AAPM 2011 Summit on CT Dose

CTA Throughout the Ages

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MASSACHUSETTS GENERAL HOSPITAL
HEART CENTER

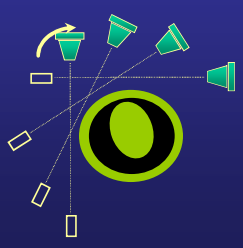
The **Electric and Musical Industries Ltd** (EMI) formed in March 1931 from a merger of the UK Columbia Graphophone Company and the Gramophone Company.

EMI office at Abbey Road

1971 1st CT scanner 1972 1st patient 1973 Commerically available (EMI)

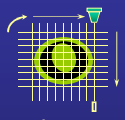
Four Generations of CT Scanners

1st Generation



Four Generations of CT Scanners

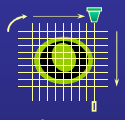
1st Generation



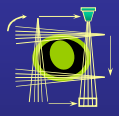
2nd Generation

Four Generations of CT Scanners

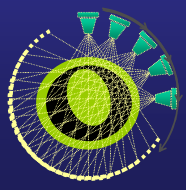
1st Generation



2nd Generation

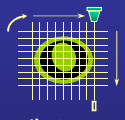


3rd Generation

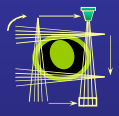


Four Generations of CT Scanners

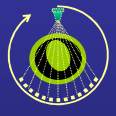
1st Generation



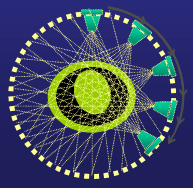
2nd Generation



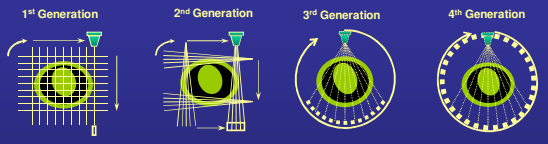
3rd Generation



4th Generation



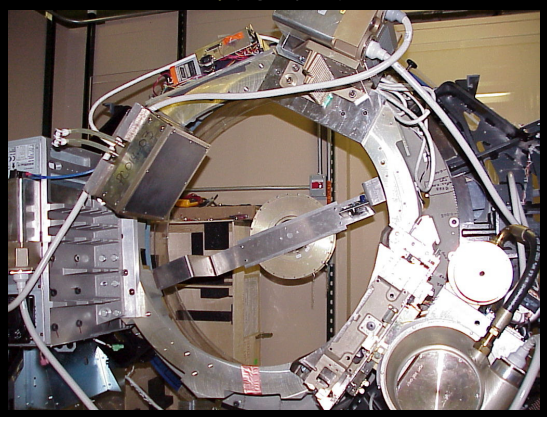
Four Generations of CT Scanners



No longer produced commercially for medical use

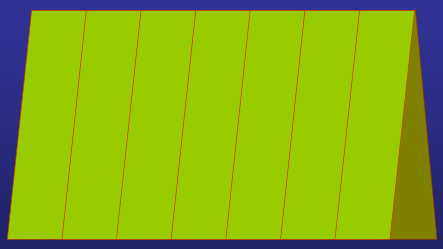
4th - not be practical as a multislice

A 3rd Generation Gantry (LightSpeed)



Spiral CT

Pitch = table feed relative to gantry rotation

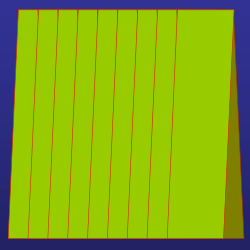


Pitch = **1.0** → no overlap, no gap
Standard acquisition

Pitch = table feed relative to gantry rotation

Pitch = **1.5** → 50% gap
Fast scan for large volumes (vascular studies)

Pitch = table feed relative to gantry rotation



Pitch = **0.3** → 70% overlap
Used in conventional retrospectively gated CT

Pitch = table feed relative to gantry rotation

Pitch = **3.0** → 200% gap

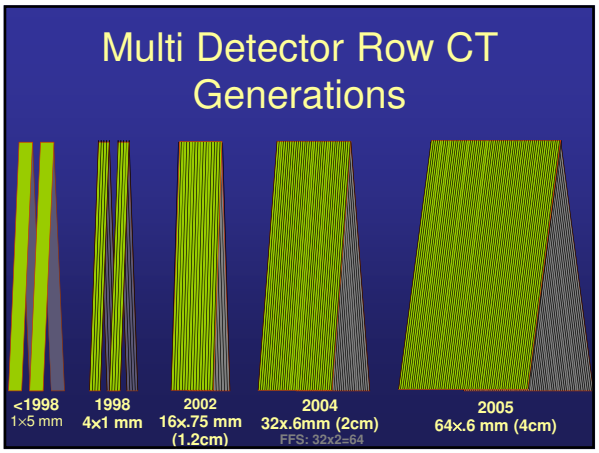
No image reconstruction on single source CT

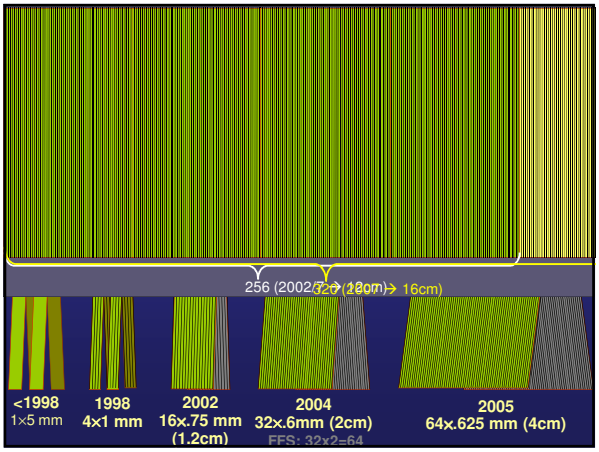
High Pitch Mode

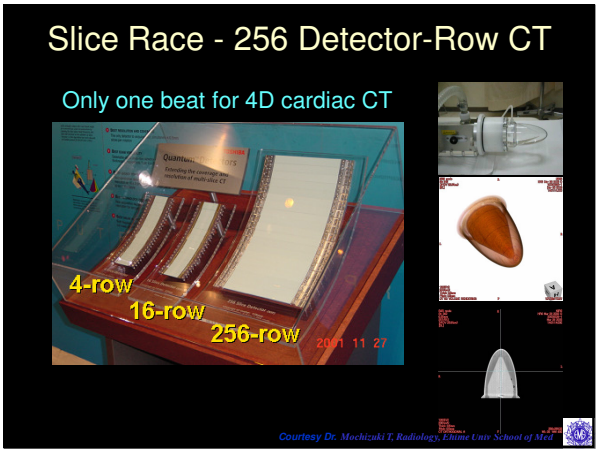
Pitch = **3.0** on Dual Source CT system

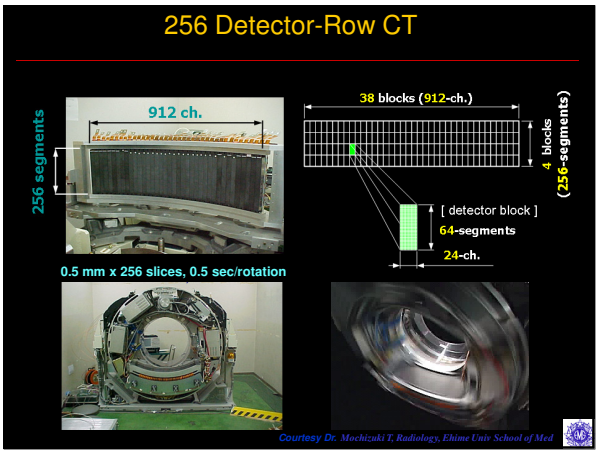
Second tube offset by 90° ('fills gap'), therefore image reconstruction is possible

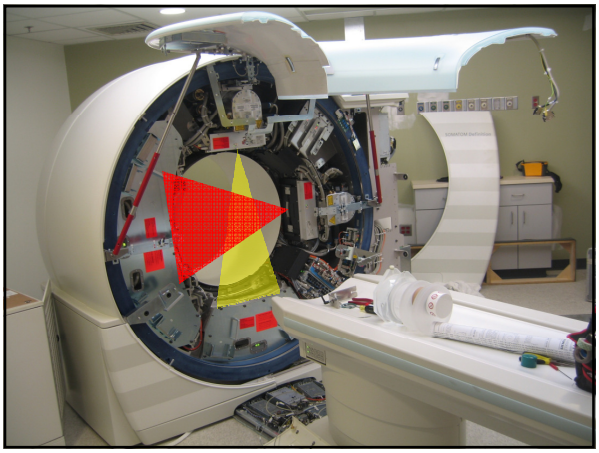
MultiDetector CT Scanners

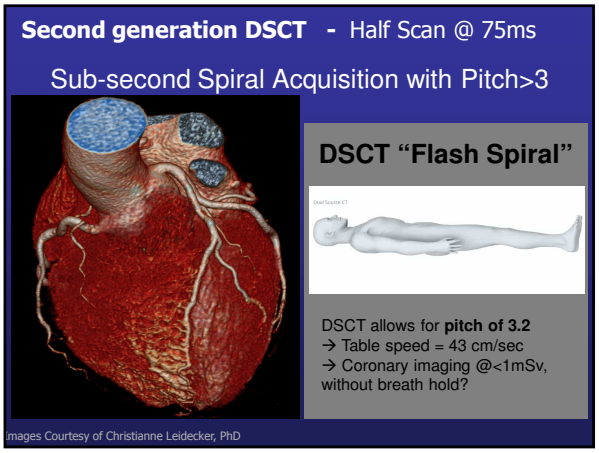

Multi Detector Row CT Generations
<1998
1×5 mm
1998
4x1 mm
2002
16x.75 mm
(1.2cm)
2004
32x.6mm (2cm)
FFS: 32x2=64
2005
64x.6 mm (4cm)

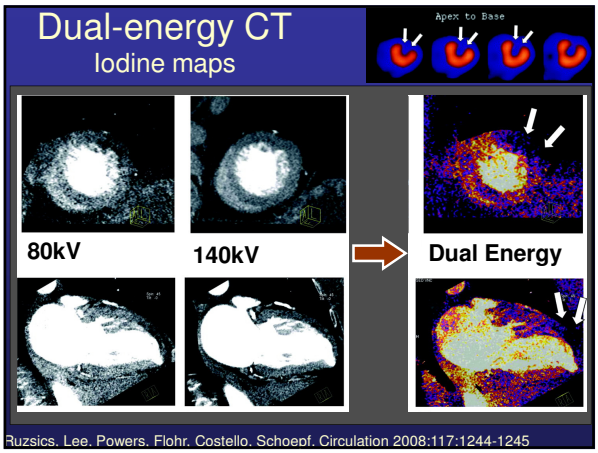

256 (2002)
32 (2004)
16cm)
<1998
1×5 mm
1998
4x1 mm
2002
16x.75 mm
(1.2cm)
2004
32x.6mm (2cm)
FFS: 32x2=64
2005
64x.625 mm (4cm)

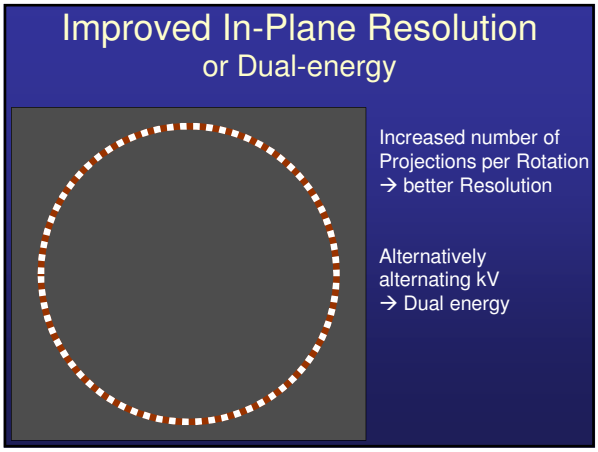

Slice Race - 256 Detector-Row CT
Only one beat for 4D cardiac CT
4-row
16-row
256-row
2001 11 27
Courtesy Dr. Mochizuki T, Radiology, Ehime Univ School of Med

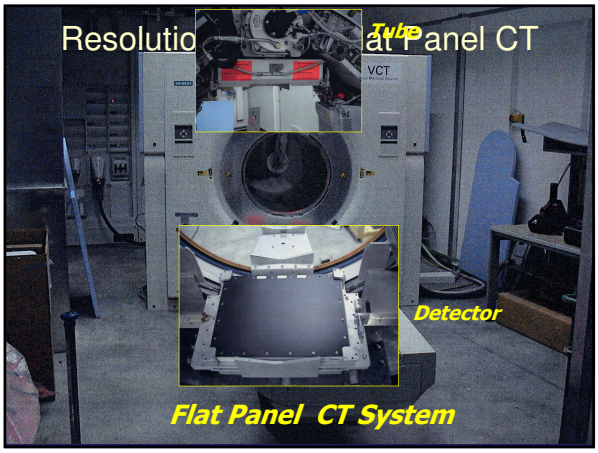

256 Detector-Row CT
912 ch.
256 segments
38 blocks (912-ch.)
4 blocks (256-segments)
[detector block]
64-segments
24-ch.
0.5 mm x 256 slices, 0.5 sec/rotation
Courtesy Dr. Mochizuki T, Radiology, Ehime Univ School of Med

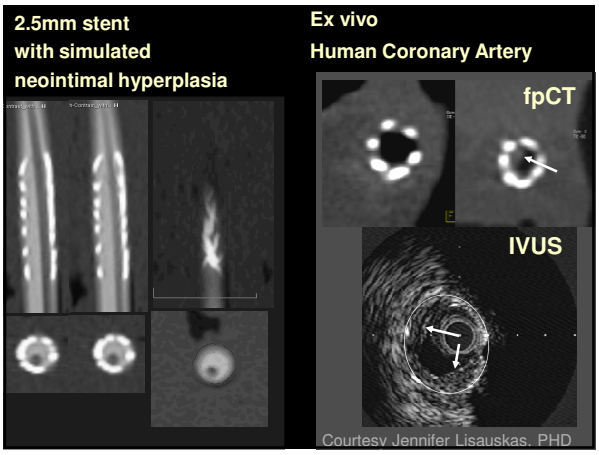


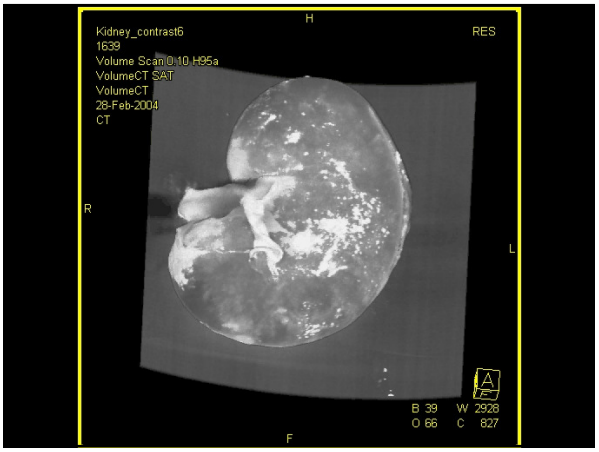

Second generation DSCT - Half Scan @ 75ms
Sub-second Spiral Acquisition with Pitch>3
DSCT "Flash Spiral"
DSCT allows for pitch of 3.2
→ Table speed = 43 cm/sec
→ Coronary imaging @<1mSv, without breath hold?
Images Courtesy of Christianne Leidecker, PhD


Dual-energy CT
Iodine maps
Apex to Base
80kV
140kV
Dual Energy
Ruzsics, Lee, Powers, Flohr, Costello, Schoepf. Circulation 2008:117:1244-1245


Improved In-Plane Resolution
or Dual-energy
Increased number of
Projections per Rotation
→ better Resolution
Alternatively
alternating kV
→ Dual energy


Resolutio
at Panel CT
Tube
VCT
Detector
Flat Panel CT System


2.5mm stent
with simulated
neointimal hyperplasia
Ex vivo
Human Coronary Artery
fpCT
IVUS
Courtesy Jennifer Lisauskas, PHD


Kidney_contrast6
1639
Volume Scan 0 10 H95a
VolumeCT SAT
VolumeCT
26-Feb-2004
CT
H
RES
R
L
F
B 39
W 2928
O 66
C 827

CTA

Single detector row scanners - limitations

- Cannot Image entire lower extremity inflow / runoff due to time restriction:
  - To cover aortic bifurcation to feet at 2.5mm slices:
  - 1000mm/2.5=400slices
  - @ pitch of 2, 0.75s rotation time →**150s acquisition time**
  - @ 3cc/sec → 400-450cc of contrast required
  - Thinner slices, larger coverage and higher injection rates desired → longer scan time and more contrast

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4-slice CT

DLP = 1578 mGy × cm
CTDI = 12.97 mGy

Parameter	Value
Scanning coverage (mm)	1,233 ± 98 (988–1,410)
Scanning duration (sec)	66 ± 5.2 (53–75)
Number of transverse sections	908 ± 96 (766–1,129)
Iodine dose (g)	55.2 ± 1.8 (52.5–60.0)
Volume of contrast medium (mL)	184 ± 5.9 (175–200)
Contrast medium injection rate (mL/sec)	3.5 ± 0.3 (2.8–4.0)
Injection duration (sec)	53 ± 6.3 (45–71)
Scanning-to-injection duration ratio	0.81 ± 0.08 (0.66–0.95)
Delay between contrast medium initiation and scanning (sec)	22.3 ± 3.7 (18–30)

Rubin et al. Radiology. 2001 MDCT angiography of lower extremity arterial inflow and runoff: initial experience.

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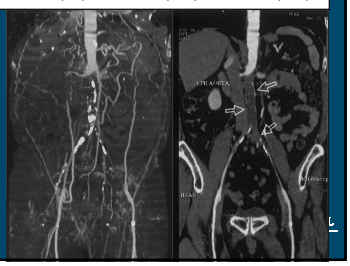
4-slice CT

Veins	Arteriovenous Difference (HU)	No. of Locations	No. of Legs	No. of Patients
Deep	<30	4/180 (2%)	3/48 (6%)	3/24 (13%)
	<50	7/180 (4%)	5/48 (10%)	4/24 (17%)
Superficial	<30	5/174 (3%)	5/48 (10%)	5/24 (21%)
	<50	8/174 (5%)	7/48 (15%)	6/24 (25%)
All	<30	9/354 (3%)	5/48 (10%)	5/24 (21%)
	<50	15/354 (4%)	9/48 (19%)	7/24 (29%)



Rubin et al. Radiology 2001

CTA - **Advantages**

- Non invasive, readily available, fast
- Moderate cost compared to Angio & MRI
- Excellent spatial resolution / true 3D datasets
  - Great re-test reliability
  - Centerline reconstructions
- Excellent depiction of lumen, mural thrombus, calcifications and side branches
- Alternative diagnoses

CTA - **Disadvantages**

- Radiation
- Iodinated contrast material required
- Bone hinders MIP images of LE
  - Bone extraction algorithms and Dual Energy
- Contraindications:
  - Contrast allergy, renal failure (Crea. >1.5), pregnancy etc.

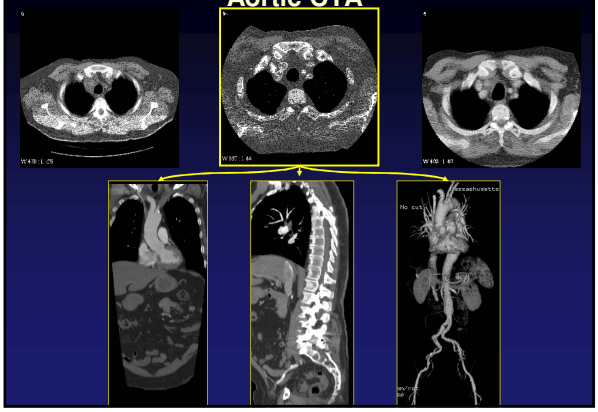
CTA - **Role**

- Initial screening test for suspected symptomatic AAA
- Follow Up of known AAA
  - Radiation & iodinated contrast → does not allow for short intervals!
- Procedure planning!
  - Ideal for surgery and stent placement planning
- Follow Up after treatment

Aortic CTA – Imaging Protocol

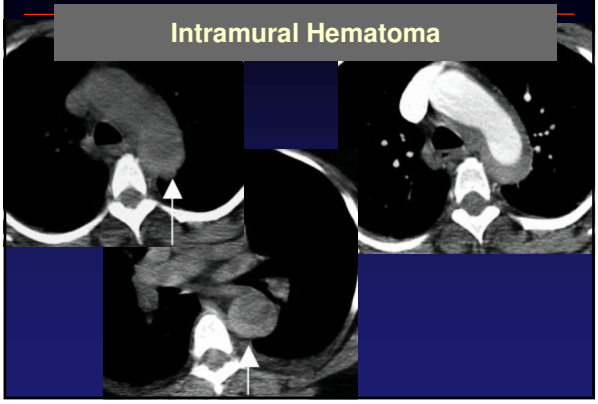
- **non-contrast scan**
  - slice thickness 5mm to reduce radiation
  - intramural hematoma
  - displacement of intimal calcifications in dissections
- **CTA acquisition**
  - 100-135cc of nonionic iodinated contrast
  - 3-5cc/second
  - automated threshold triggering (smart prep, care bolus etc.)
  - or: test bolus
- **Delayed scan**
  - thicker collimation
  - 2 minutes following injection
  - false lumen in dissection
  - Extravasations: trauma / aneurysm rupture
  - endoleak following stent-graft for aortic aneurysms

Aortic CTA

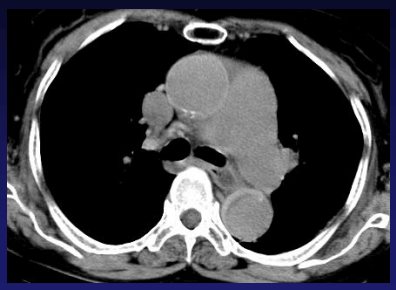


Why pre-contrast scan?

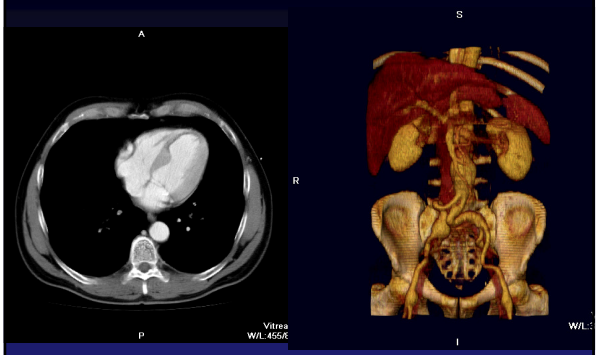
Intramural Hematoma



Intramural Hematoma

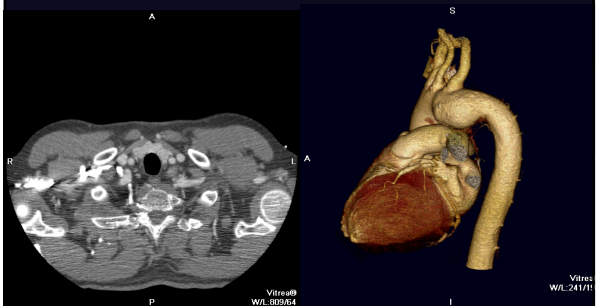


Why add Thoracic CTA?



Courtesy Dr. Alexander Lembcke

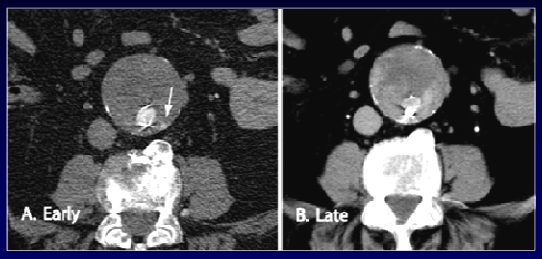
Multiple Aneurysms



Check for Popliteal Artery Aneurysms!

Courtesy Dr. Alexander Lembcke

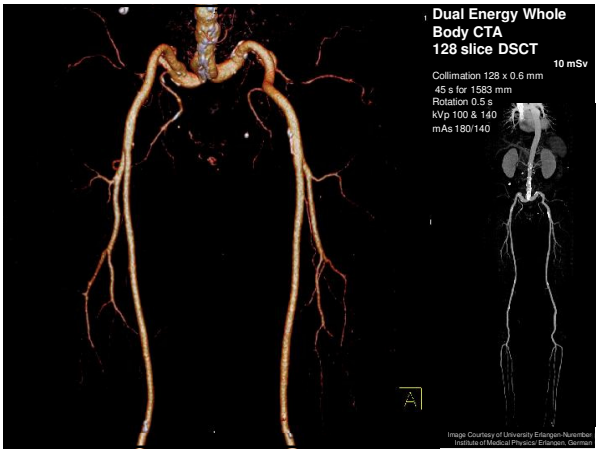
Why delayed Imaging?



Courtesy Chieh-Min Fan, MD

Problems: Bones, clips, & Calcium

Lopera et al.
RadioGraphics 2008;28:529-548



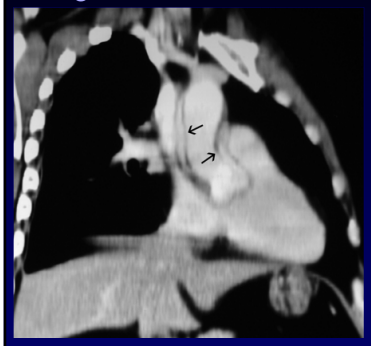
Why Gate Thoracic CTA

- **Reduces motion artifact in ascending aorta**
  - **Non-gated MDCT: >84% pulsation artifact***
- **Additional information:**
  - **coronary arteries**
  - **cardiac function**
  - **aortic valve**

Ko et al. AJR. 2005 Apr;184(4):1225-30

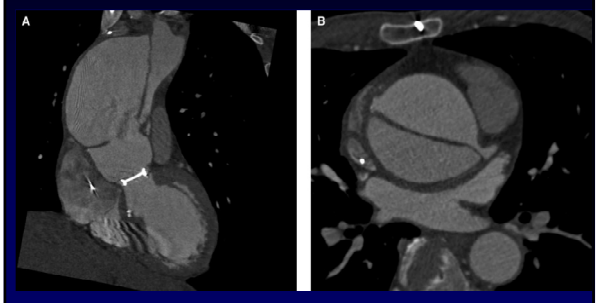
Cheong, Flamm. J Am Coll Cardiol, 2007; 49:1751

Pseudodissection on non-gated MDCT



Ko et al. AJR. 2005 Apr;184(4):1225-30

Type A Dissection (cardiac gated CT)



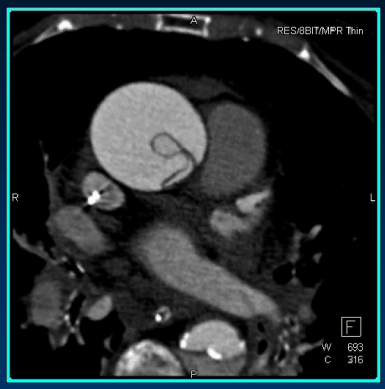
Abbara S et al. JCCT 2007, 1(1): 40-54

Cardiac Gated Thoracic Aortic CTA

- Eliminates pulsation artefact and pseudo-flaps
- Virtually eliminates false positive CTA

Type A Dissection

Flap extents into LM ostium



Thank you!

SAbbara@Partners.org