CT Clinical Perspective—Present & Future

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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
- Post-processing Workstation
  - 64 channel
- Software
  - Comprehensive Cardiac Analysis (CCA)
Clinical Utility of CT:
Exclusion of CAD

CT Clinical Utility: RCA
Proximal Occlusion

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

Note: vessel details distal to complete occlusion are available in post-processed images
Diffuse coronary calcification: CAG > MDCT

Fast heart rate: CAG > MDCT

Stent evaluation: CAG > MDCT

Diffuse coronary artery disease and plaque burden: MDCT > CAG
Evaluation of segments distal to obstruction: MDCT > CAG

Acute or Subacute Chest Pain Scenario

Noninvasive angiography will provide the most efficient chest pain stage 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
Brilliance 64 Is Reshaping Clinical CT Demand: Noninvasive CTA

Coronary Imaging

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

CT64 Provides Confidence and Quality Advantages Over CT16 for Coronary CTA

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.
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, 1/3 sec, 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.

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 mfrs assume that the HR is constant during this period.

Variation occurs during 5-6s CT acquisition!

Arrhythmia Editing
Without correction
With correction
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.


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

Upper Layer Image (HU)

Iodine
Calcium
Separation
Why Simultaneous Multi-Energy CT?

<table>
<thead>
<tr>
<th></th>
<th>Conventional MSCT</th>
<th>Simultaneous Multi-Energy CT</th>
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<tbody>
<tr>
<td>Differentiation</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bone Removal in CTA</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bone Mineral &amp; Bone Density Assessment</td>
<td>✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Detection of small concentrations of targeted contrast material</td>
<td>✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Low contrast resolution (soft tissues)</td>
<td>✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Applications with mixtures of contrast agents</td>
<td>✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Enable tracking drug delivery of vectorized heavy-based materials</td>
<td>X</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>

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

Simultaneous Multi-Energy Detector

- Initial phantom tests - Fall 2005

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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.

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.

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.
Simultaneous Multi-Energy detectors

Conventional Image with calcium blooming artifact

Reduction of calcium blooming artifact with Simultaneous Multi Energy detectors

CT of Massively Obese Patients

Images courtesy of Hadassah Medical Organization, Jerusalem, Israel.

Works-in-Progress: Pending commercial availability and regulatory clearance.

Waist Circumference Matters

Healthy

Overweight

Obese

33"

45"

60"
Gantry Aperture 70 cm

X-ray Tube FOV 50 cm

Patient Detector Array

Large Bore Aperture (85 cm)

70 cm 85 cm

85 cm 70 cm
Many obese adult patients require imaging examinations, but the options available may be few. For very large patients, imaging modalities are limited by table weight capacity, x-ray beam attenuation, gantry aperture size, penetration (for US), and other physical constraints.
Time-density curves

- Aorta
- Tumor

CT perfusion metrics

- Tumor size (cm³)
- 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, 150 ml contrast
- Non enhanced CT
- CT perfusion (CTP)
  - CTP evaluation, TTP, CBE, CBV
- CT angiography (CTA)
  - CTA evaluation, source image, MPR, VRT
- +/- Post Contrast CT
- Imaging Time <15 minutes
- AJNR 24:688-690, April 2003

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

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**CT PERFUSION**

**Advantages**

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

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**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

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

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”.

From Vulnerable Plaque to Vulnerable Patient—Part III: Executive Summary of the Screening for Heart Attack Prevention and Education (SHAPE) Task Force Report

The American Journal of Cardiology
Volume 99, Issue 2, Supplement 1, 17 July 2006, Pages 2:15

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

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• Philips; Siemens; GE

References

BMI – Body Mass Index

Body Mass Index or BMI is a tool for indicating weight status in adults. It is a measure of weight for height. BMI correlates with body fat. The relation between fatness and BMI differs with age and gender. For example, women are more likely to have a higher percent of body fat than men for the same BMI. On average, older people may have more body fat than younger adults with the same BMI.