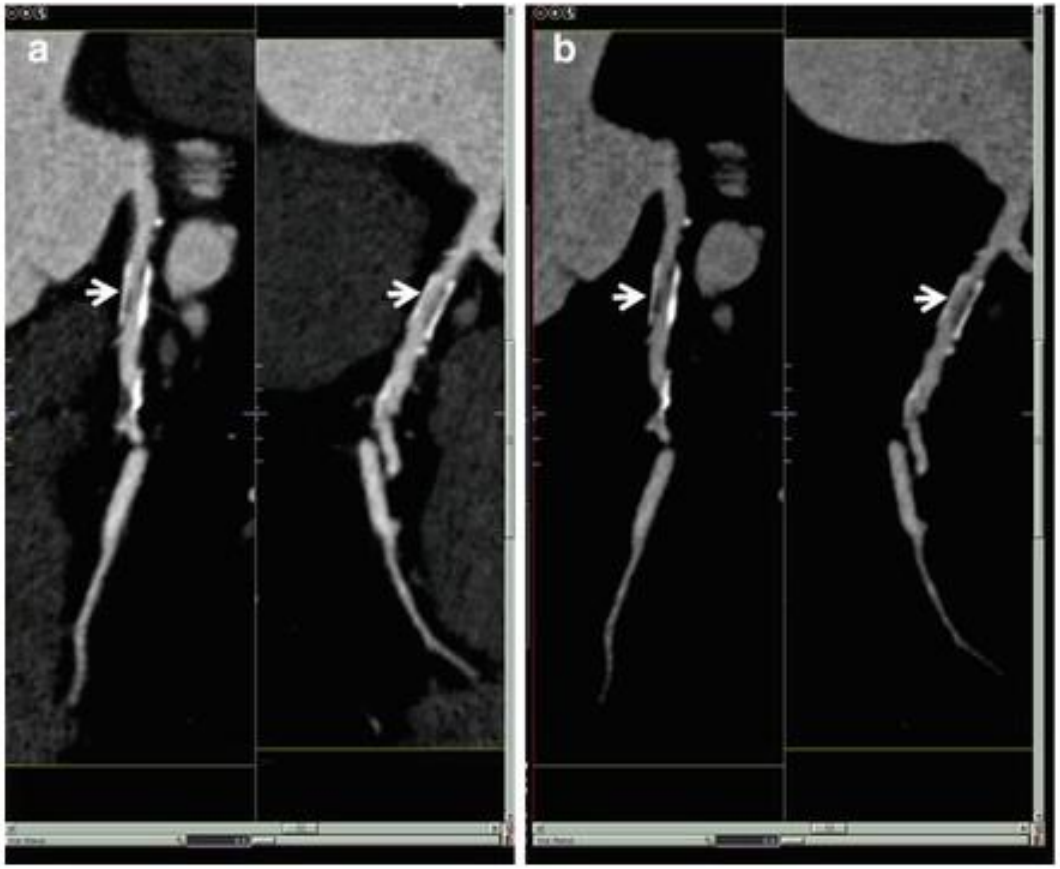
Particular density of a voxel is an average of the neighboring voxel

Different filters use different weighting equations with sharper filters reducing the average from neighboring voxel

Filters

Sharp filters use less information from the neighboring voxel -good for calcification and stents

Smooth filters use more information from the neighboring voxel -good for reducing noise

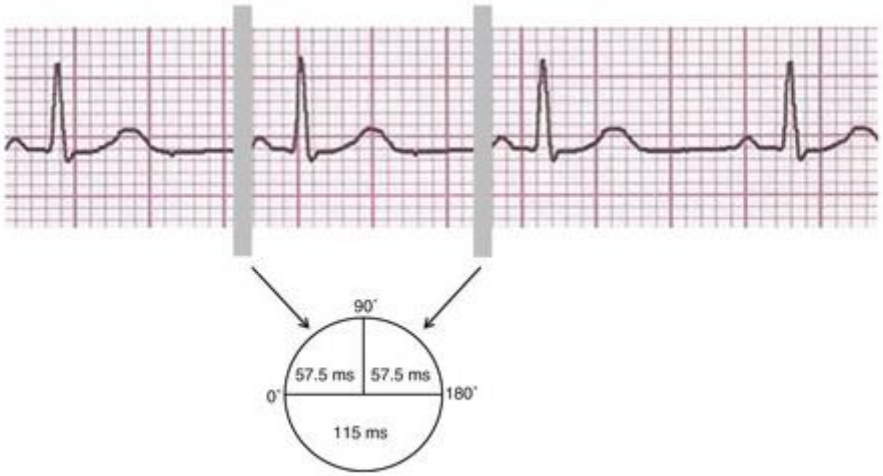


On the left is smooth filter within the stent with restenosis
On the right is sharp filter with the same restenotic lesion
Image on the right is grainier which means it has more noise but better edge detection of the lesion

Varrying the Z plane

- Filters vary the the x and y plane with different effects
- Slice thickness varies the z plane
- Similarly it smoothens out the image at the expense of missing image details
- A very focal lesion can be missed if the slice thickness is too thick

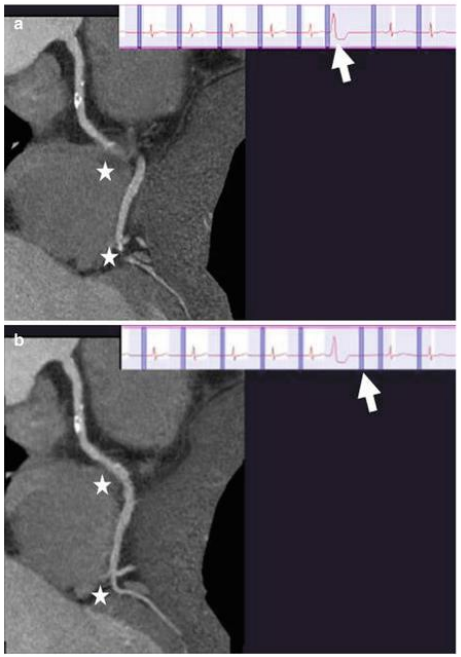
Single beat vs multi-beat image acquisition



single beat acquisition is possible in the 320 slice Elmhurst CT scanner if heart rate is controlled
avoids motion artifacts due to heart rate variability causing blurring of the images

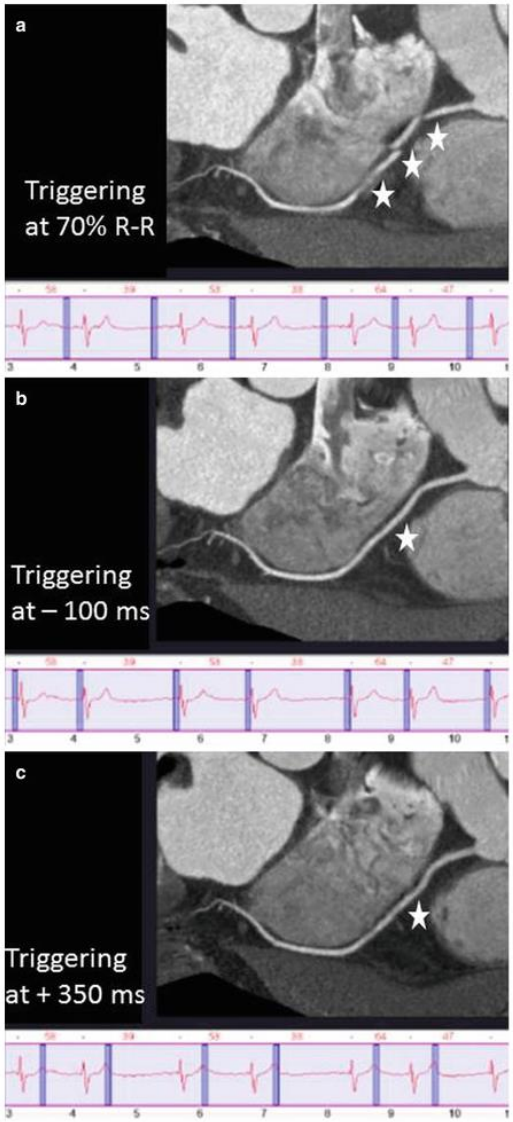
ECG editing

ECG editing may be performed for arrhythmias by the technician and is variable by different vendor software

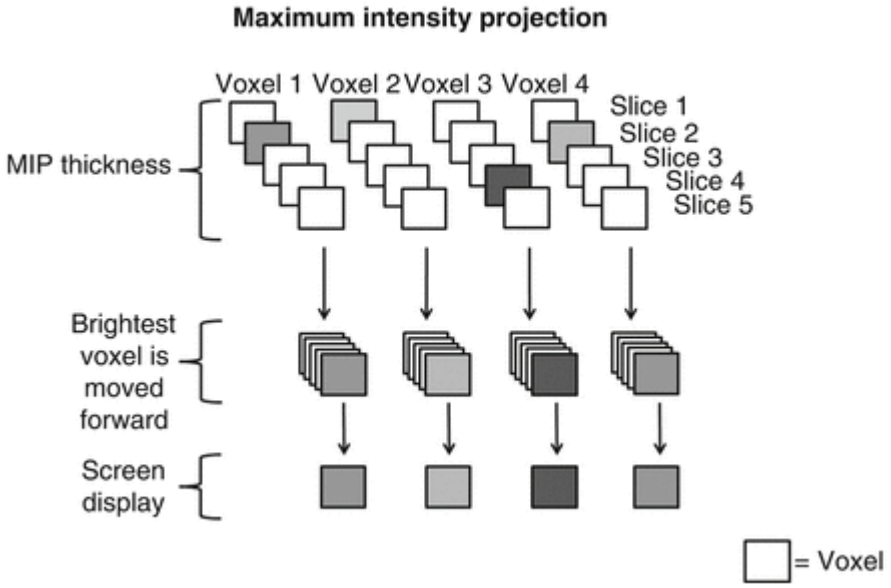


trigger moved to diastolic phase of PVC

Atrial fibrillation - use ms trigger not R-R trigger or use systolic frame sometimes



MIP - Maximum intensity projection



averages multiple voxels in a MIP slice and brings the brightest voxel forward
improves image brightness at the expense of detail
allows for visualization of a large portion of a tortuous vessel in multiple CT slices using custom MIP slices

MIP

coronary stenosis can be missed if it focal and the MIP slice thickness is larger than lesion

does not show plaque characteristics as well as multiplaner reformat (MPR)

MPR is raw data in an axial or oblique plane and can be used to measure the Hounsfield Unit (HU) to characterize the plaque

HU allows differentiation between ** good contrast scan at least 350 HU ** soft plaque - 42 to -47 ** intermediate plaque 61 to 112 HU ** calcified plaque 126 to 736 HU

Reporting coronary stenosis

Cardiac CT can have a variation of 25% in comparison to invasive coronary angiography*

Coronary stenosis presented in a range of 0-29%, 30-49%, 50-69%, 70-99% as well as qualitative minimal, mild, moderate, severe corresponding to above

CTA is highly accurate at determining bypass graft stenosis severity and origin of grafts

*Budoff MJ, Dowe D, Jollis JG, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. J Am Coll Cardiol. 2008;52: 1724– 32.

Diagnostic performance

Very high negative predictive value - best to rule out CAD in low to intermediate risk populations

Upto 39% of cardiac caths* have no significant disease and CTA can be a gatekeeper

*Patel MR, Peterson ED, Dai D, et al. Low diagnostic yield of elective coronary angiography. N Engl J Med. 2010;362: 886– 95.

Diagnostic performance in comparison to stress testing

CT: 99% sensitive, 89% specific

Positive predictive value is however 64%

Able to characterize plaque

You will never hear normal CTA and 3 vessel CAD on cath, have you heard that before with another modality?

Study	Sens.	Spec.	PPV	NPV
Accuracy[3]	95 %	83 %	64 %	99 %
CORE64[4]	85 %	90 %	91 %	83 %
Meijboom[5]	99 %	64 %	86 %	97 %
OMCAS[6]	81 %	93 %	92 %	85 %

What about 0 calcium score does that mean 0 CAD?

- Calcium score of 0 has a highly favorable prognosis
- CONFIRM registry of 10,000 patients

** 84% no CAD ** 13% nonobstructive CAD

** 3.5% obstructive CAD

Application of CT in ER chest pain

- Role of ER chest pain evaluation is to rule out ACS as first priority
- To rule out ACS 2 sets of troponins and serial EKG are done followed by stress testing
- CTA is perfect for this scenario in the low to intermediate risk group of patients

Goldstein study*

202 low risk patients without known CAD, ischemic EKG changes, BMI being < 39 kg/m2 underwent CTA compared to standard of care

** Minimal CAD patients discharged ** Over 70% stenosis underwent cardiac cath

** 50-70% stenosis underwent stress testing

** Both were safe ** 25% of patients needed stress testing for intermediate lesions

** CTA significantly reduced cost and length of stay

** Fewer repeat evaluations

Goldstein JA, Gallagher MJ, O'Neil WW, et al. A randomized controlled trial of multi-slice coronary computed tomography for evaluation for acute chest pain. J Am Coll Cardiol. 2007;49: 863– 71.

CT-STAT study

Multicenter study with 16 hospital

Compared MPI stress test to CTA

54% reduction in time to diagnosis

38% lower cost

Goldstein JA, Chinnaiyan KM, Abidov A, et al. The CT-STAT (Coronary Computed Tomographic Angiography for Systematic Triage of Acute Chest Pain Patients to Treatment) trial. J Am Coll Cardiol. 2011;58: 1414– 22.

ARIN-PA study

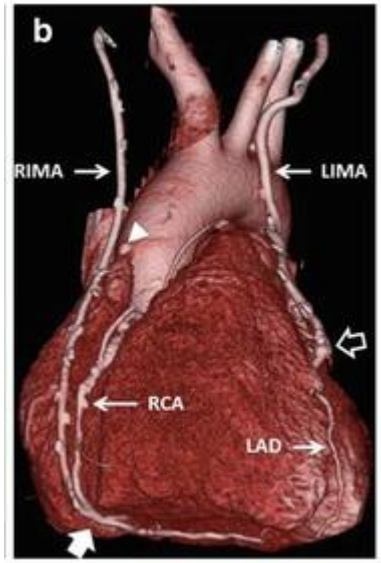
- 1370 patients assigned 2:1 to CTA vs standard of care who were low to intermediate risk
- Both strategies were safe
- Faster discharge from hospital in CTA group

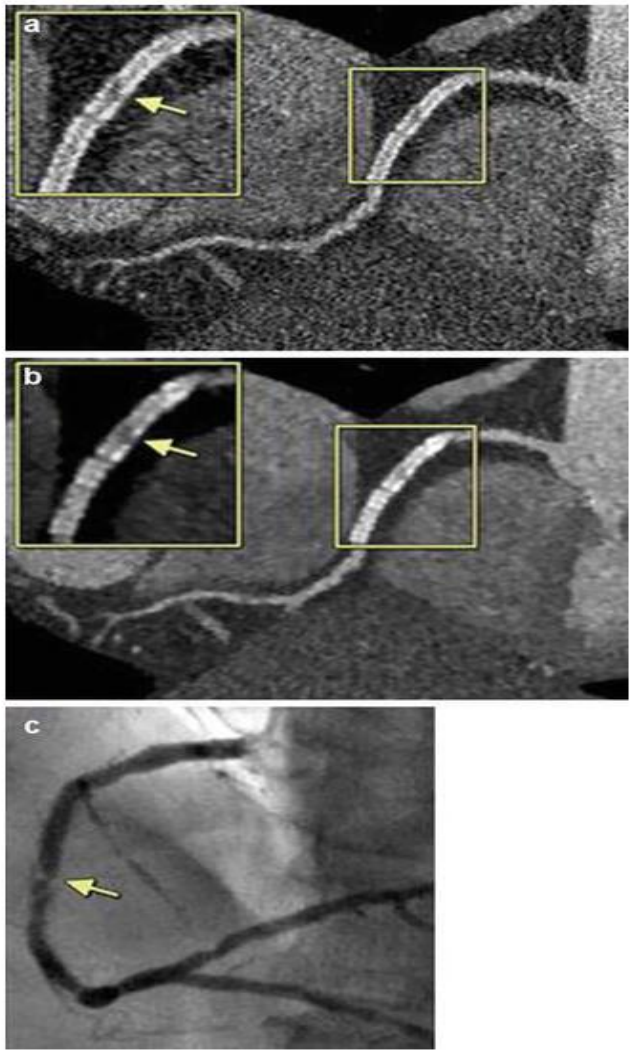
Litt HI, Gatsonis C, Snyder B, et al. CT angiography for safe discharge of patients with possible acute coronary syndromes. N Engl J Med. 2012;366: 1393– 403.

What is low to intermediate risk?

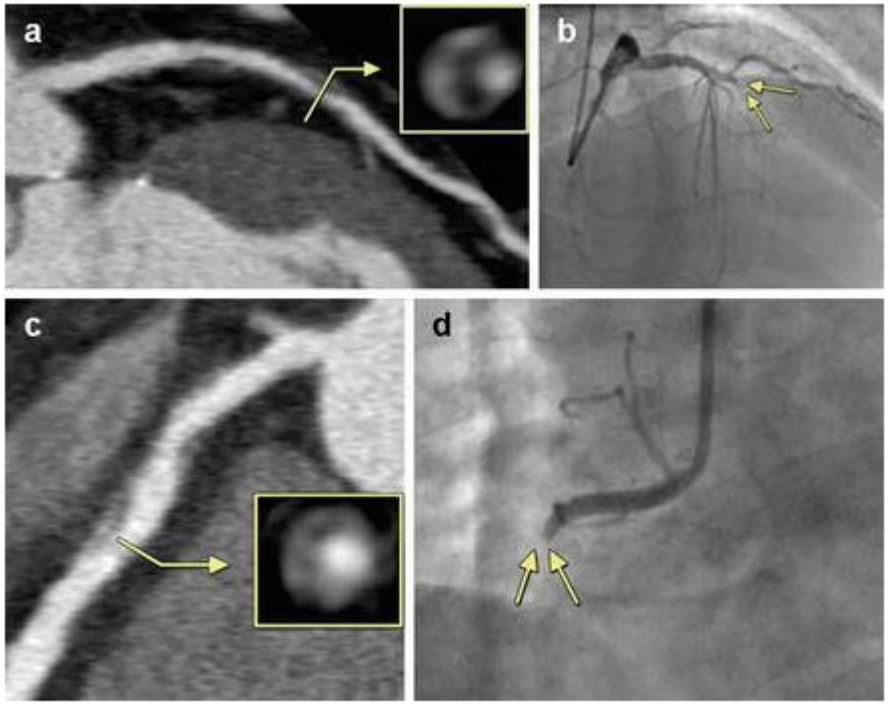
Age, (years)†	Gender	Typical or Definite Angina Pectoris	Atypical or Probable Angina Pectoris	Nonanginal Chest Pain	No Symptoms
30-39	Male	Intermediate	Intermediate	Low	Very low
	Female	Intermediate	Very low	Very low	Very low
40-49	Male	High	Intermediate	Intermediate	Low
	Female	Intermediate	Low	Very low	Very low
50-59	Male	High	Intermediate	Intermediate	Low
	Female	Intermediate	Intermediate	Low	Very low
60-69	Male	High	Intermediate	Intermediate	Low
	Female	High	Intermediate	Intermediate	Low

Other applications



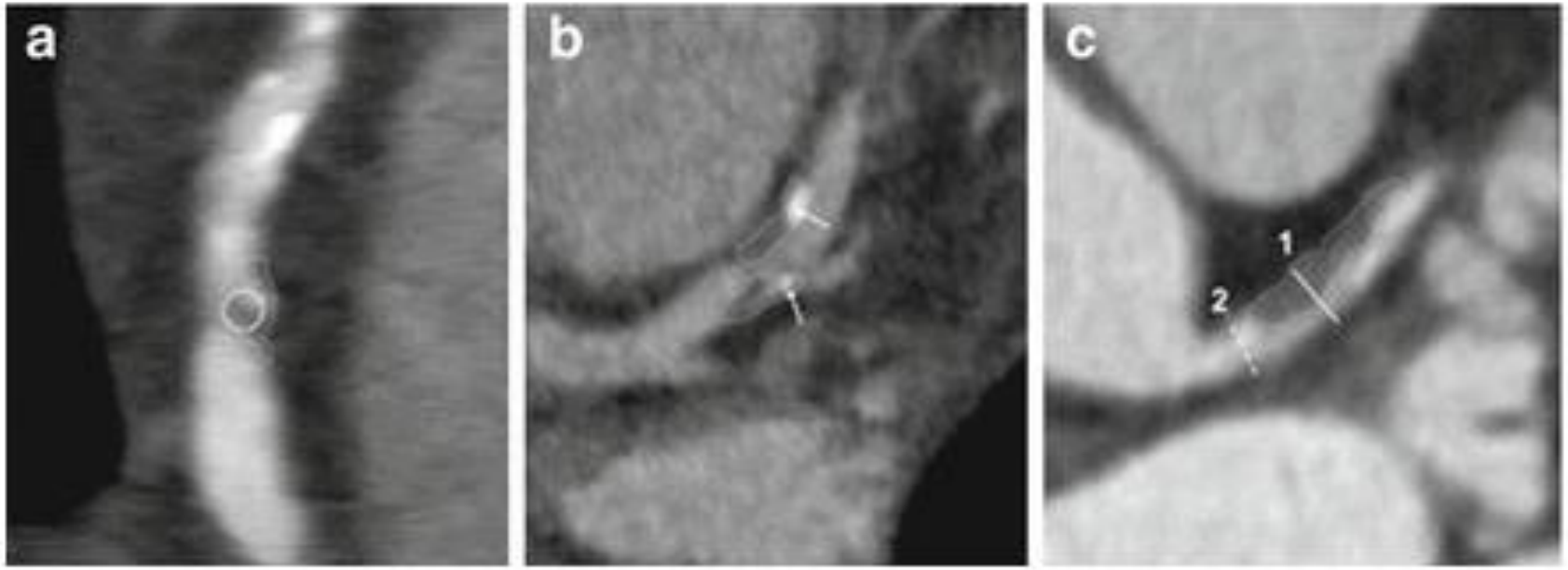


Plaque characterization and future events



Napkin ring sign predicts future events
Don’t ignore the vulnerable plaque encroaching on the lumen!

The vulnerable plaque features by CT



a: Plaque with low HU (<30 HU)
b: Microcalcification predicts vulnerable plaque vs heavy calcification is more stable plaque
c: Positive remodeling where segment 1 diameter total is > 5% of segment 2

Shmilovich H, Victor Y, Cheng B, et al. Vulnerable plaque features on coronary CT angiography as markers of inducible regional myocardial hypoperfusion from severe coronary artery stenoses. Atherosclerosis. 2011;219(2): 588– 95.

CT FFR the holy grail

For intermediate lesions 50-70% CT is limited in evaluation for ischemia and alternative stress testing must be performed

Fractional flow reserve is the measurement of maximum hyperemic flow in a diseased vessel after administration of a vasodilator in comparison to a normal segment of the vessel

FAME, FAME 2 and DEFER trials pushed FFR as the gold standard for stenosis significance

FFR < 0.8 as a cutoff for revascularization vs an angiographic only guided approach leads to lower adverse events

CT FFR measures the functional significance of a lesion without changes to the performance of the CT

Able to assess physiological significance of a lesion

It uses complex mathematical models of fluid dynamics in a coronary tree to simulate blood flow in a particular vessel

CT FFR

This was not possible in the past due to the massive computational requirement of the simulation

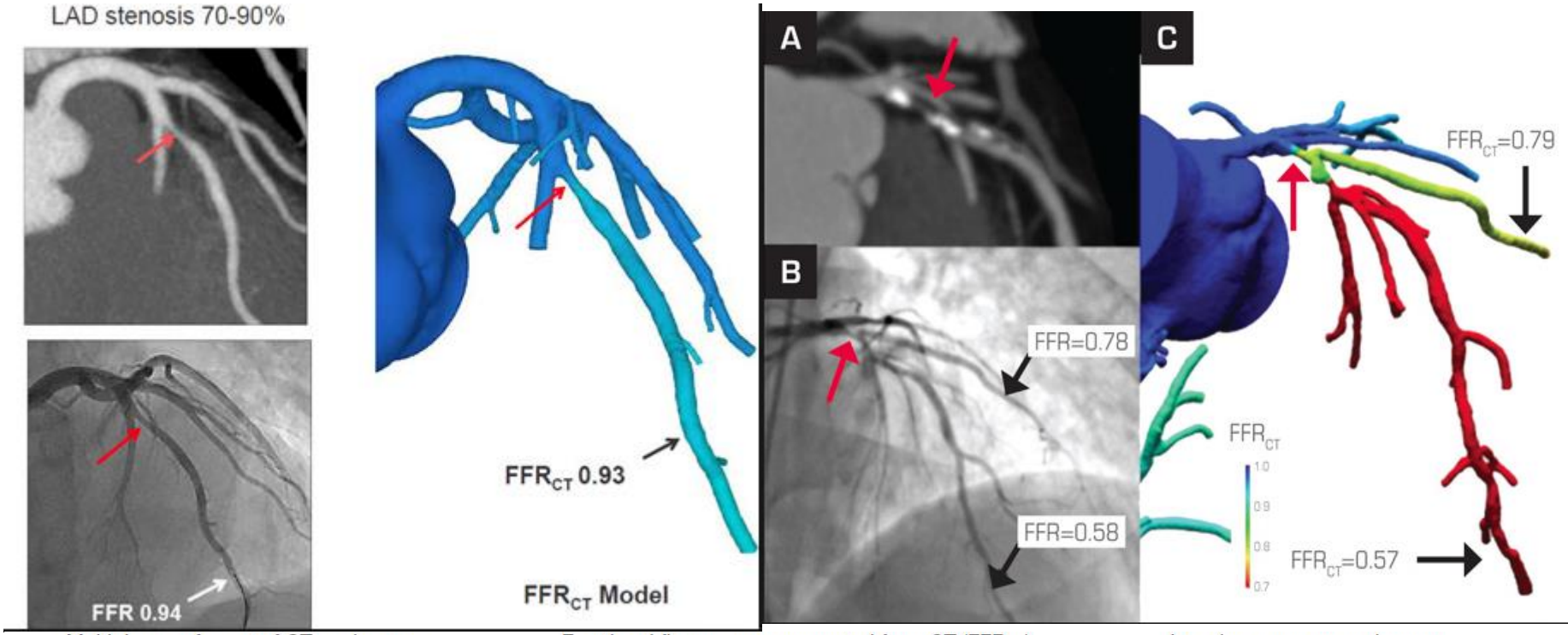
This computational fluid dynamics was a result of similar application in automotive and aerospace industry where fluid flow is simulated over a car or wing surface

Millions of complex equations are solved by the computer to come up with a fluid simulation model for the patient as if the blood is moving through the coronary vasculature

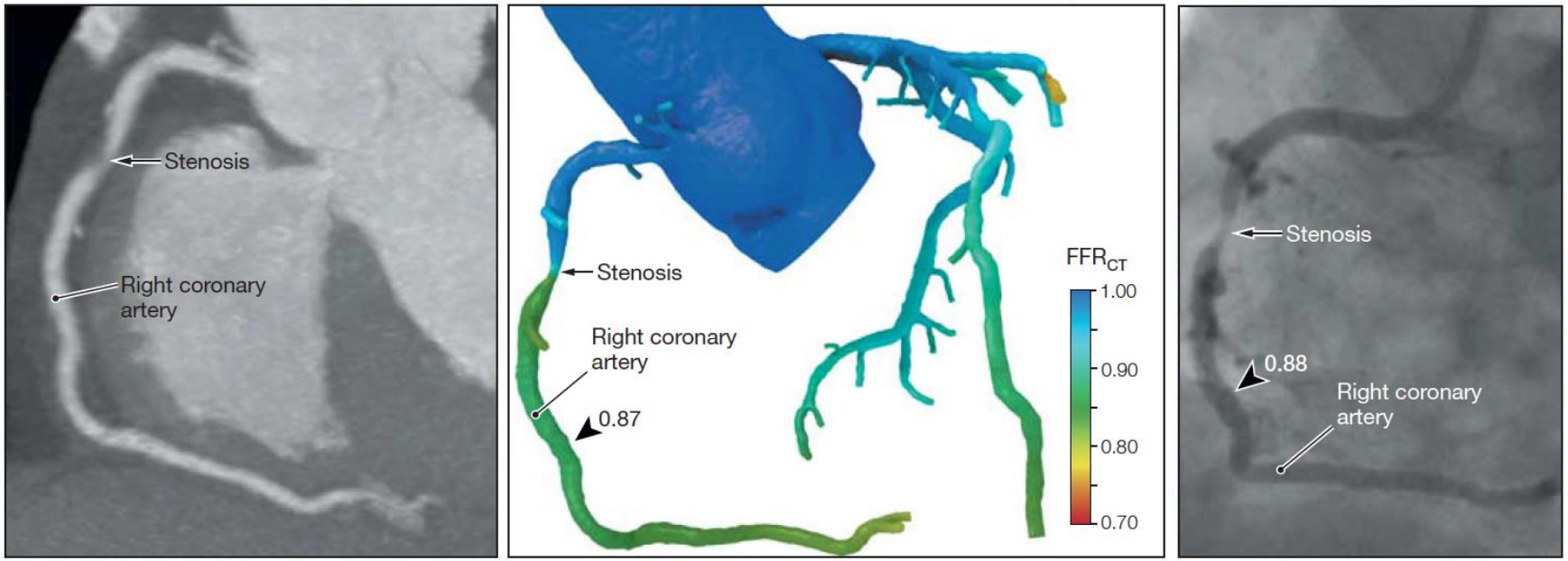
CT FFR

Variables needed for CT FFR

- Quality images
- Brachial blood pressure
- Heart rate
- Cardiac mass calculated by CT



Multiplanar reformat of CT angiogram | Fractional flow reserve computed from CT (FFR$_{CT}$) | Invasive coronary angiogram



Studies validating CT FFR technology

Discover-FLOW study

Defacto study

Heartflow NXT trial

Koo BK, Erglis A, Joon-Hyung D, et al. Diagnosis of ischemia-causing coronary stenosis by noninvasive fractional flow reserve computed from coronary computed tomographic angiograms: results from the prospective multicenter DISCOVER-FLOW (Diagnosis of Ischemia-Causing Stenoses Obtained Via Noninvasive Fractional Flow Reserve) study. J Am Coll Cardiol. 2011;58: 1989– 97.
Min JK, Leipsic J, Pencina MJ, et al. Diagnostic accuracy of fractional flow reserve from anatomic CT angiography. JAMA. 2012;308: 1237– 45.
Norgaard BL, Leipsic J, Gaur S, et al. Diagnostic performance of noninvasive fractional flow reserve derived from coronary computed tomography angiography in suspected coronary artery disease. The NXT trial (Analysis of Coronary Blood Flow Using CT Angiography: Next Steps). J Am Coll Cardiol. 2014;63: 1145– 55.

Discover FLOW trial

4 sites, 103 patients

Compared FFR CT to invasive angiogram and CT

4 false negative vessels where CT FFR was > 0.8 the invasive FFR was indeterminate between 0.75 to 0.8

When FFRct was compared to invasive FFR on a per vessel basis, the sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy were 87.9 %, 82.2 %, 73.9 %, 92.2 % and 84.3 % respectively.

DeFACTO trial

17 sites and 285 patients

FFRct yielded a 73 % accuracy, a 90 % sensitivity, a 54 % specificity, a 67 % positive predictive value and an 84 % negative predictive value.

Heartflow NXT trial published in 2014

- 251 patients in 10 sites
- used improved lumen edge detection and physiological microcirculation model
- Sensitivity of 81%
- Specificity of 79%

Limitations of CT FFR

- Mathematical assumptions are not exact
- Proprietary technology needs off-site analysis
- Super computer needed for calculations which is not readily available
- Need good images free of excessive calcium or motion artifact

Opportunities of use at the hospital in the ER chest pain patient

**Ideal candidate: Heart rate 60- 70, BMI < 35, low to intermediate risk of CAD, considering MPI stress test

**Good candidate: Heart rate 70-80, BMI < 35

Potentially acceptable candidate: Heart rate above 80 but acceptable BP, BMI up to 39 but not all at chest

Poor candidate: Heart rate above 80 and BMI > 39, history of asthma/COPD with wheezing, poor renal function, heavily calcified coronary arteries, history of small stents < 3 mm, atrial fibrillation with significant variation in HR, chest pain patient with bypass grafts (cannot see native coronary arteries well in these patients due to heavy calcification)

Opportunities of use of CT at your hospital in the inpatient and outpatient setting

- Use instead of MPI stress test after giving 2 oral doses of beta blocker
- Use to assess patency of bypass grafts not seen on cardiac cath
- Recurrent chest pain patient with recent MPI stress test
- Equivocal stress test results with unimpressive history
- Myocarditis patient with low likelihood of CAD
- Newly diagnosed cardiomyopathy of unknown etiology

Thank you