Cardiac CT

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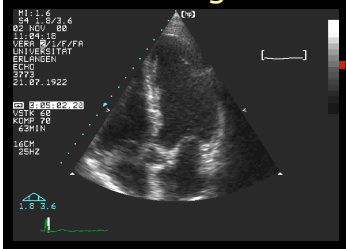
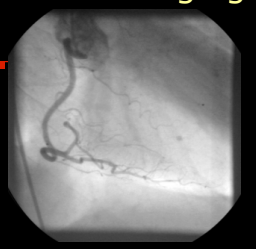
Disclosures

- Current and/or past funding:
  - CIMIT/DoD
  - NIH
  - GE, Siemens
  - Massachusetts Tech Transfer Center

The Challenge for Cardiac Imaging

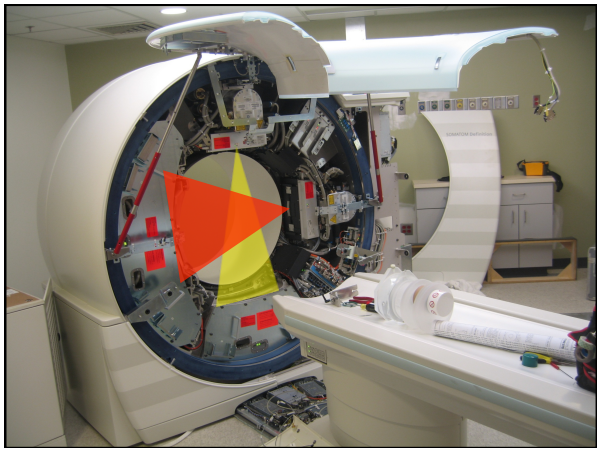




Rapid motion ⇩ High temporal resolution

Small structures, complex anatomy ⇩ High spatial resolution

Images Courtesy S. Achenbach



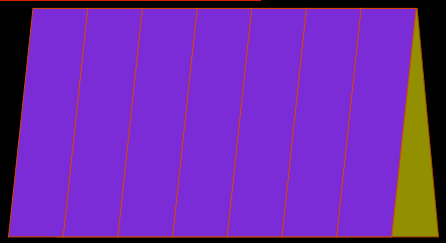
Three Modes

Dual Source Mode
- Both tubes with same kVp
- Excellent for fast acquisition
- Temporal resolution ~80ms

Dual Energy Mode
- Two tubes at different energies (80 and 140kVp)
- Excellent for dual energy applications

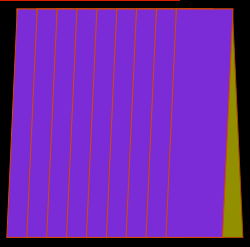
Flash Mode
- Two tubes at same energy
- Interleaved spirals

Pitch = table feed relative to gantry rotation



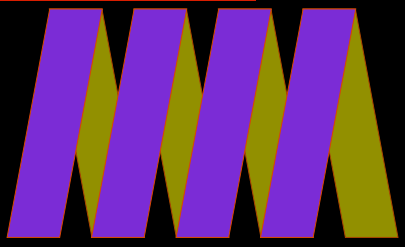
Pitch = 1 → no overlap, no gap

Typical Cardiac Pitch: Retrospective Recon



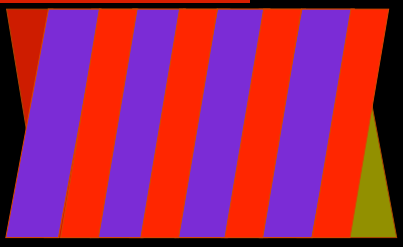
Pitch = 0.2 → 80% overlap

Limit of pitch for single source



Pitch = 1.5 → 50% gap

Flash Mode: Ultra high-pitch mode

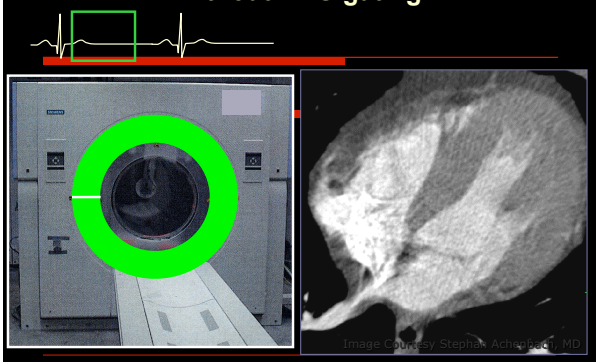


Pitch = 3.0 to 3.4; No gap

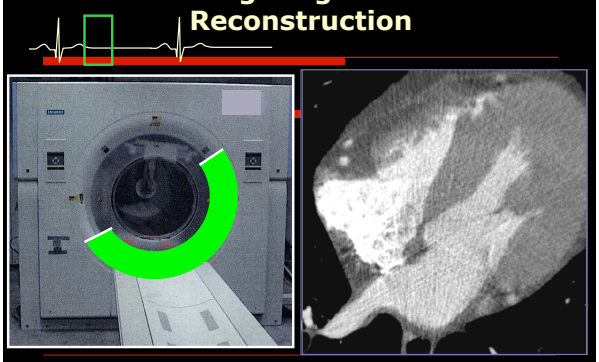
Unique Technical Aspects of Cardiac CT

- Data Reconstruction
  - Half-scan recon
  - Multi-sector recon
- Cardiac Synchronization
  - Retrospective
  - Prospective
  - None (Flash mode)

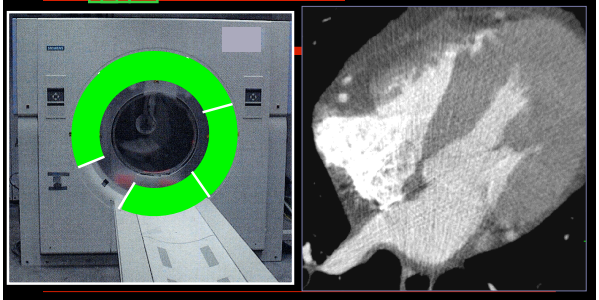
Without ECG gating



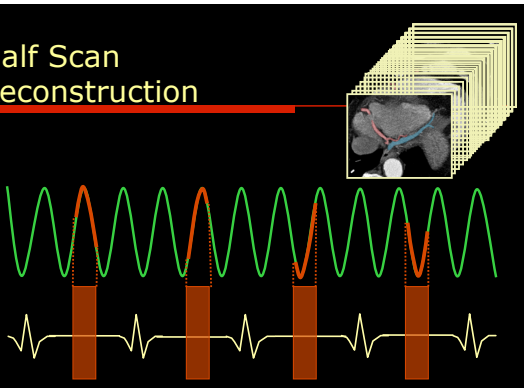
ECG gating & Halfscan Reconstruction



ECG gating & Halfscan Reconstruction

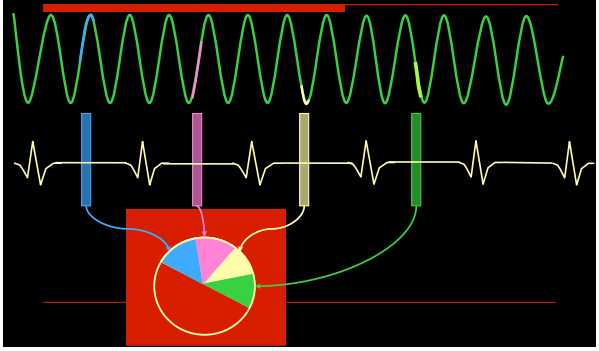


Half Scan Reconstruction



Multi Segment Reconstruction

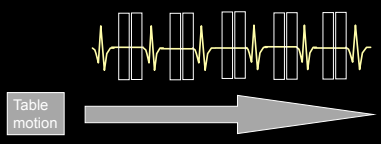
4 x 45° projections



Synchronization with Cardiac Cycle

- Retrospective gating
- Prospective triggering

Retrospective Gating

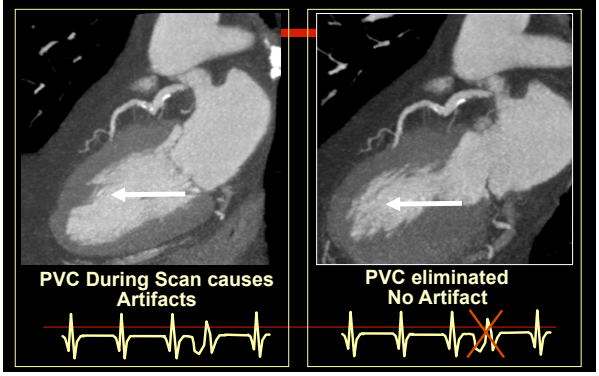


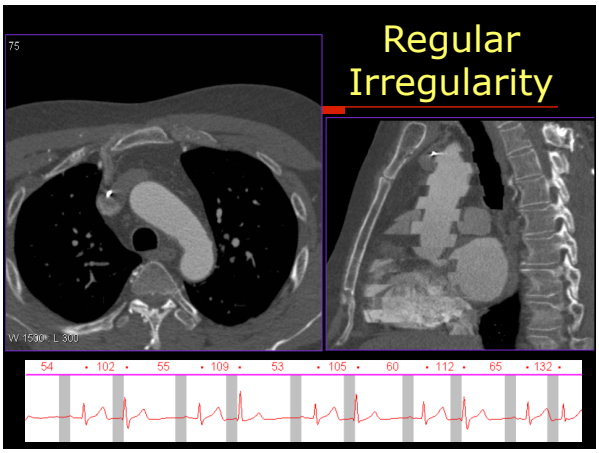
Higher radiation dose!

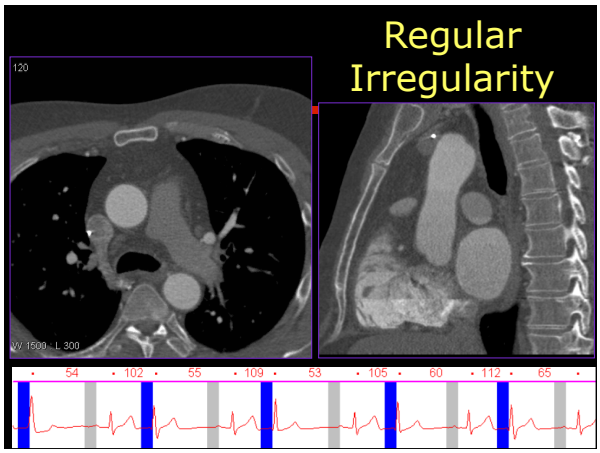
Allows multiple time points in R-R interval

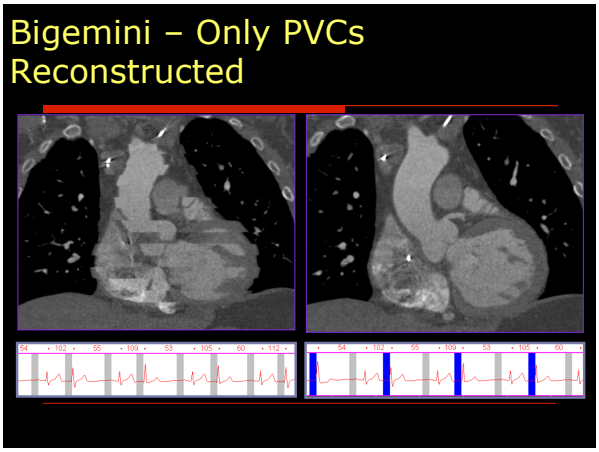
Allows ECG editing

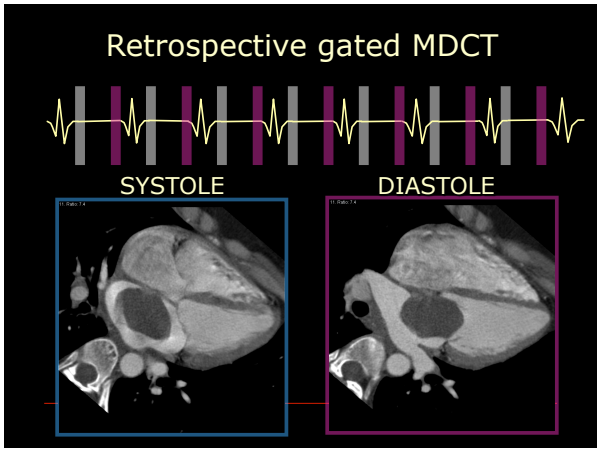
Retrospective ECG-Gating

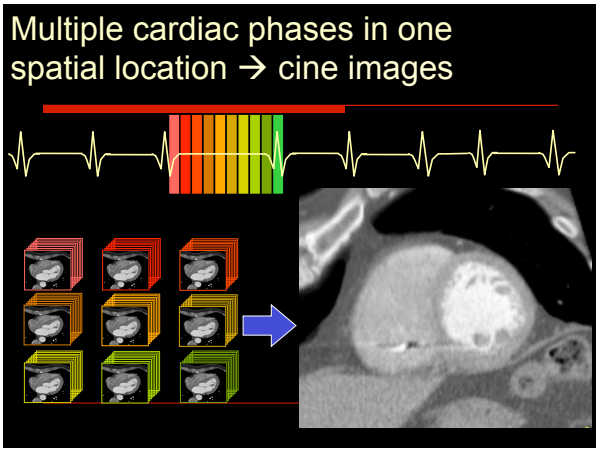


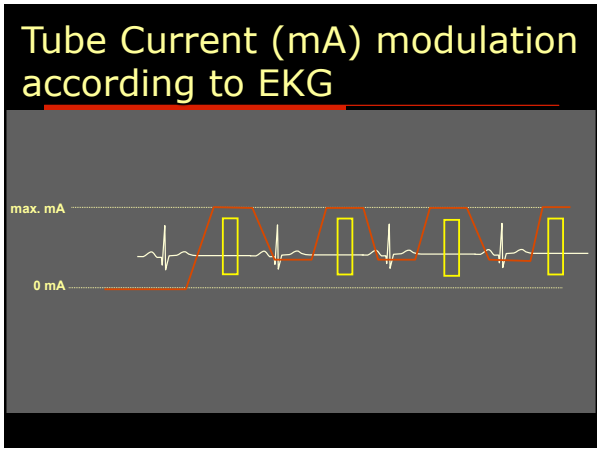

Regular Irregularity


Regular Irregularity

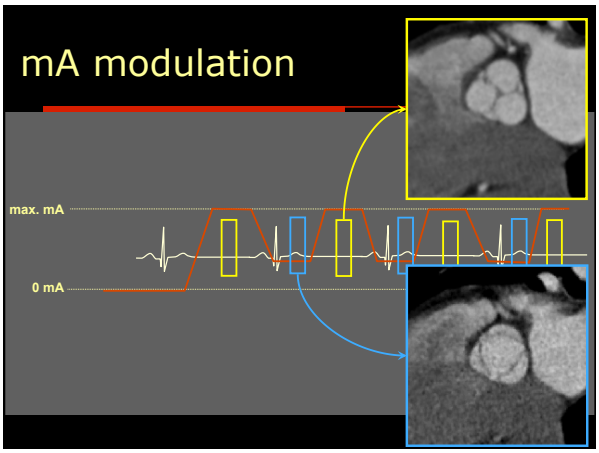

Bigemini – Only PVCs Reconstructed


Retrospective gated MDCT
SYSTOLE
DIASTOLE


Multiple cardiac phases in one spatial location → cine images


Tube Current (mA) modulation according to EKG
max. mA
0 mA

mA modulation



Synchronization with cardiac motion

- **Prospective ECG Triggering**

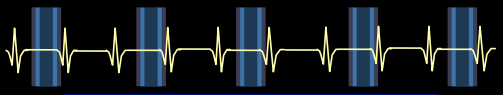
Synchronization with cardiac motion

- **Prospective ECG Triggering**

Low radiation dose!
Only limited number of phases (time points) in diastole

Synchronization with cardiac motion

- **Prospective ECG Triggering**



Low radiation dose!
Only limited number of phases (time points) in diastole

Analyzing Cardiac CT Data

- Scrolling through axial source data sets
- Best source of information

Axial images

MPR

MIP

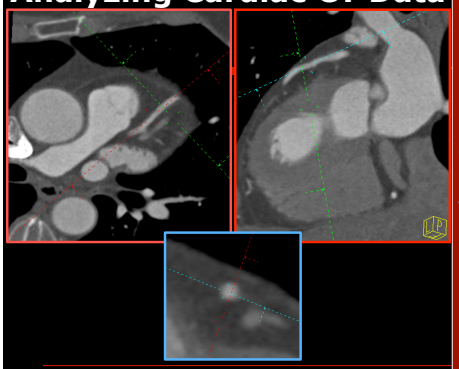
Curved MPR

VRT (3D)

Function MPR

Function 4D

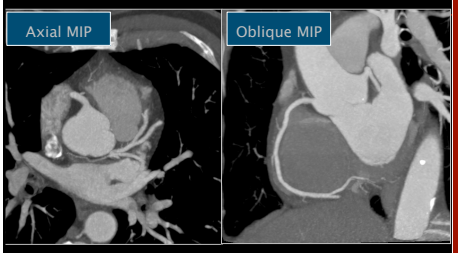
Analyzing Cardiac CT Data



Allows creation of oblique planes in the long and short axis

Axial images
MPR
MIP
Curved MPR
VRT (3D)
Function MPR
Function 4D

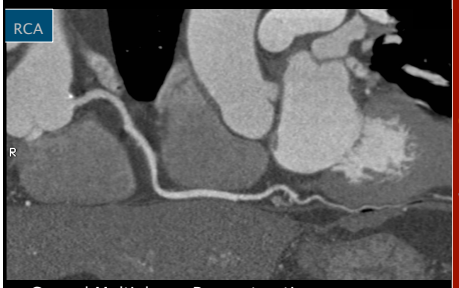
Analyzing Cardiac CT Data



- Maximum Intensity Projection – "thickens up"
- Any plane, any slice thickness

Axial images
MPR
MIP
Curved MPR
VRT (3D)
Function MPR
Function 4D

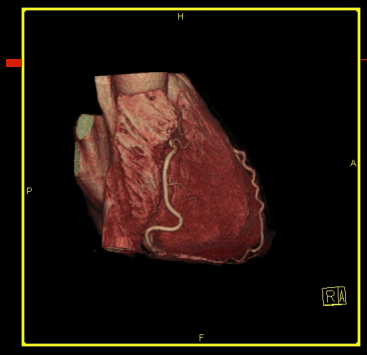
Analyzing Cardiac CT Data



- Curved Multiplanar Reconstruction
- Follows centerline of one vessel, distorts anatomy

Axial images
MPR
MIP
Curved MPR
VRT (3D)
Function MPR
Function 4D

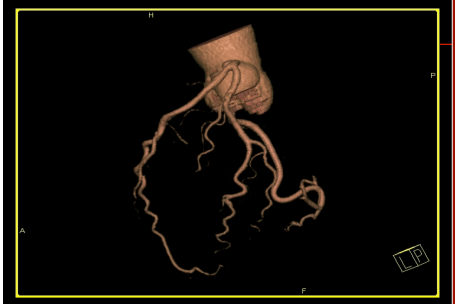
Analyzing Cardiac CT Data



Volume rendered technique (VRT) is useful for graft and fistulas analysis – not for stenosis assessment

Axial images
MPR
MIP
Curved MPR
VRT (3D)
Function MPR
Function 4D

Analyzing Cardiac CT Data



Allows semiautomatic extraction of coronary arteries and display in 3D VRT or curved MPR

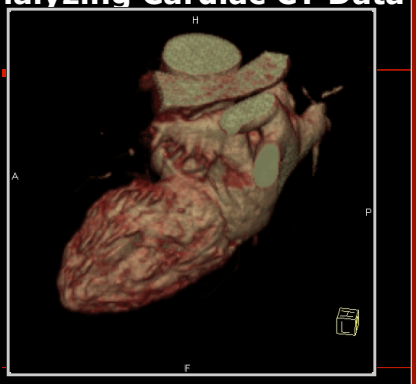
Axial images
MPR
MIP
Curved MPR
VRT (3D)
Function MPR
Function 4D

Analyzing Cardiac CT Data

- Three chamber cine; Any plane can be obtained

Axial images
MPR
MIP
Curved MPR
VRT (3D)
Function MPR
Function 4D

Analyzing Cardiac CT Data

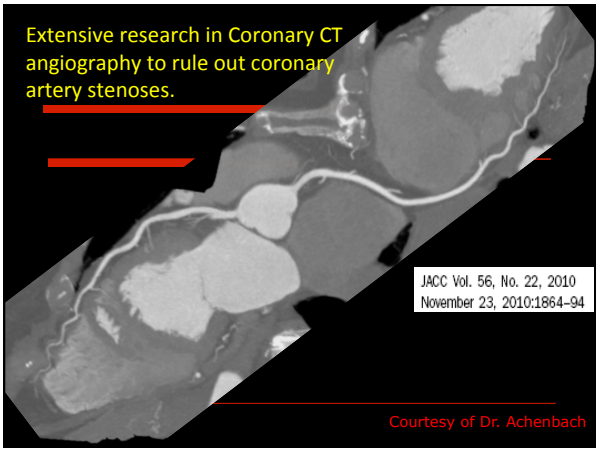


4D CT-ventriculogram

- Axial images
- MPR
- MIP
- Curved MPR
- VRT (3D)
- Function MPR
- **Function 4D**

Coronary Arteries

Extensive research in Coronary CT angiography to rule out coronary artery stenoses.



Courtesy of Dr. Achenbach

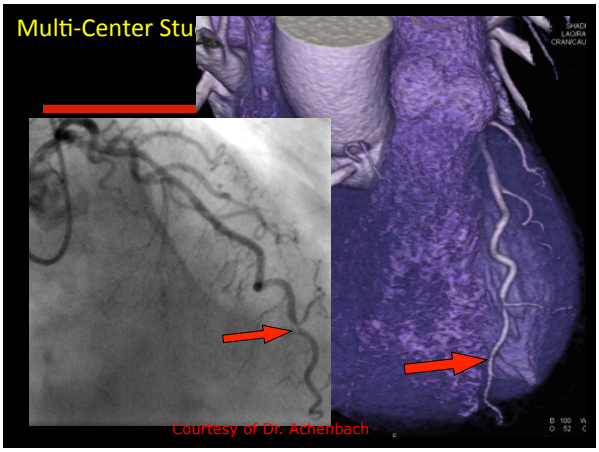
Multi-Center Studies

	n	Sensitivity	Specificity	Prevalence
ACCURACY[1]	230	95%	83%	24%
Meijboom[2]	360	99%	64%	68%
CORE 64[3]	291	85%	90%	56%

1 Budoff et al, JACC 2008
2 Meijbom et al, JACC 2008
3 Miller et al, NEJM 2008

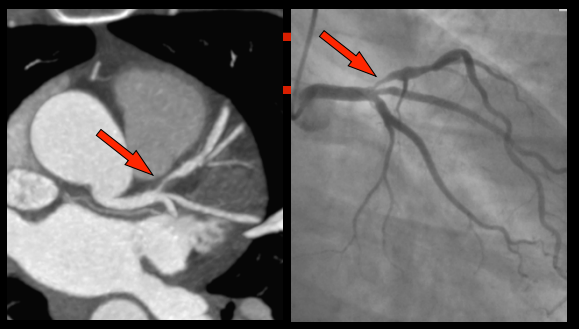
Courtesy of Dr. Achenbach

Multi-Center Stu



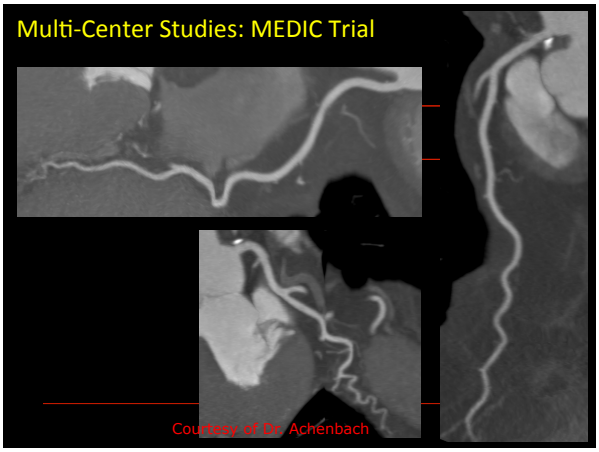
Courtesy of Dr. Achenbach

Multi-Center Studies: MEDIC Trial



Courtesy of Dr. Achenbach

Multi-Center Studies: MEDIC Trial

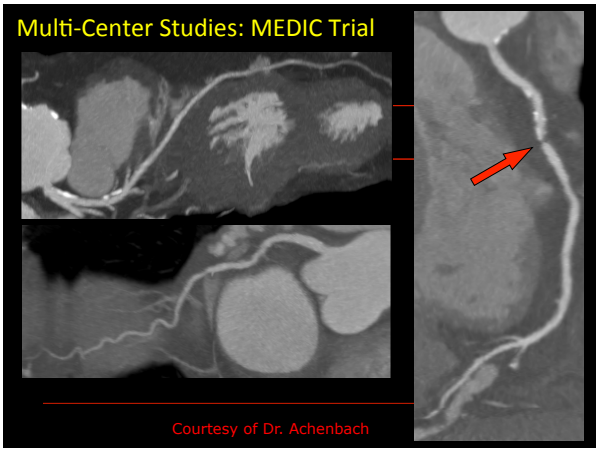


Courtesy of Dr. Achenbach

Multi-Center Studies: MEDIC Trial

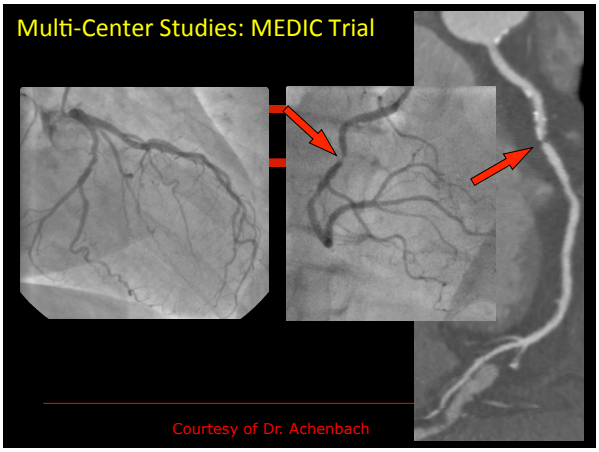
Courtesy of Dr. Achenbach

Multi-Center Studies: MEDIC Trial



Courtesy of Dr. Achenbach

Multi-Center Studies: MEDIC Trial



Courtesy of Dr. Achenbach

Multi-Center Studies: MEDIC Trial

Mean heart rate :	72/min
Mean effective dose:	5.9 mSv

Identification of 83 patients who subsequently underwent revascularization:

Sensitivity:	95%
Specificity:	91%
Neg. pred. value:	99%
Pos. pred. value:	71%

Courtesy of Dr. Achenbach

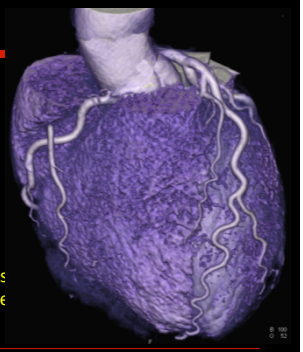
Rule out Stenoses

- In a symptomatic patient, if Cardiac CT shows no stenosis, there is essentially 0% event rate.
- Safe to discharge

Courtesy of Dr. Achenbach

Coronary CTA

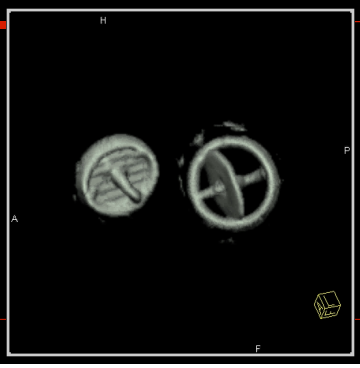
- Coronary CTA can rule out stenoses with high accuracy
- Safe to rule out stenoses in symptomatic individuals
- Presence of coronary stenoses and extensive coronary plaque have prognostic implications



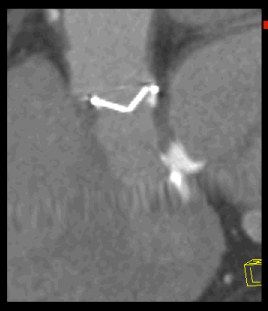
Courtesy of Dr. Achenbac

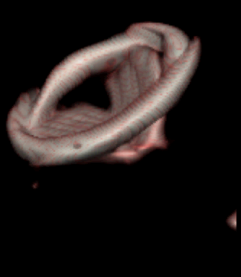
Other Cardiac Pathology

Tilting Disc Valve



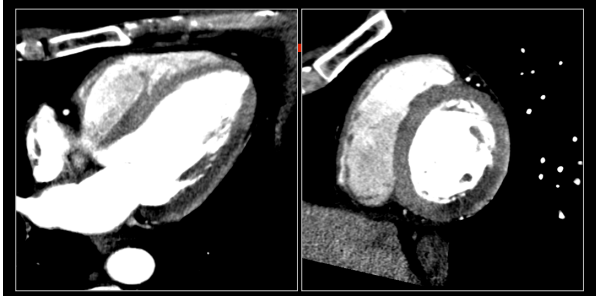
Stuck Valve





Courtesy Dr. Stephan Achenbach

Perfusion

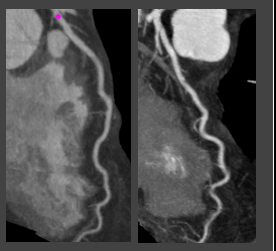


Narrow Window centered around enhanced myocardium
5mm-8mm MPR or MinIP (NOT MIP)

CARDIAC MRCT PROGRAM

First generation DSCT - Half Scan @ 83ms

3D Volume Rendering

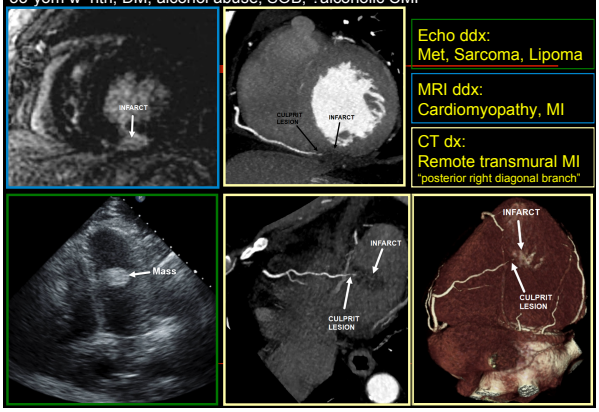


Diastole Systole

Cardiac Scan at 89-96 bpm

Courtesy of S. Achenbach, University of Erlangen

53-yom w htn, DM, alcohol abuse, SOB, ?alcoholic CMP

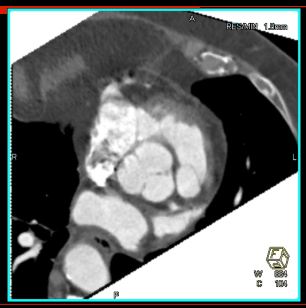


Echo ddx:
Met, Sarcoma, Lipoma

MRI ddx:
Cardiomyopathy, MI

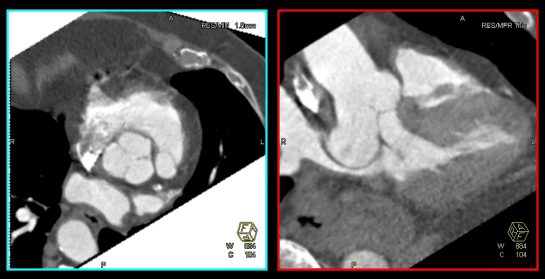
CT dx:
Remote transmural MI
"posterior right diagonal branch"

Sinus of Valsalva Aneurysm

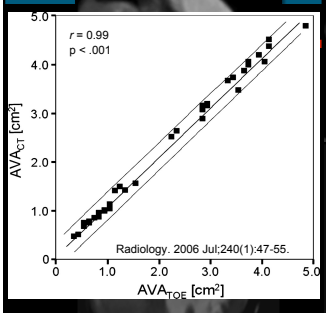


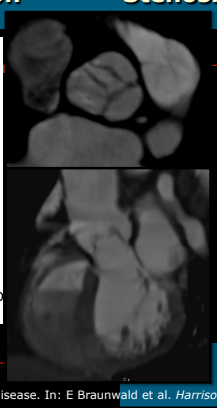
Sinus of Valsalva Aneurysm

Echocardiogram Normal

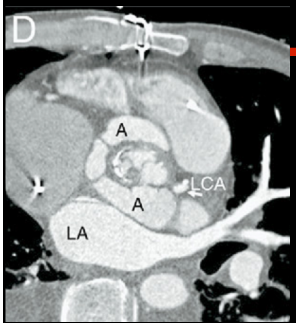


Aortic Regurgitation **Stenosis**





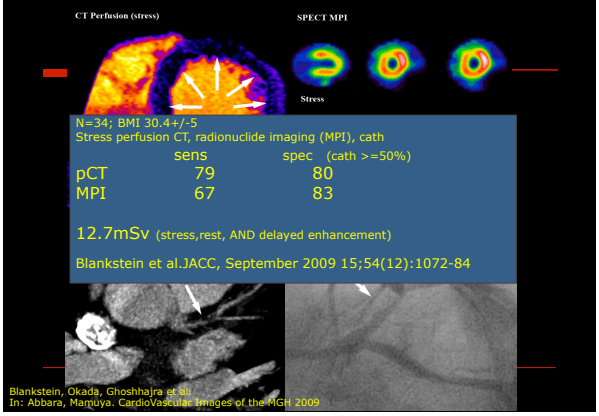
A Soni, S Abbara. CT Assessment of Vavlular Heart Disease. In: E Braunwald et al. *Harrison's*



Per-valve-based analysis	Percent	95% CI
Sensitivity (28/29)	97	82%–100%
Specificity (42/44)	95	85%–99%
Positive predictive value (28/30)	93	78%–99%
Negative predictive value (41/42)	98	88%–100%
Diagnostic accuracy (70/73)	96	88%–99%

G. Feuchtner, ..., H. Alkhadi.
J Am Coll Cardiol 2009;53:436–44

Adenosine Stress CTp



N=34; BMI 30.4+/-5
Stress perfusion CT, radionuclide imaging (MPI), cath

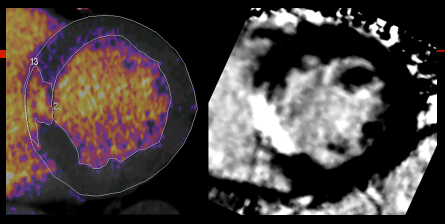
	sens	spec (cath >=50%)
pCT	79	80
MPI	67	83

12.7mSv (stress,rest, AND delayed enhancement)

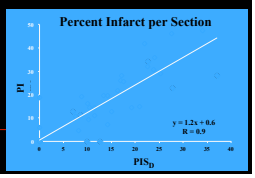
Blankstein et al.JACC, September 2009 15;54(12):1072-84

Blankstein, Okada, Ghoshhajra et al.
In: Abbara, Manjuya. CardioVascular Images of the MGH 2009

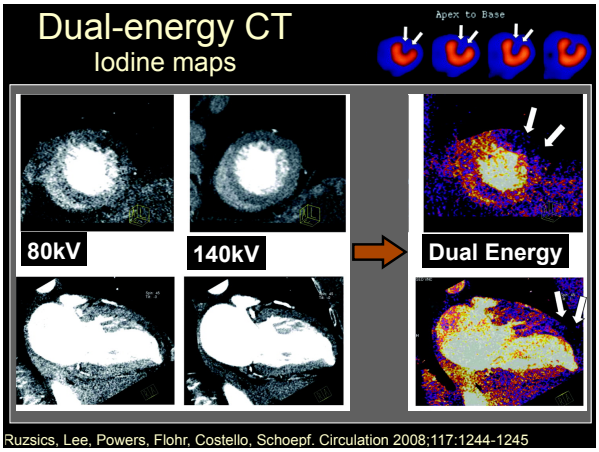
Scar / Viability Imaging



Delayed Enhancement Dual Energy CT vs. MRI, Rosenblum, Ruzsics, … Schoepf, MUSC. AHA09

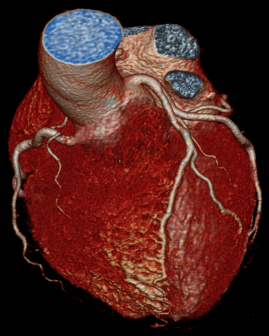


Dual-energy CT
Iodine maps



Ruzsics, Lee, Powers, Flohr, Costello, Schoepf. Circulation 2008;117:1244-1245

Second generation DSCT - Half Scan @ 75ms
Sub-second Spiral Acquisition with Pitch>3

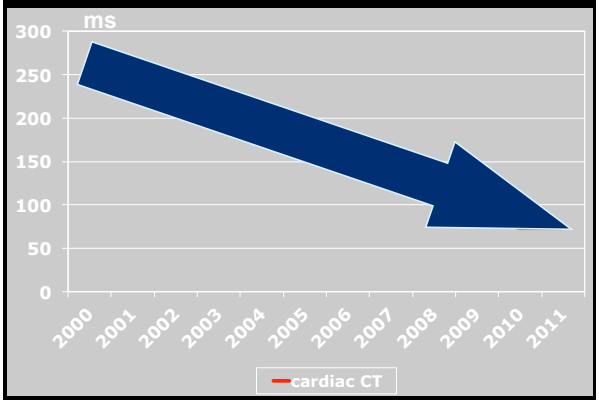


DSCT allows for **pitch of 3.2**
→ Table speed = 43 cm/sec
→ Coronary imaging @<1mSv, without breath hold?

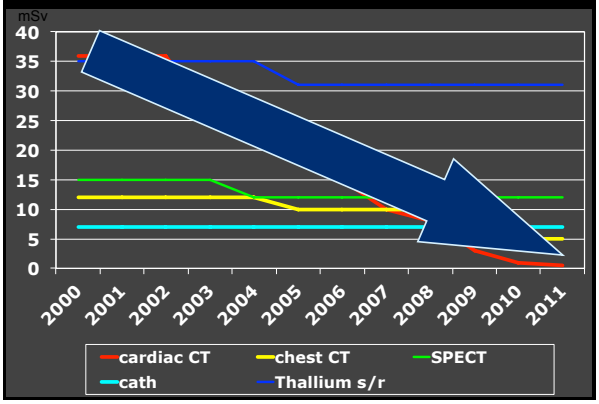
Images Courtesy of Christianne Leidecker, PhD

Future of Cardiac CT

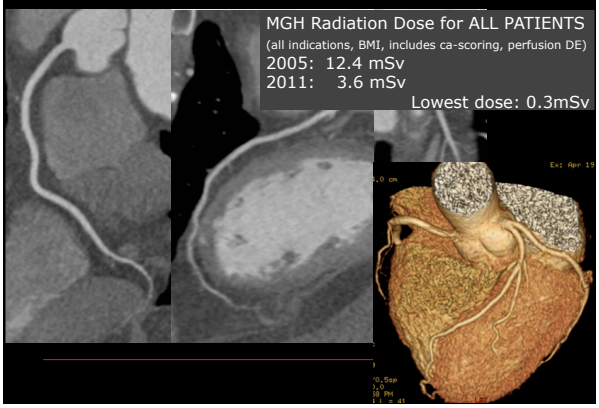
Temporal Resolution



Changes in Radiation Doses past 10 Years

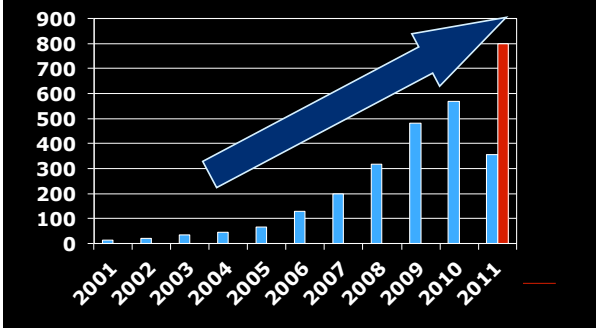


61yof, BMI 31 → Effective Dose 1.3 mSv



(((((("cardiac CT") OR "cardiac CTA") OR "coronary CT") OR "coronary MDCT") OR "coronary CTA") AND "20xx – 200xx+1"[Publication Date]
Not all articles captured!

Pubmed cited articles by years



CORE-64 Multicenter Accuracy Trial

Measure of Accuracy	Patient-Based Detection	
	Quantitative MDCTA (N=291)	Visual MDCTA (N=291)
AUC — median (95% CI)	0.93 (0.90–0.96)	0.93 (0.89–0.95)
Stenosis by CCA — no.	163	163
Negative predictive value — % (95% CI)	83 (75–89)	81 (73–87)

MEDIC International Multicenter Trial
(Achenbach et al. SCCT 2011)
Sens. & Spec. in 90's
NPV high 90's!

Miller et al. New Engl J Med 2008;359:2324-36

Prediction for Cardiac CT in 2021

- All scans completed in <1 second
- Temporal resolution will rival or exceed that of cardiac Cath, MRI, and echo
- Excellent contrast resolution
- Minimal radiation penalty
- Clinical benefits established with randomized, multicenter trials
- Many applications beyond coronary arteries

Courtesy of Dr. Sunhy Abarra, MGH

The Emergency Room of the Future