On the Importance of Computation in Clinical Radiology

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My Disclaimer

- I’ve received golf balls from Toshiba…
- I’ve received golf balls from Siemens…
- I’ve not received golf balls from GE…
- But I don’t play golf so it doesn’t matter!!!
- If I have a lot of graphics from Siemens, is because they have shared those with me and the other guys haven’t…
- My favorite brands are Fender and Yamaha, and they don’t make radiology equipment…

Typical Radiology Operation in Terms of Volume and Revenue (c 1985)

- Plain radiography (film-screen -processor QC!!!!-)
- Fluoroscopy (image intensifier-based)
- Interventional Angiography (fluoroscopy and DSA-based)
- CT (sequential scanners)
- MRI (single and dual-channel scanners)
- Nuclear Medicine (single-head cameras)
- Laminar Tomography
- 2D Sonography
- Mammography (film-screen)

Typical Radiology Operation in Terms of Volume and Revenue (2007)

- CT (-up 3- multidetector: 16, 32, 64-slice scanners)
- Interventional Angiography (-up 1- flat panel based)
- MRI (-up 2- eight and sixteen channel scanners)
- Nuclear Medicine (-up 2- SPECT and PET scanners)
- Plain radiography (down 4)
  - Computed radiography (CR)
  - Digital radiography (DR)
- Fluoroscopy (-down 4- flat panel based)
- 4D and vascular Sonography (up 1)
- Full-field digital mammography (up 1)

Typical Systems Found in a Large Radiology Department (c 1985)

- Plain Radiography: 5-8 systems
- Fluoroscopy: 3-4 systems
- Interventional Angiography: 1-2 systems
- CT: 1-2 scanners
- MRI: 1 scanner
- Nuclear Medicine: 2 cameras
- Laminar Tomography: 1 system
- Ultrasound: 2 systems
- Mammography: 2 systems

Typical Systems Found in a Large Radiology Department (2007)

- Plain Radiography: 2-4 systems
- Fluoroscopy: 2-3 systems
- Interventional Angiography: 5-6 systems
- CT: 3-4 scanners
- MRI: 2-3 scanners
- Nuclear Medicine: 4-5 cameras
-
- Ultrasound: 6-8 systems
- Mammography: 1 system

Typical Systems Found in a Large Radiology Department (2007)

CR

DR

PET/CT

MRI

FFDM

So…it's ALL digital now!!
…but not only in radiology….

IT in Medicine

- Goal: LEMR (Lifetime Electronic Medical Record), an integration of the main Hospital Information System (HIS) and other hospital subsystems:
  - Clinical Lab/Pathology
  - Pharmacy
  - Radiology Information Systems (RIS)
  - Picture Archiving and Communications System (PACS)

PACS

- All imaging modalities are natively digital
- Gigabit capability is becoming standard in most major hospitals' networks
- Fast lines also becoming standard for remote transmission
- Compression of studies no longer a legal or practical issue
- Archiving costs continue to decrease

The UF & Shands PACS

- 10 CT scanners
- 7 Interventional Suites
- 8 MRI scanners
- 1 PET/CT scanner
- 4 SPECT scanners
- 4 Gamma cameras
- 5 Digital Radiography suites
- 32 Computed Radiography devices
- 10 Digital Fluoroscopy suites
- 22 Ultrasound units
- 3 Digital Mammography systems


CR/DR
MRI
MED PLAZA
US
AGH
CT
LIVE OAK
LAKESHORE
R&F
NM
PAIC

The UF & Shands PACS

- Almost half a million studies per year from 6 hospitals and four outpatient clinics
- 160 TB worth of studies available online
- 60 GB (uncompressed) of information per day
- Average retrieval time is
  - Under 20 seconds for same day studies
  - Under 2 minutes from deep archive
- Over 100 workstations system wide
- 2 TB available on web-based access system
- Studies also distributed via CD/DVD

Specific Applications in Radiology

- Radiology is the driving force behind technological advancement in may hospitals and sites
- Study times are only going to get shorfaster, stduies only larger
- 64-slice CT scanners can easily generate 2,000 to 3,000 slices in matter of minutes
- FFDM images, at 4k x 4k, 16-bit resolution are very large files
- Faster workstations
- More sophisticated viewing and processing

Specific Applications in Radiology

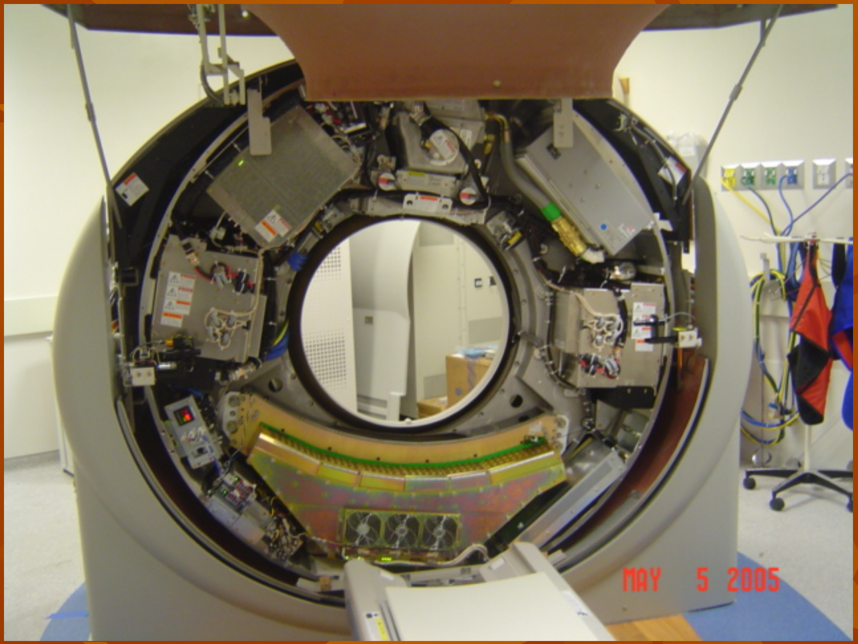
- Image processing algorithms
- Image reconstruction algorithms
- Patient dose estimates

Specific Applications in Radiology

- Image processing algorithms
- CR and DR:
  - Noise reduction algorithms for the purpose of reducing patient dose
  - Simultaneous display of soft and bone tissues
  - AGFA’s MUSICA always the leader

Specific Applications in Radiology

- Image reconstruction algorithms
  - 256-slice MDCT
  - Cone beam flat panel CT
  - 3D and 4D reconstructions of CT/MRI images
  - Fusion imaging (PET + CT + MRI)



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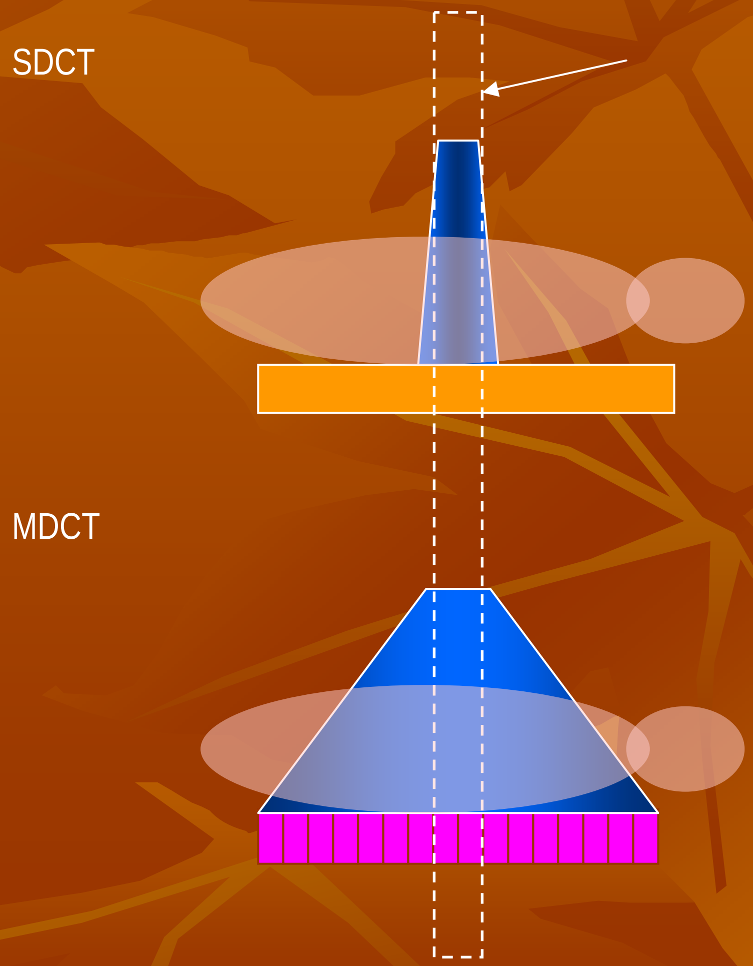

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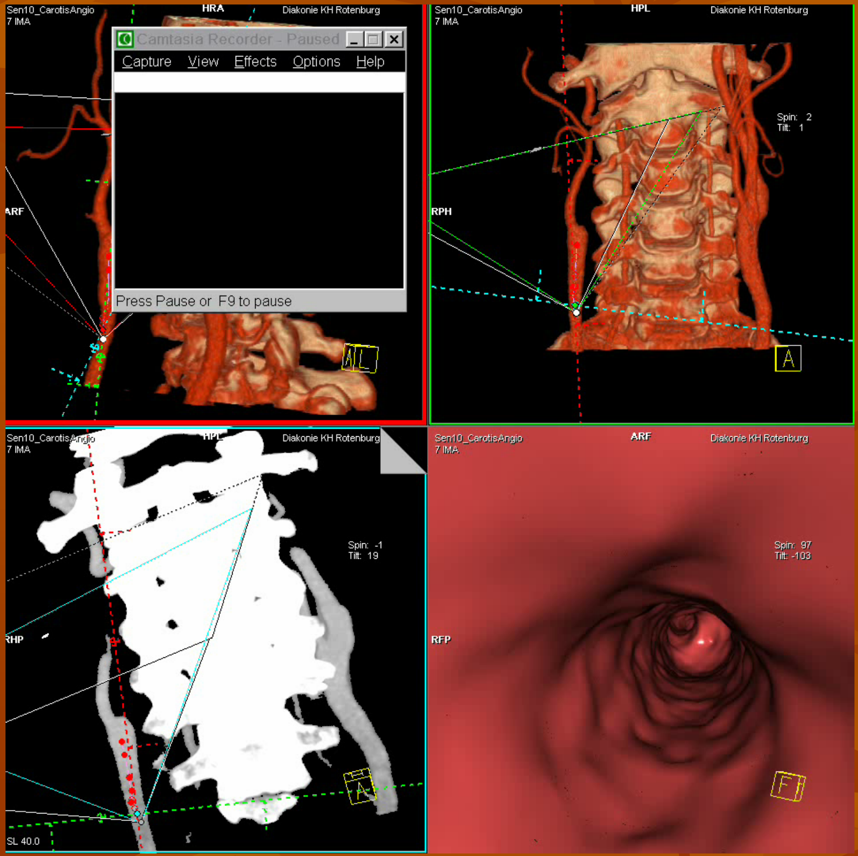

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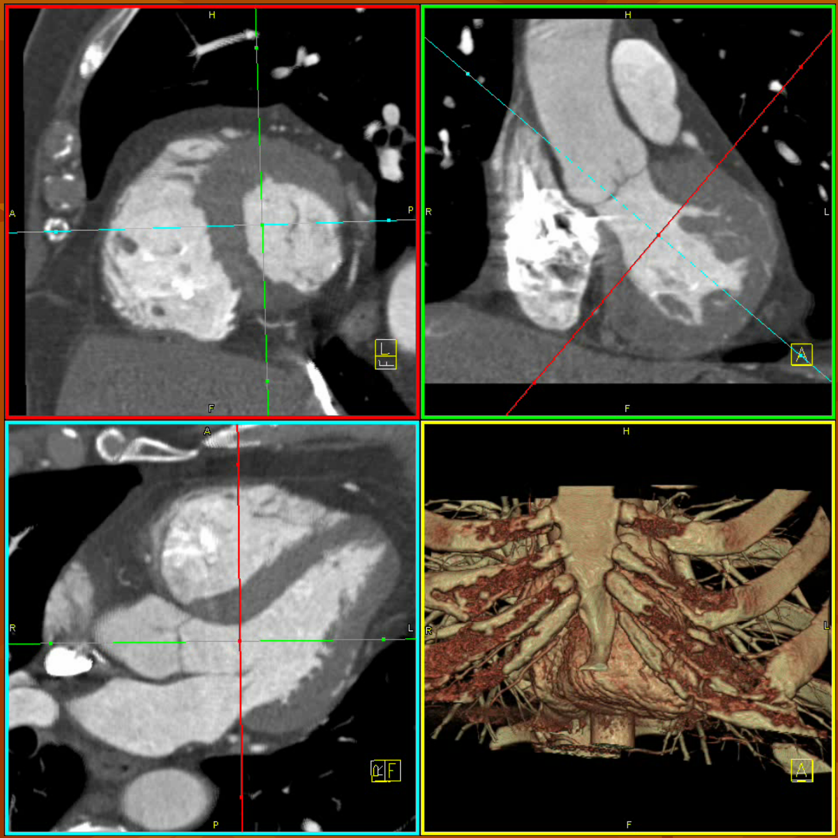

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Specific Applications in Radiology

- Patient dose estimates
  - Accuracy
  - Availability
  - Accessibility
  - Archival

Dose Issues in CT

- Rotation times are now 300 ms per revolution and likely to get shorter
- 64 MDCT allows for a head trauma scan to be performed in les than a minute
- 256 MDCT will permit this to be done in seconds
- Use of CT will increase significantly over time
- Though new ceramic scintillators have high efficiencies, shorter rotation times and pitch values require higher tube currents
- Max mA used to be about 400…it is now 800 or higher!

Dose Issues in CT

- CT studies account for only about 10% of all radiological studies in the U.S.
- It accounts for about 70% of the dose to the population from medical studies
- 256-slice scanners will partially replace some modalities
  - Some radiographic studies
  - Diagnostic angiographic studies (CTA)
  - Diagnostic cardiac studies (CCTA)

Dose Issues in CT

- Patients will be more likely to have several CT scans over their lifetime
- Doses per scan are likely to go up, not down
- More radiosensitive organs are of concern:
  - Lens of the eye
  - Thyroid
  - Female breast
  - Gonads
- Pediatric and female patient populations are at higher risk

Dose Issues in Interventional Radiology (IR)

- Diagnostic cardiac and interventional radiology procedures quickly being replaced by CTA and MRA
- Cardiac cath lab and interventional radiology departments becoming therapeutic (i.e., “treatment-only”) modalities
- Premise is to save patient’s life and health
- Thus, excessive use of radiation (and iodinated contrast agents *may* be “justified”
- Knowledge of radiation dose thus more imperative than ever

Dose Issues in Interventional Radiology (IR)

- Organ of concern in IR is the skin
- Skin effects are deterministic
- In terms of the Peak Skin Dose (PSD) studies are classified as:
  - *Low-dose* if PSD < 1 Gy (pulmonary angiographies, nephrostomies)
  - *Moderate-dose* if 1 Gy > PSD >2 Gy (pelvic embolizations, stent placements)
  - *High-dose* if PSD > 2 Gy (biliary drainages)
  - *Very high-dose* if PSD > 5 Gy (transjugular intrahepatic portosystemic shunt "TIPS" procedures, neuroembolizations)

Dose Issues in Interventional Radiology (IR)

- In terms of their typical PSD values, IR procedures can be classified as:
  - Low-dose: 53%
  - Moderate dose: 12%
  - High Dose: 15%
  - Very high dose: 20 %
- Which means that about 1 in every 5 procedures could potentially result in a high or very high PSD
- The American College of Radiology (ACR), Joint Commission and the FDA have guidelines and regulations in place

Dose Knowledge: Importance

- As recently learned, medical radiation is now the largest contributor to radiation exposure of the U.S. population
- The total number of radiological procedures per year in the U.S. is likely to increase
- Clinically, sites must address this by
  - Optimizing imaging protocols
  - Implementing dose-reduction policies and procedures
  - Verifying staff competency periodically
  - Requiring strict and comprehensive radiation safety training for all staff involved
- Shands and UF doing all these!!

Dose: Measure or Estimate?

- Dose measurement on site is still not a viable alternative to calculated estimates
  - OSLD
  - TLD
- Accuracy or reliability of these not an issue
- Resource availability (OSLD system and who manages it!) is the problem

Dose: Measure or Estimate?

- Thus, dose estimates from simulations appear to be the answer…
- The codes exist, so the issue is application in the clinical setting
- Away from any radiation transport expert
- Away from megacomputer arrays
- Sometimes, even away from any medical physicist….

The Approach to Dose Calculations in the Clinical Radiology Setting

Step 1: Develop reliable and accurate dose simulation codes

- Beam data
  - Problematic due to proprietary information from manufacturer, especially in CT (bowtie filters, etc.)
  - Easy to utilize for different beam energies, intensities, spectral filters, pulsed modes of operations, etc.
- Patient simulation
  - Stylized phantoms inadequate
  - Anthropomorphic computational phantom models necessary for various ages and both genders
- Both done at UF!

Step 2: Develop online dose estimate software (IR)

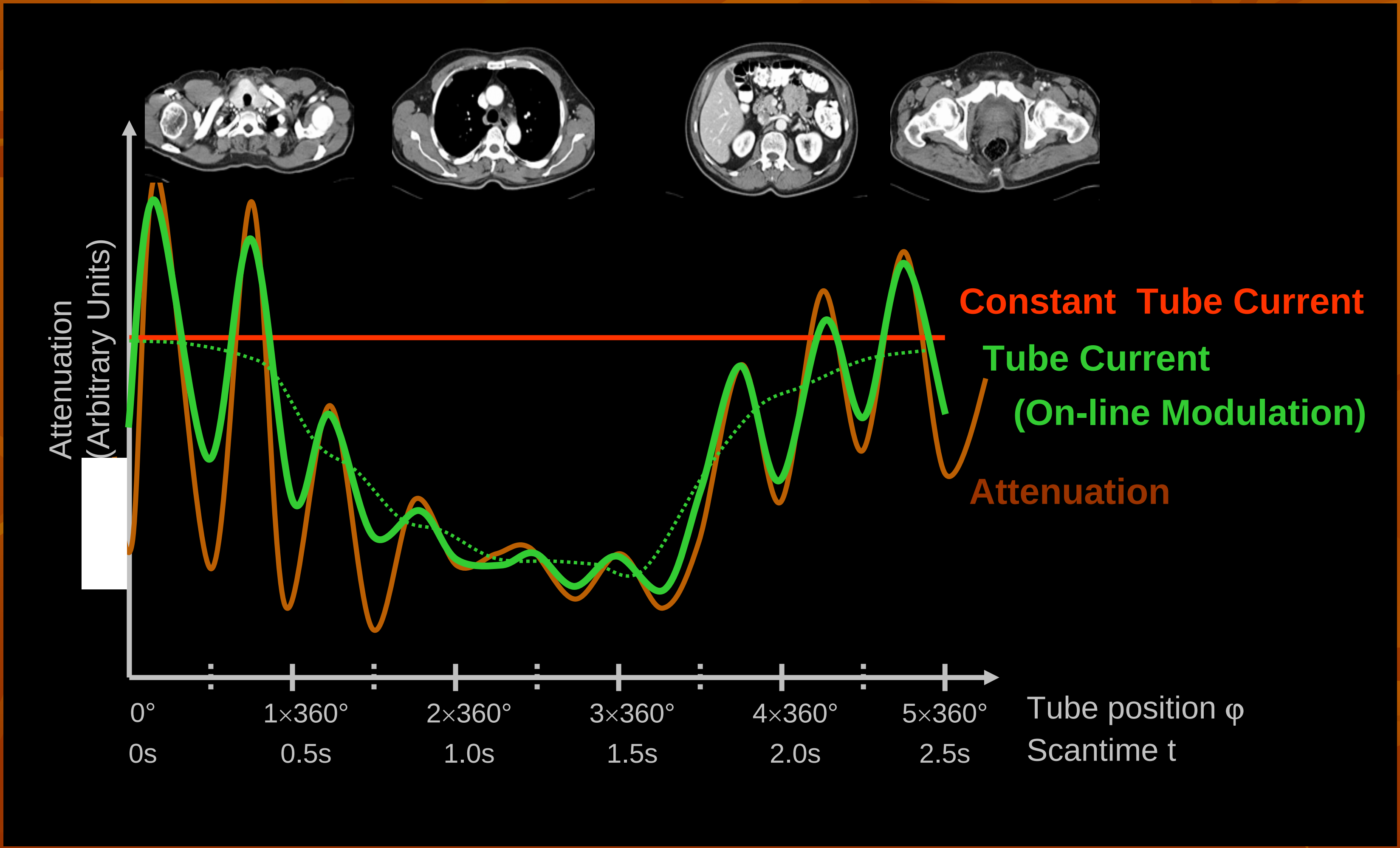
- Necessarily on separate computer system
- However, interface to x-ray generator controlling system would be ideal for direct downloading of
  - kVp, mA, mode of operation (pulsed fluoroscopy or digital run)
  - ABC/AEC dose curve, frame rate and pulse width
  - FOV, magnified views, spectral filtration
  - SID and table position
  - Patient information
- Simplified GUI for technologist or tech assistant to use

Step 2: Develop online dose estimate software (IR)

Step 2: Develop online dose estimate software (CT)

- Necessarily on separate computer system
- However, interface to x-ray generator controlling system would be ideal for direct downloading of
  - kVp, mA, rotation time, mode of operation (helical or sequential)
  - Current modulation and gating
  - Beam width, FOV
  - Patient information
- Simplified GUI for technologist or tech assistant to use

Step 2: Develop online dose estimate software (CT)



Step 2: Develop online dose estimate software (other modalities)

- Intention would be to include all modalities
  - Fluoroscopy
  - CR, DR
    - How to incorporate the varied and complex geometry sometimes used
    - Some systems do not have an automatic way to record kVp and mAs
- FFDM
- Nuclear Medicine
  - Plain, SPECT and PET
  - Radiosotopes, studies

Step 3: Lifetime Patient Dose Database (LPDD)

- Kept on dedicated LPDD server
- Must incorporate
  - all studies
  - from all hospital network sites and clinics
  - all modalities
- Must comply with all HIPPA and IHE standards
- Must include
  - Total lifetime effective dose
  - Equivalent dose to critical organs
- Incorporate routine to warn and advise healthcare personnel of moderately high and high doses

Step 4: Incorporation into the LEMR

- Available at point of POE
- Advise ordering physician about dose classification of procedure to be ordered (low, moderate or high dose)
- Upon selection of procedure, pull LPD information
- Advise ordering physician, if necessary about elevated
  - Lifetime effective doses
  - Critical organ doses
- Require physician confirmation when procedure may result in moderate to higher doses

Quite a Task, Isn't It?

Questions?