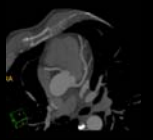
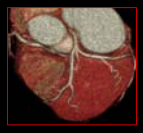
CT Clinical Perspective– Present & Future




Michael W. Vannier, MD
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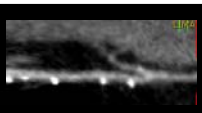
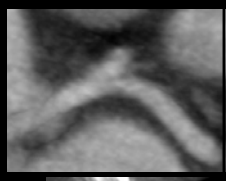
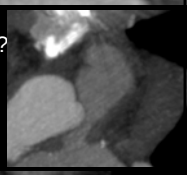
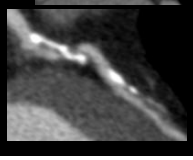
THE UNIVERSITY OF CHICAGO
DEPARTMENT OF RADIOLOGY

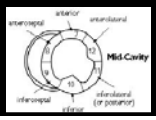
Topics

- Cardiac CT
- Area Detectors (>64 channels; >4 cm)
- Dual Energy CT
- Large Aperture Gantry; Table Wt. Capacity
- CT Perfusion
- CT Biomarkers
- External Factors and Future

Cardiac CT

- Why?
  - Why cardiac CT in 2006?
- What?
  - What tools are available for cardiac CT?
- How?
  - How is the exam performed?
- When?
  - When should we do cardiac CT?
- Future



Cardiac CT Tools

CT Scanner

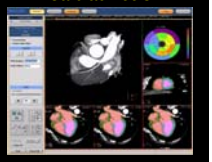

40 channel

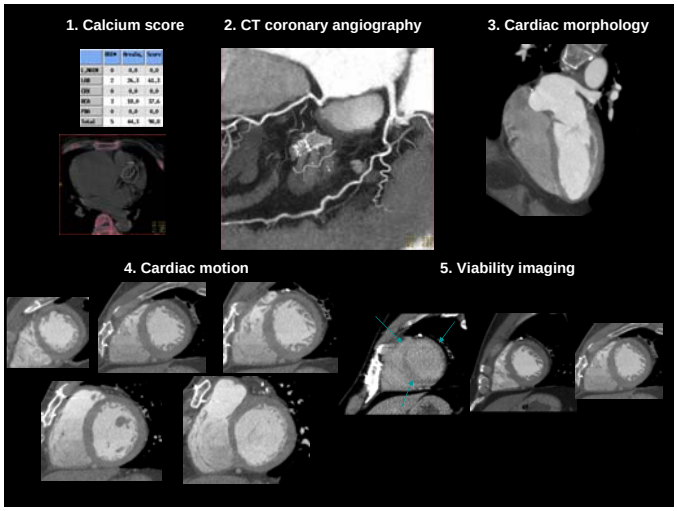
64 channel

Post-processing Workstation

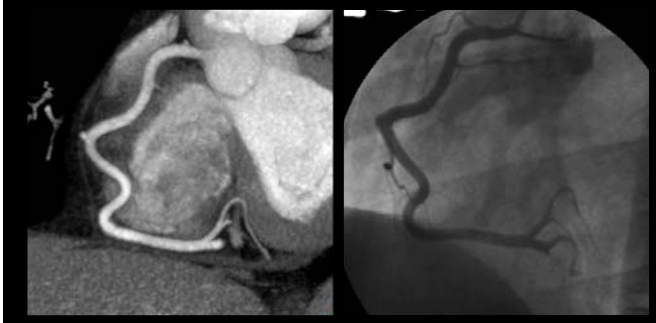
Software


Cardiac Tools


Comprehensive Cardiac Analysis (CCA)

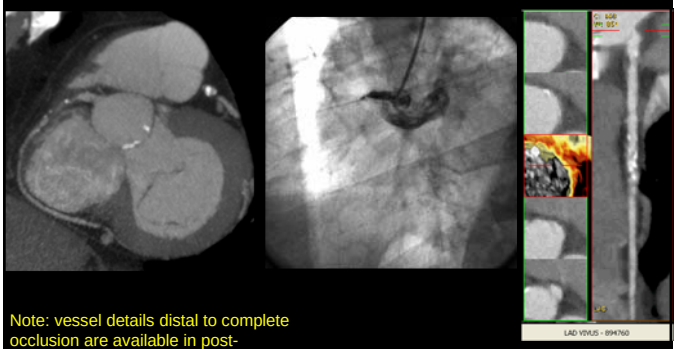


Clinical Utility of CT: Exclusion of CAD



Cardiac CT | Conventional Angiogram

CT Clinical Utility: RCA Proximal Occlusion

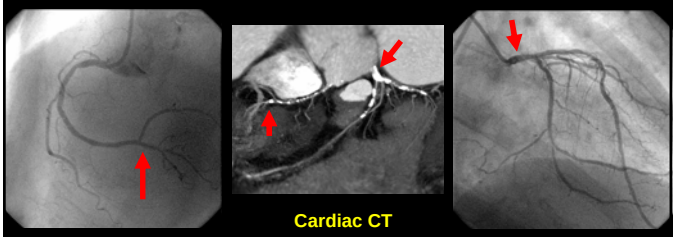


Note: vessel details distal to complete occlusion are available in post-processed images

Coronary Angiogram (CAG) vs. Cardiac Multirow Detector CT (MDCT)

1.	Diffuse Coronary Calcification:	CAG > MDCT
2.	Fast heart rate:	CAG > MDCT
3.	Stent evaluation:	CAG > MDCT
4.	Diffuse CAD & plaque burden:	**MDCT > CAG**
5.	Distal to occlusion:	**MDCT > CAG**

Diffuse coronary calcification: CAG > MDCT

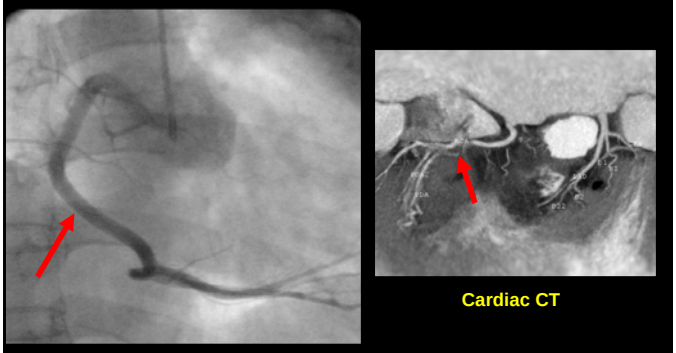


CAG

Cardiac CT

CAG

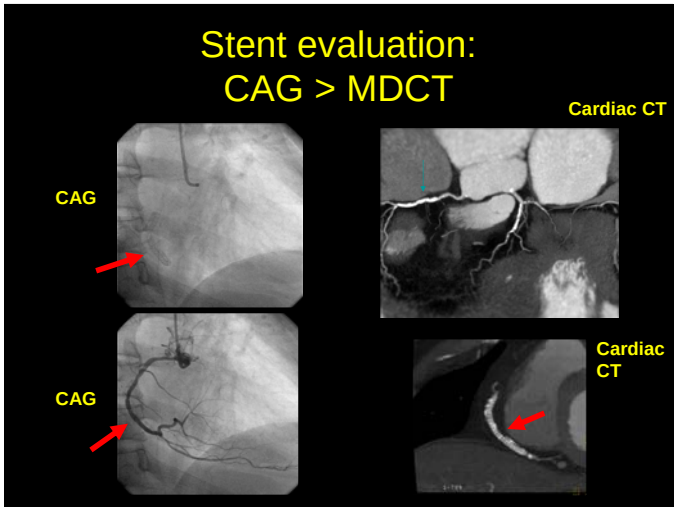
Fast heart rate: CAG > MDCT



CAG

Cardiac CT

Stent evaluation: CAG > MDCT



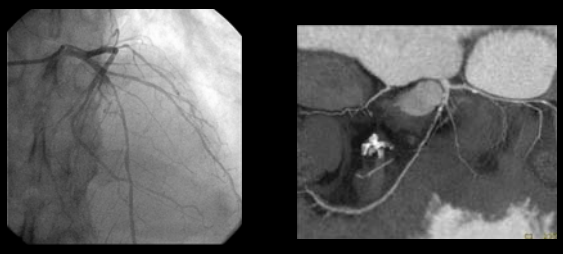
CAG

CAG

Cardiac CT

Cardiac CT

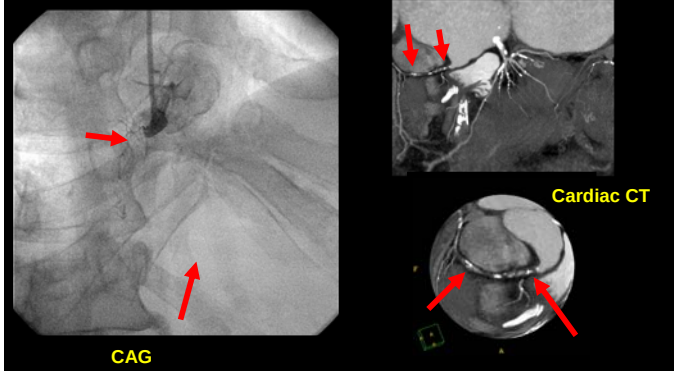
Diffuse coronary artery disease and plaque burden: MDCT > CAG



CAG

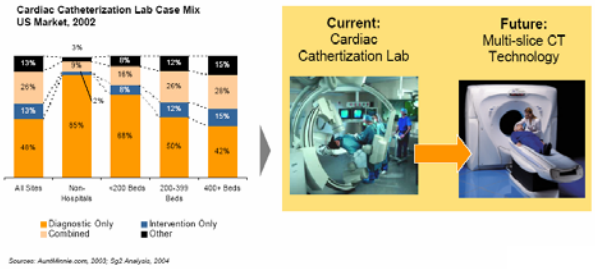
Cardiac CT

Evaluation of segments distal to obstruction: MDCT > CAG

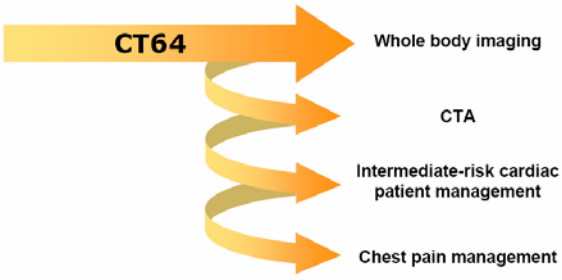


Acute or Subacute Chest Pain Scenario

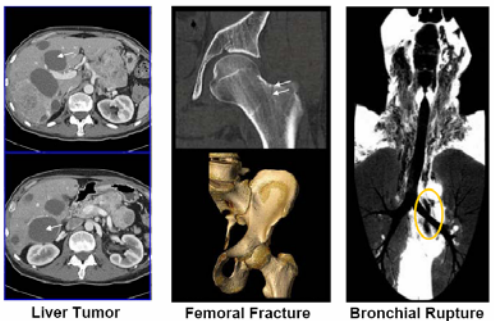
Noninvasive angiography will provide the most efficient chest pain triage for many patients excluding those with obvious ST segment elevation MI who require emergent primary coronary intervention



CT64 Is the Most Robust Whole Body Scanner in 2005

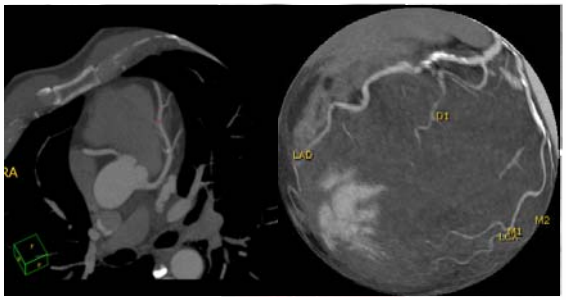


CT64 Is Reshaping Clinical CT Demand: Whole Body Imaging Tool

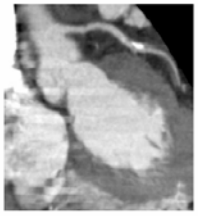


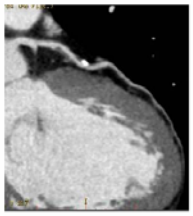
CT64 Is Reshaping Clinical CT Demand: Noninvasive CTA

CT64 Will Drive Angioplasty Volumes, Especially in Atypical Chest Pain Patients



CT64 Provides Confidence and Quality Advantages Over CT16 for Coronary CTA



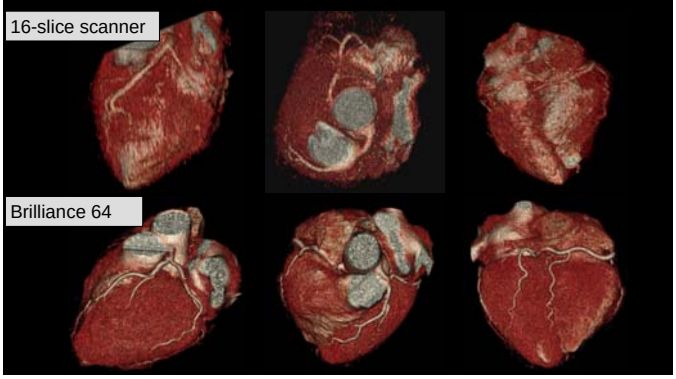


Consistent Clinical Performance*: Typical Readable Coronary Segments

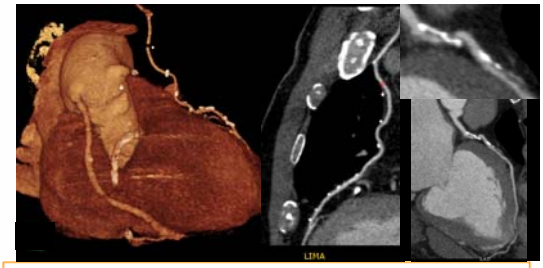
CT4	24–32% unreadable segments
CT16	12–16% unreadable segments
CT64	0–2% unreadable segments

Coronary Imaging

Compare the top row of volume rendered images of coronaries performed on a 16-slice CT to the bottom row of images from a Brilliance 64 scanner. Faster scans, thinner section slices, and true isotropic voxels allow for this much improved image quality.



CABG Grafts and ED Chest Pain Imaging: Challenging Breath-Holds for Patients



Challenge: Getting great images in the ED on all patients
Needed: More slices = shorter breath-hold & better coverage
More slices with less dose

Patent stent in LAD & new tight stenosis in RCA

51 y/o woman, with recurrent chest pain 6 months post stent implantation in prox. LAD. RCA was normal.

On CTA: patent stent in LAD, tight stenosis in RCA ——→ Stent placement in RCA

Triple rule-out

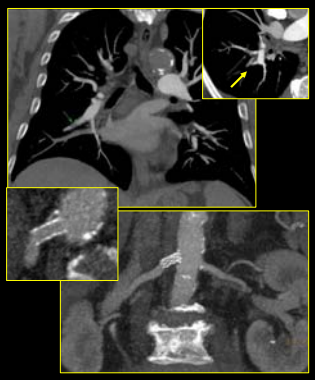
- Acute chest pain may be due to:
  - Aortic dissection
  - Pulmonary embolism
  - Coronary stenosis and angina
- Request from ED to determine cause (or rule-out these conditions) with a single CT examination
- Controversy – Should we attempt this?

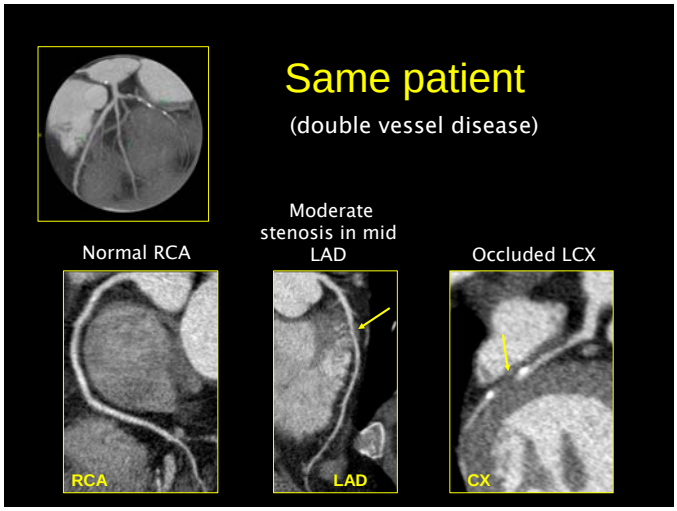
Complex Patient – Triple rule out

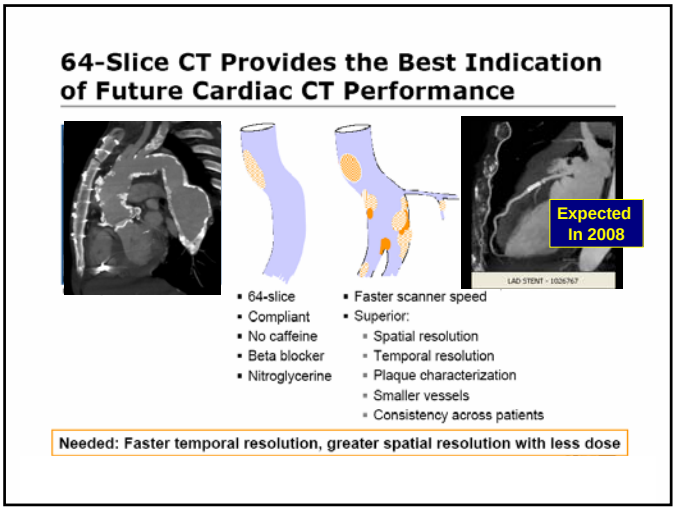
70y/o male with HTN exacerbation, chest pain & dyspnea

Positive PE, patent stent in Rt RA

290mm, 17sec,100cc@5cc/sec



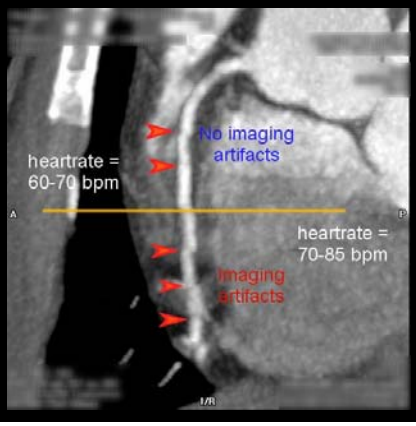




Future of Cardiac CT

- Most cardiac CT scanners are very sensitive to arrhythmias
  - Ectopic beats
  - Heart rate variability
- With prospective gating, there is high likelihood of an unsatisfactory exam
- With retrospective gating, correction for arrhythmias is possible, but software post-processing tools are required to correct for abnormal EKG effects

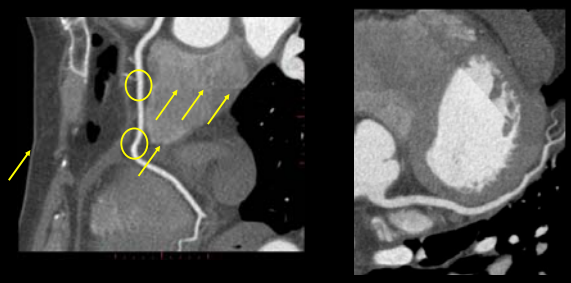
Drawbacks of Fixed Delay



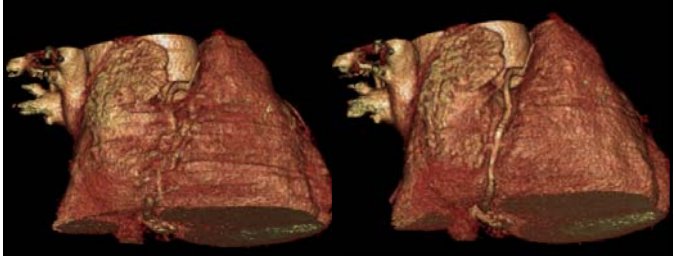
Employing fixed delay "R" wave

Phase Mis-registration

A 64-channel system using a fixed (%) delay, still exhibits heart rate variability -- leading to potential false findings



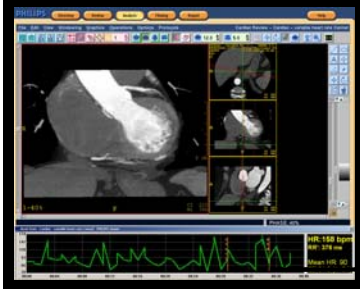
Adaptive Scan Acquisition - Rate Responsive™ CVCT



Fixed Offset

Variable Delay

Heart Rate Variation



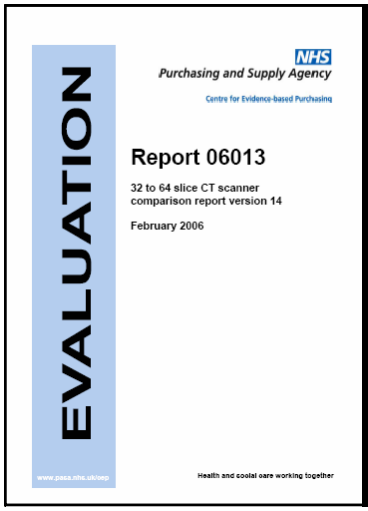
The graph shows how heart rate varies between 50 and 150 bpm over a 38 second period.
Only 5-6 secs are required for a 64-channel CT data acquisition.
Most mfgrs assume that the HR is constant during this period.

Variation occurs during 5-6s CT acquisition!

Arrhythmia Editing

Without correction

With correction



UK – NHS - CEBP

www.pasa.nhs.uk/cep

Sobering Thoughts on 64-channel Cardiac CT

- At the Stanford MDCT meeting, where there was a presentation from Dr David Kandzari of the Duke Center for Evidence-Based Practice. He reviewed all the evidence for the use of coronary CTA, after being asked to do so by the Agency for Healthcare Quality and Research and this data was then presented to the Centers for Medicare and Medicaid (CMS).
- The article says that the data needs to be examined with caution, since all the studies so far have skewed populations and many patients who have been excluded from the studies due to high calcium scores or poor-quality.

http://bhavin.typepad.com/cardiac_images/2006/07/sobering_though.html

Dual Energy CT Methods

- Dual Source
- Energy Discriminating Detectors
- kVP Switching

Dual Energy CT Methods

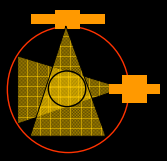
- Dual Source
  - Siemens
- Energy Discriminating Detectors
  - Philips
- kVP Switching
  - GE

Dual Source

Dual source configurations:

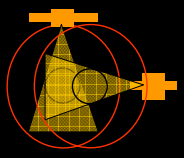
Co-planar configuration for...

- Temporal resolution improvement or dual energy for tissue characterization
- Siemens is working on a co-planar configuration



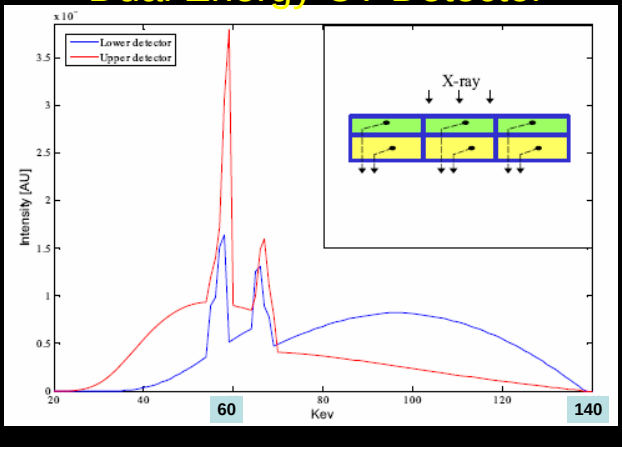
Staggered configurations for...

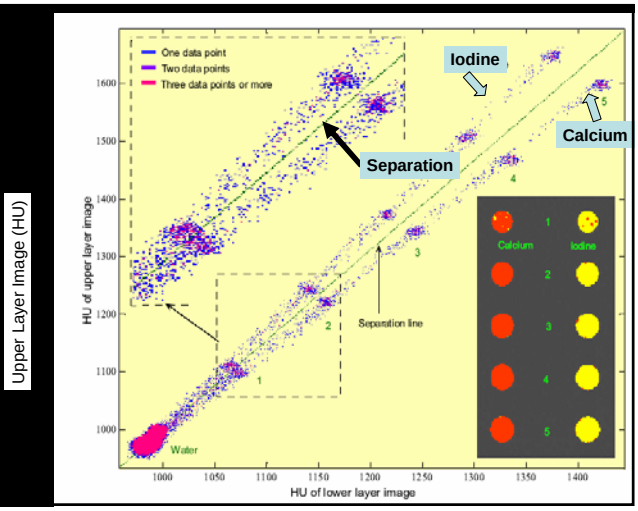
- High temporal resolution spiral scans or
- High power spiral scans or
- Dual energy spiral scans or Dual circular orbit scans



Simultaneous Multi-Energy Detector

Dual Energy CT Detector





Why Simultaneous Multi-Energy CT?

	Conventional MSCT	Simultaneous Multi-Energy CT
Differentiation between calcification and contrast material in CTA and Cardiac CTA	✓	✓✓
Bone-Removal in CTA (Cage Removal, Skull Removal etc.)	✓	✓✓
Soft Plaque Separation	✓	✓✓
Bone Mineral & Bone Density Assessment	✓	✓✓✓
Detection of small concentrations of targeted contrast material	✓	✓✓✓
Low contrast resolution (soft tissues)	✓	✓✓✓
Applications with mixtures of contrast agents	✓	✓✓
Enable tracking drug delivery of vectorized heavy-based materials	X	✓✓✓

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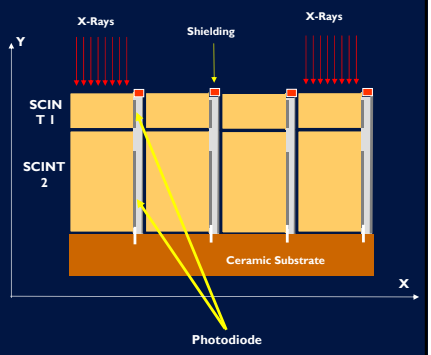
Simultaneous Multi-Energy Detector Concept

- The new detector consists of upper and lower scintillators
  - Upper scintillator stops and detects the lower-energy X-rays
  - Bottom scintillator stops and detects higher-energy X-rays
  - Signals from both scintillators can be combined as well



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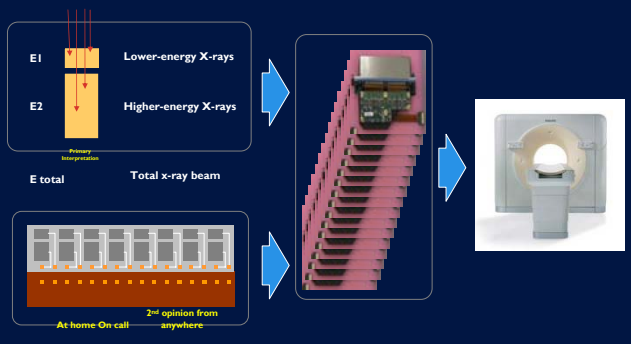
Simultaneous Multi-Energy Detector



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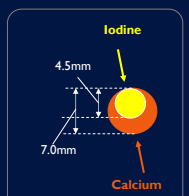
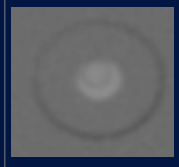
Simultaneous Multi-Energy Detector

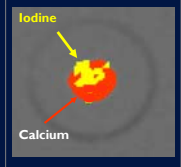
Initial phantom tests- Fall 2005



Phantom



Conventional CT



Simultaneous Multi Energy Detector

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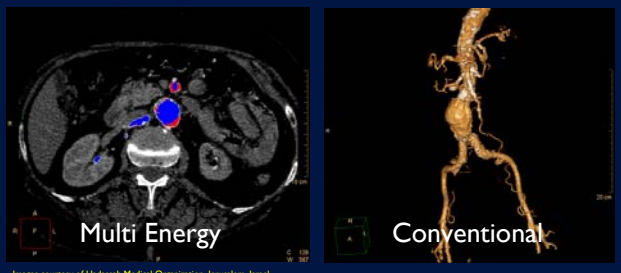
Simultaneous Multi-Energy detectors Initial clinical results, Nov. 2005

Red = calcified plaque
Blue = contrast filled vessels



Images courtesy of Hadassah Medical Organization, Jerusalem, Israel.
Works-in-Progress: Pending commercial availability and regulatory clearance.

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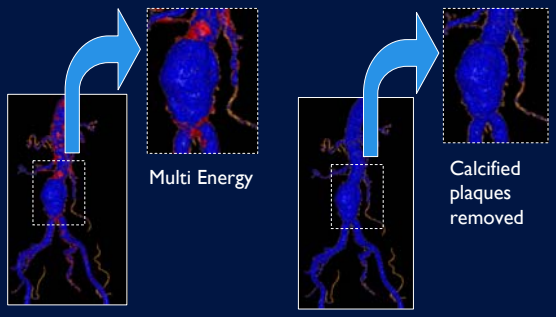
Simultaneous Multi-Energy detectors



Images courtesy of Hadassah Medical Organization, Jerusalem, Israel.
Works-in-Progress: Pending commercial availability and regulatory clearance.

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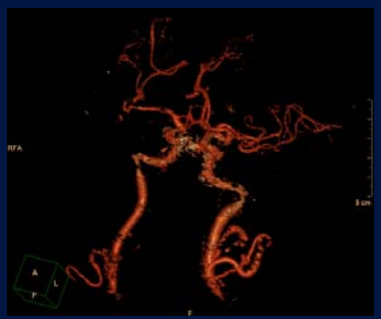
Simultaneous Multi-Energy detectors



Auto-removal of calcium and bone in COW

Images courtesy of Hadassah Medical Organization, Jerusalem, Israel.
Works-in-Progress: Pending commercial availability and regulatory clearance.

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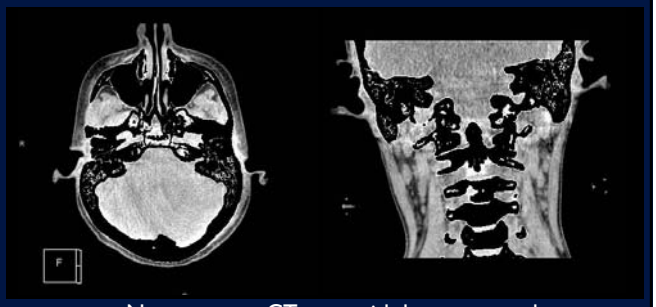
Simultaneous Multi-Energy detectors



Non-contrast CT scan with bone removal

Images courtesy of Hadassah Medical Organization, Jerusalem, Israel.
Works-in-Progress: Pending commercial availability and regulatory clearance.

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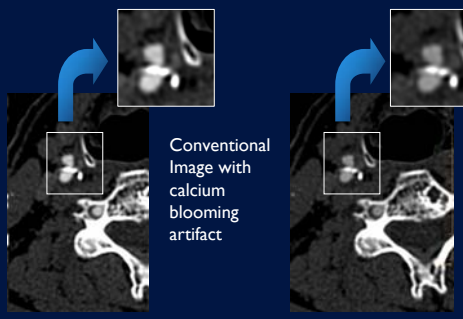
Simultaneous Multi-Energy detectors



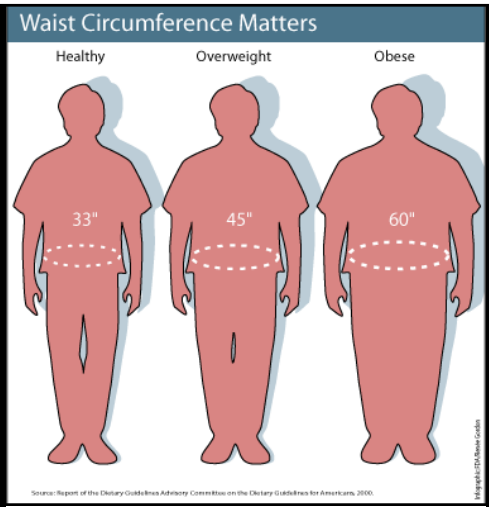
Conventional Image with calcium blooming artifact

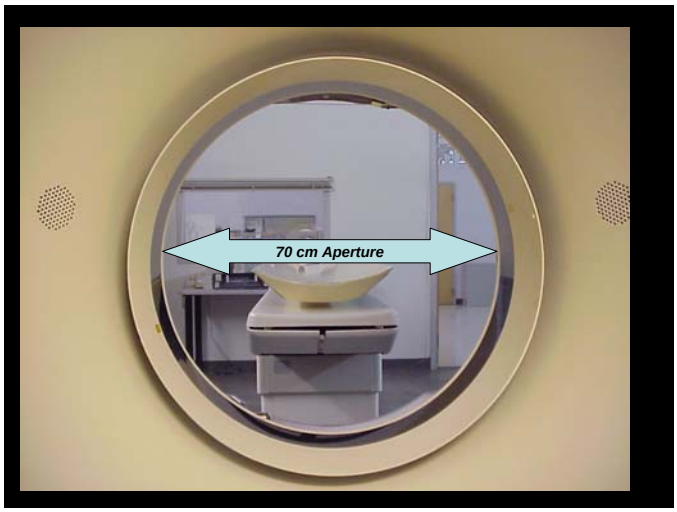
Reduction of calcium blooming artifact with Simultaneous Multi Energy detectors

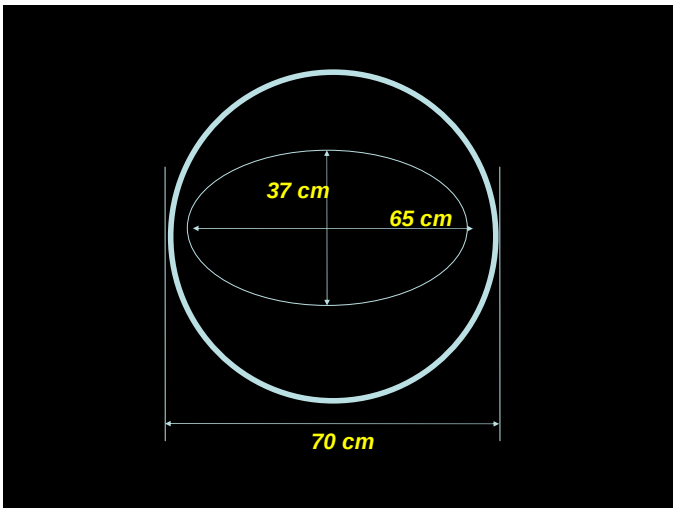
Images courtesy of Hadassah Medical Organization, Jerusalem, Israel.
Works-in-Progress: Pending commercial availability and regulatory clearance.

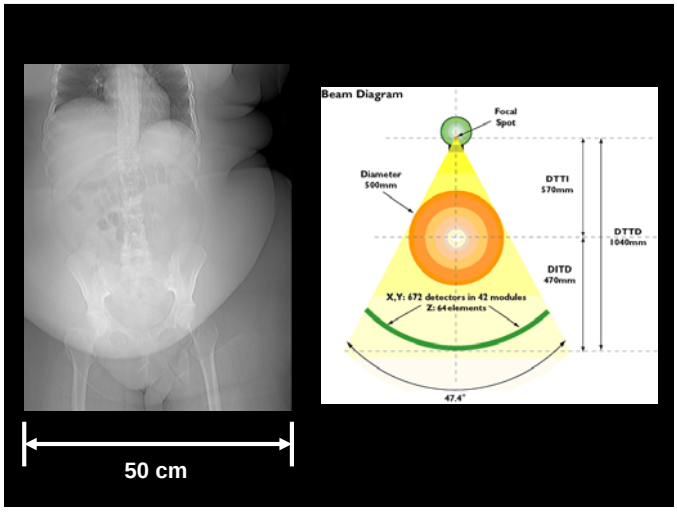
49

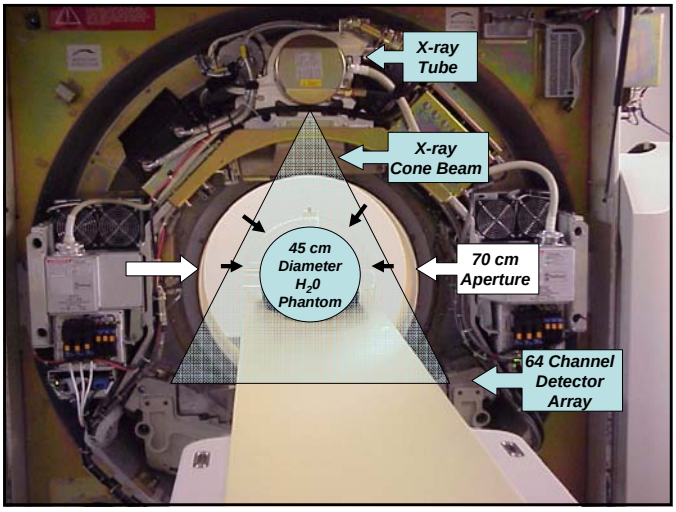
CT of Massively Obese Patients

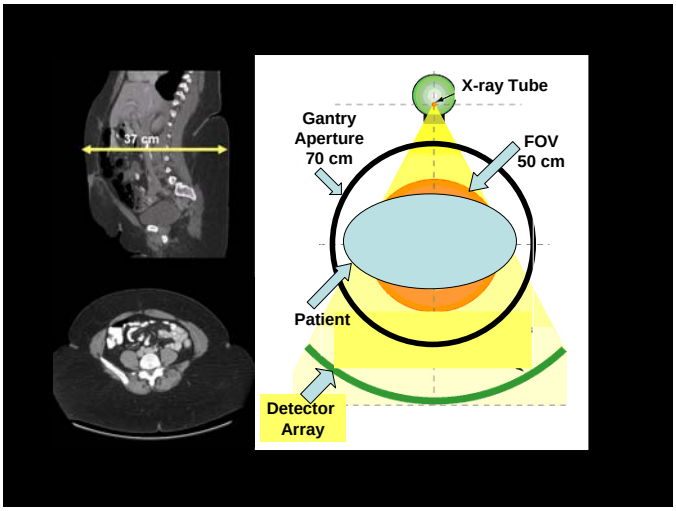


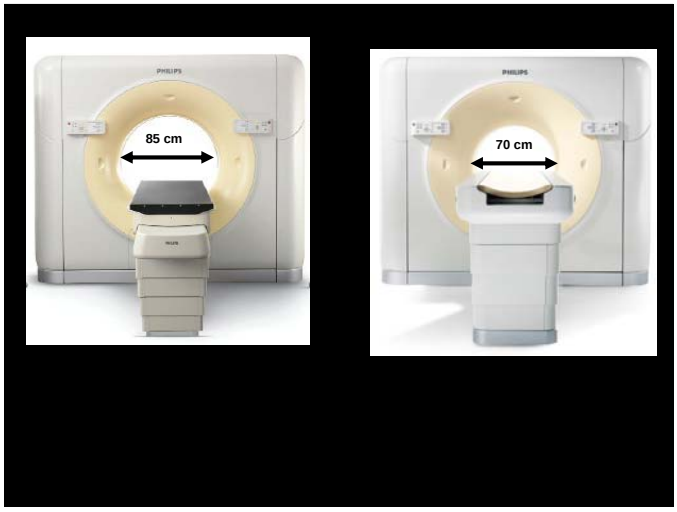

70 cm Aperture


37 cm
65 cm
70 cm

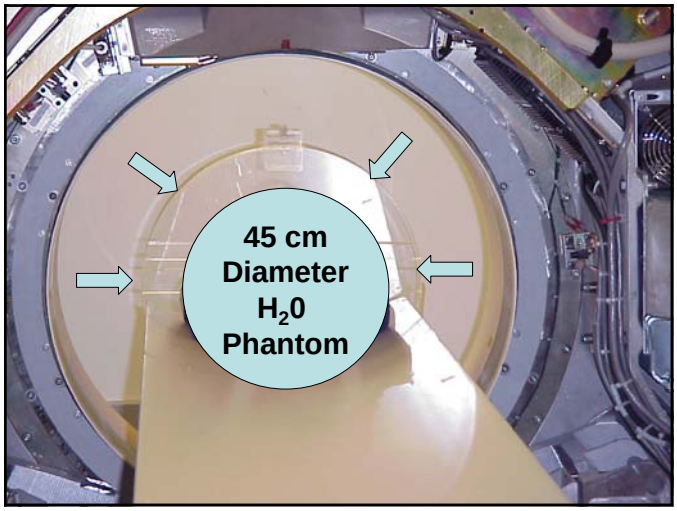

Beam Diagram
Focal Spot
Diameter 500mm
DTTI 570mm
DTTD 1040mm
DITD 470mm
X,Y: 672 detectors in 42 modules
Z: 64 elements
47.4°
50 cm


X-ray Tube
X-ray Cone Beam
45 cm Diameter H_20 Phantom
70 cm Aperture
64 Channel Detector Array


37 cm
X-ray Tube
Gantry
Aperture
70 cm
FOV
50 cm
Patient
Detector
Array


85 cm
70 cm


PHILIPS



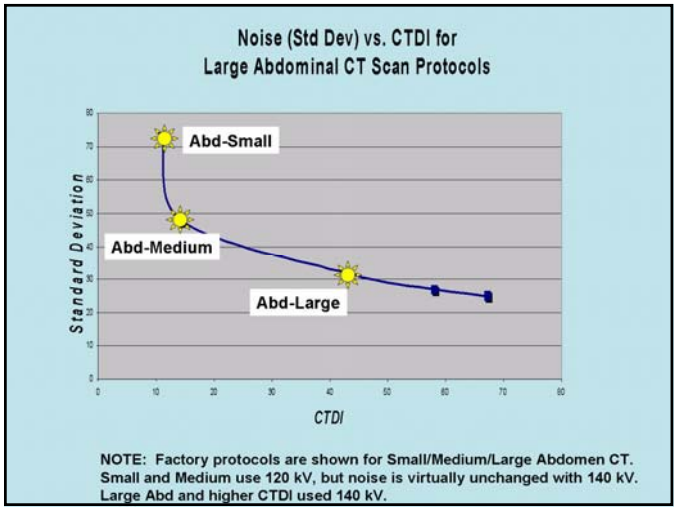
Protocols for Philips Brilliance 64-Channel CT Scanner

Name		Pitch	RT (s)	kV	mAs		CTDI[1]	Std Dev[2]
Abd Small		1.11	0.5	120	150		10.8	73.3
Abd Med		1.11	0.75	120	200		14.4	47.7
Abd Large		0.735	1	140	400		43	31.9
Abd Large		0.735	1	140	540		58	27
Abd Large		0.64	1	140	625		67.2	25.3
Abd Large[3]		0.64	1	140	625		67.2	24.9

The tradeoff between dose (CTDI) and noise (std dev) is illustrated.

For all protocols: Collimation = 64 x 0.625 mm. Matrix = 768^2.
Field of View (FOV) = 50 cm. Slice thickness = 3 mm. Slice increment = 3 mm.

[1] CT Dose Index (CTDI) was reported by the scanner in mGy.
[2] Standard Deviation (Std Dev) was measured with a large Region of Interest (ROI) in a uniform object.
[3] Reconstruction protocol used adaptive filtering of projection data prior to back projection.



CT Perfusion

Eur Radiol (2004) 14:1226–1233
DOI 10.1007/s00330-004-2288-2

CHEST

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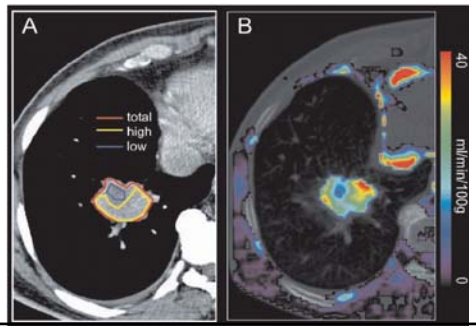
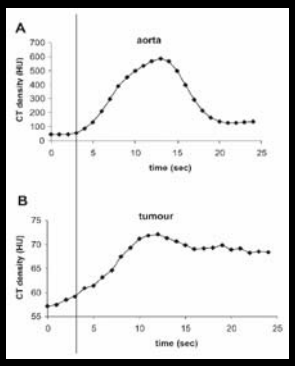
J. Boese
C. Corvinus
J. R. Ederle
I. Zuna

Perfusion CT in patients with advanced bronchial carcinomas: a novel chance for characterization and treatment monitoring?

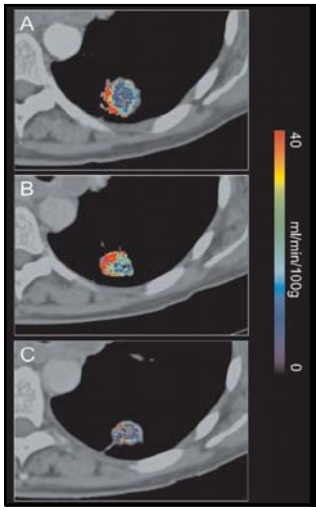


Time-density curves



Aorta

Tumor



Baseline

First treatment cycle

Second treatment cycle

CT perfusion metrics

- Tumor size (cm^3)
- Perfusion (ml / 100 g / min)
- Time-density curves & maps
  - Peak enhancement relative to pre-contrast value
  - TTP = time to peak
  - MTT = mean transit time
  - Regional blood volume
  - Regional blood flow

STROKE WORKUP

- 16 g I.V.
- Power injector, 150ml contrast
- Non enhanced CT
- CT perfusion (CTP)
  - CTP evaluation, TTP, CBF, CBV
- CT angiography (CTA)
  - CTA evaluation, source image, MPR, VRT
- +/- Post Contrast CT
- Imaging Time <15 minutes
- AJNR 24:688-690, April 2003

CTA

PERFUSION PHYSIOLOGY

- NORMAL BLOOD FLOW
  - 50-60 Ml/100g/min
  - <35 mL/100g/min protein synthesis stops. Tissue survives with no other CBF insult
  - <20 mL/100g/min loss of neural function, tissue at risk
  - <10 mL/100g/min irreversible cell death
- Regional CBV
  - Normal 4-5 mL/100g

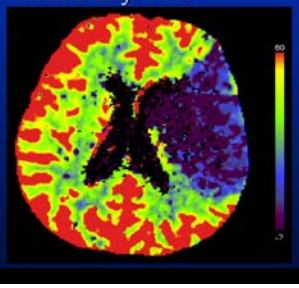
CT PERFUSION

- Cerebrovascular physiology in acute stroke patients
  - Irreversibly injured tissue
  - Tissue at risk but potentially viable
- Options for evaluating physiology
  - PET
  - SPECT
  - Xenon CT
  - MR Diffusion / Perfusion
  - CT Perfusion
- LATCHAW ET AL., AHA GUIDELINES FOR PERFUSION IMAGING, STROKE, 2003; 34: 1084-1104.

CT PERFUSION
Intracranial Studies

Tube Voltage: 80 kV
Effective mAs: 160 mAs
CTDIw: 656mGy
Slice Collimation: 1.5 mm
Slice Width: 12.0 mm
Rotation Time: 0.75 s
Table Feed / s: 0 mm
Scan Range: 24 mm
Scan Time: 27 s
50 scans X 2 positions

Contrast (I.V.):
Volume: 30-60 cc
Flow Rate: 8.0 cc/sec
Scan Delay: 4 sec

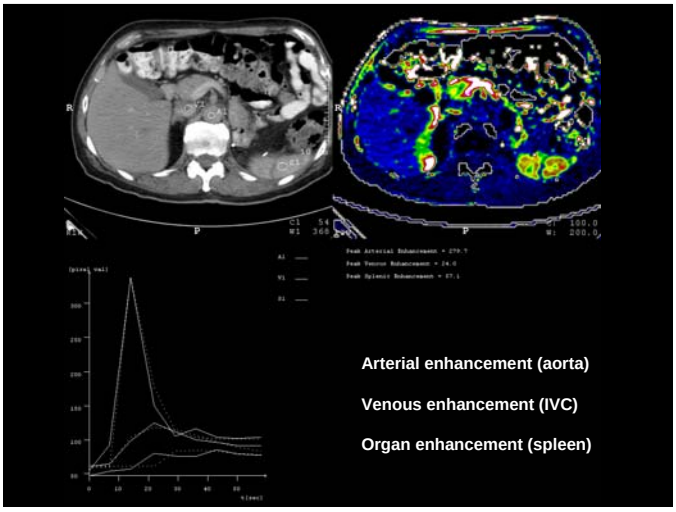


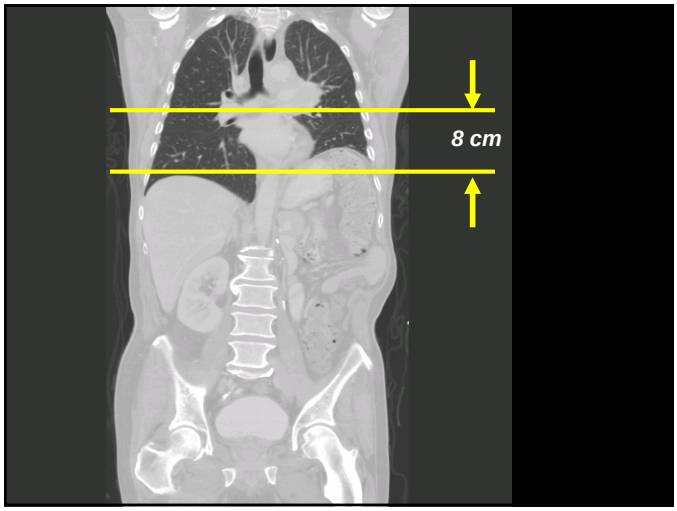
CT PERFUSION
Advantages

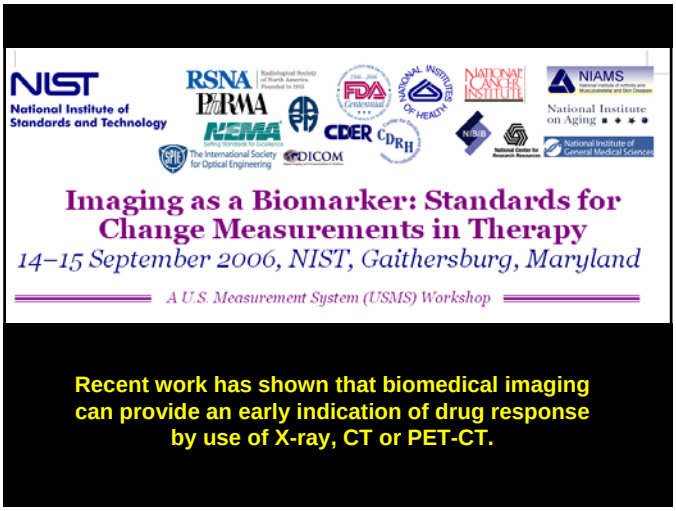
- Readily available
- Rapid examination
- On-line post-processing
  - User-friendly for technologists/radiologists
  - Results available in minutes
  - Instant Color maps (TTP, rCBV, rCBF)
  - ROI measurements for quant. Analysis
  - Can Perform CTA at same time
- Stroke 2002;33:2025-2031

CT PERFUSION
Limitations

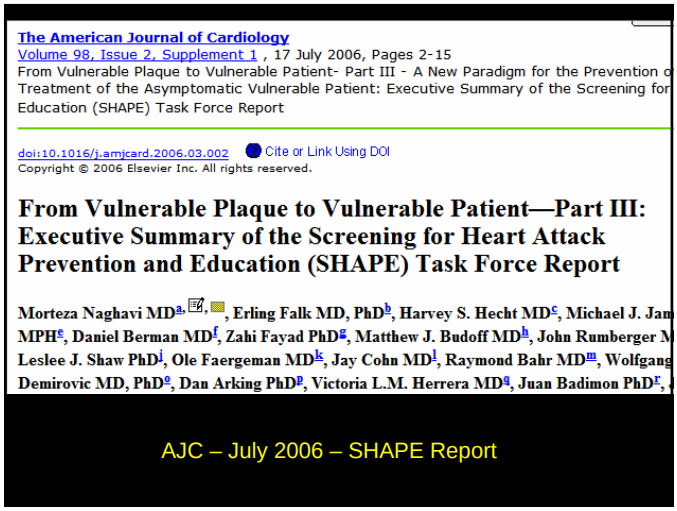
- Large bore IV necessary
- Limited coverage
  - Only 1-2 slices vs. MR or Xe-CT
  - May miss lacunar disease
- Bony artifact limits evaluation of posterior fossa structures
- Radiation Dose
- ROI measurements may be more important on a relative basis than absolute values
- Absolute Quantification difficult
- Koenig M, Klotz E, Luka B, et al. "Perfusion CT of the Brain: Diagnostic Approach for Early Detection of Ischemic Stroke." *Radiology* 1998; 209: 85-93.







Recent work has shown that biomedical imaging can provide an early indication of drug response by use of X-ray, CT or PET-CT.



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Treatment of the Asymptomatic Vulnerable Patient: Executive Summary of the Screening for
Education (SHAPE) Task Force Report

doi:10.1016/j.amjcard.2006.03.002 Cite or Link Using DOI
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From Vulnerable Plaque to Vulnerable Patient—Part III: Executive Summary of the Screening for Heart Attack Prevention and Education (SHAPE) Task Force Report

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MPH[e], Daniel Berman MD[f], Zahi Fayad PhD[g], Matthew J. Budoff MD[h], John Rumberger M
Leslee J. Shaw PhD[j], Ole Faergeman MD[k], Jay Cohn MD[l], Raymond Bahr MD[m], Wolfgang
Demirovic MD, PhD[o], Dan Arking PhD[p], Victoria L.M. Herrera MD[q], Juan Badimon PhD[r],

AJC – July 2006 – SHAPE Report

H.R. 5704 (the Access to Medicare Imaging Act of 2006)

- The US House of Representatives Energy & Commerce Health Subcommittee held a hearing on Tuesday, July 18, 2006 to discuss utilization of imaging services within the Medicare system. CMS and MedPAC both testified, along with ACR, ACC, NIA, ACOG, Nuclear Medicine, ASRT, and NEMA.
- There is a need to “fix the problem of imaging growth”.

Unmet Needs - Opportunities

- CT without IV contrast (unenhanced scan)
- Metal artifact reduction in a clinical setting
- CT in pregnancy
- CT change detection (multisession scans)
- Small vessel CT angiography (e.g., non-cardiac ischemia)
- CT and avoidance of contrast media nephrotoxicity risk

Acknowledgments

- Many colleagues, collaborators, students, residents & fellows
- Indiana University; Carmel Medical Center (Haifa); Univ of Michigan
- Philips; Siemens; GE

References

- Raz Carmi, Galit Naveh, and Ami Altman. **Material Separation with Dual-Layer CT.** 2005 IEEE Nuclear Science Symposium Conference Record.