Patient Dose: What to Record and Track and the Role of Organ Dose

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TRACKING RADIATION EXPOSURE FROM MEDICAL DIAGNOSTIC PROCEDURES
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Disclosures

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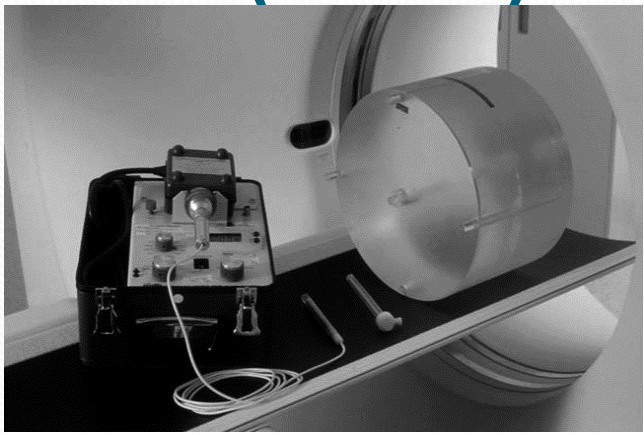
- Instructor, Medical Technology Management Institute .

What Dose Metrics Are Available?

- Current Dose Metrics are, for the most part, indicators of system output (input for Nuclear Medicine)
  - Air Kerma or Kerma Area Product
  - Administered Activity
  - $CTDI_{vol}$

CT –Specific Dose Definitions (CTDI)



- $CTDI_{vol}$ is an Index
- $CTDI_{vol}$ is dose in a phantom
- $CTDI_{vol}$ has LOTs of good uses:
  - It is a good measure of scanner output
  - It is a good index when comparing protocols and technical parameter settings
  - It is a very good indicator of how scanner output is being adjusted with patient size (think peds protocols)

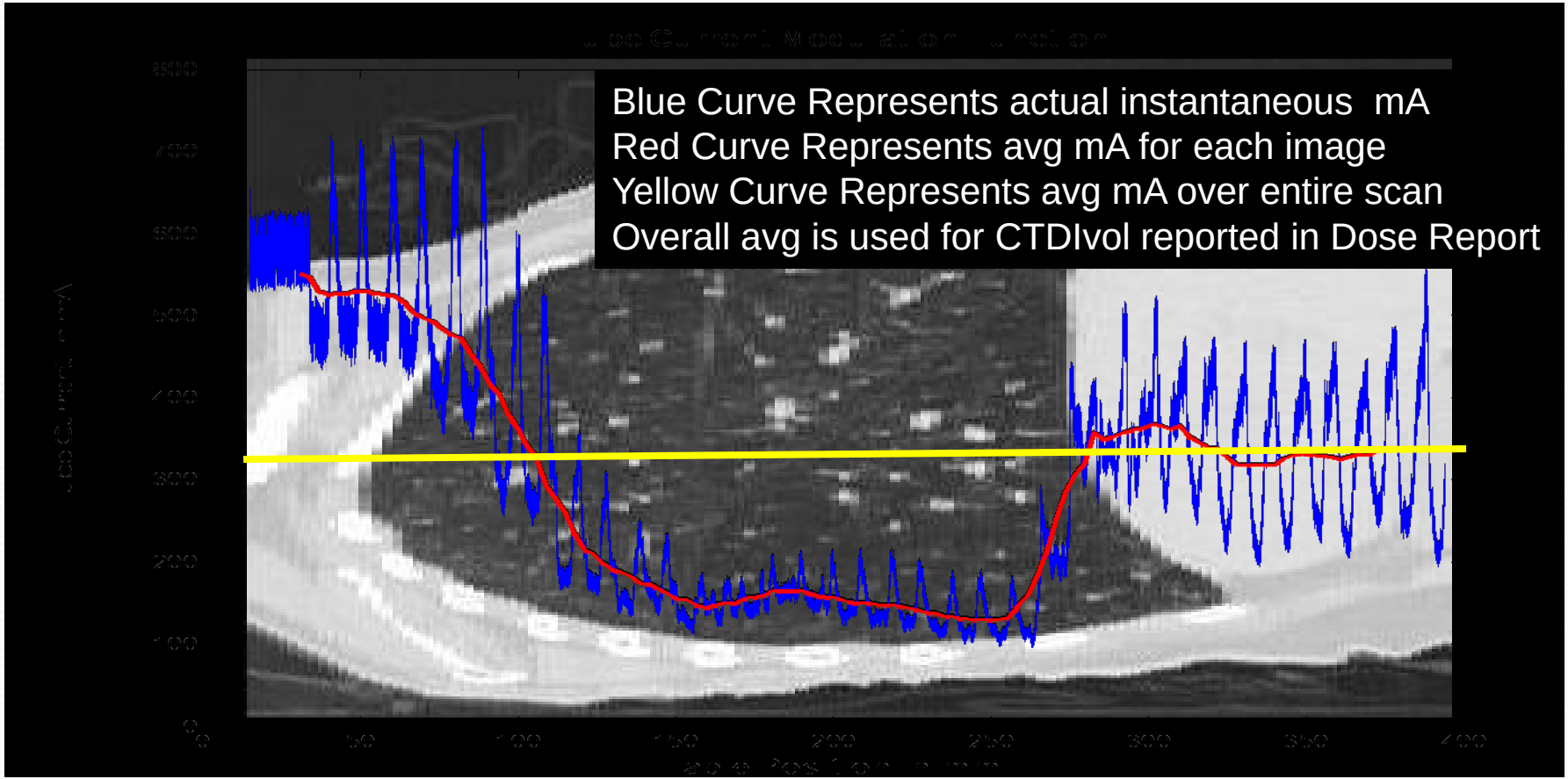
$CTDI_{vol}$ – defined (narrowly)

- CTDI Represents:
  - **Average dose in a phantom**
  - along the z direction
  - at a given **point** (x,y) in the scan plane
  - over the **central scan of a series of scans**
  - when the series consists of a **large number of scans separated by the nominal beam width** (contiguous scanning)

$CTDI_{vol}$ in Context of AEC

- When Tube current modulation is used:
  - $CTDI_{vol}$ reported is based on the ***average mA used throughout the scan***

Scan where Tube Current Modulation was used



$CTDI_{vol}$ and DLP

- Are already reported at scanner
- Are already used in DICOM RDSR (and Patient "dose reports")
- Are already used in ACR CT accreditation program
- Are used in ACR CT Dose Index Registry
- Are used in MITA XR-25 ("Dose Check") standard

- So, shouldn't we just use these?

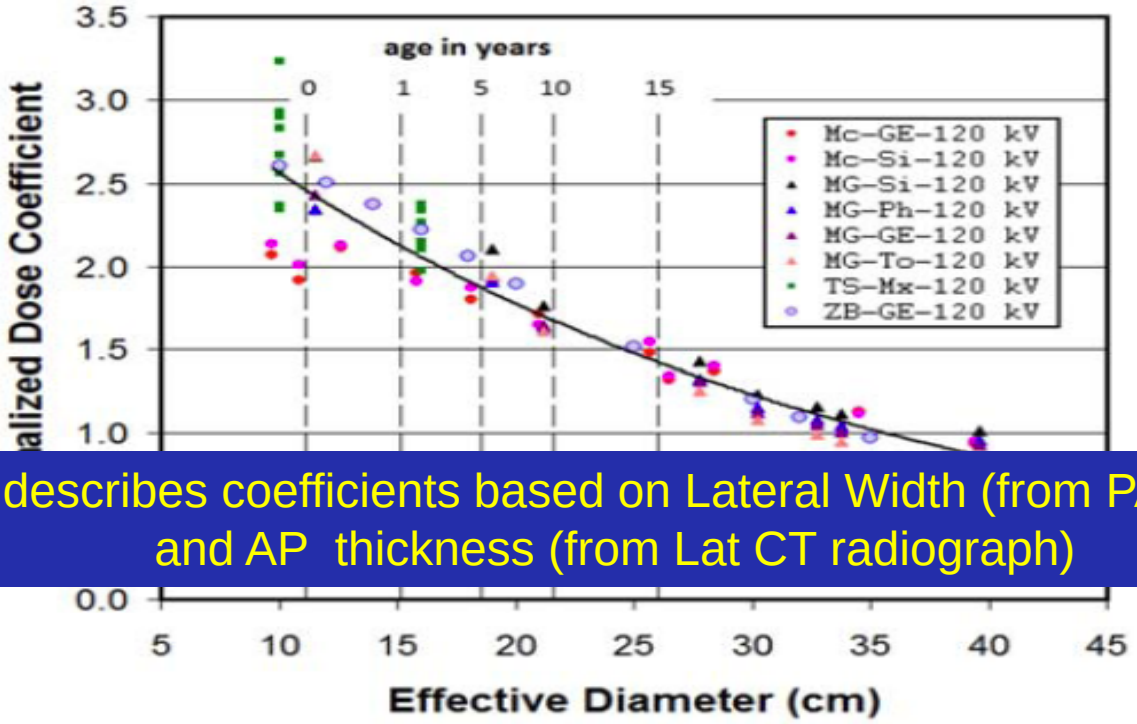
Limitations to CTDI

- $CTDI_{vol}$ does not account for patient size
  - Even though you may see different values for patients of different size; this is because scanner output is being (usually properly) adjusted for patient size
- Nor does it represent peak (skin) dose
  - Important for assessing deterministic effects (perfusion)

Overcoming Limitations to CTDI

- AAPM Report 204 describes a method to take into account patient size
- The Size Specific Dose Estimate (SSDE)

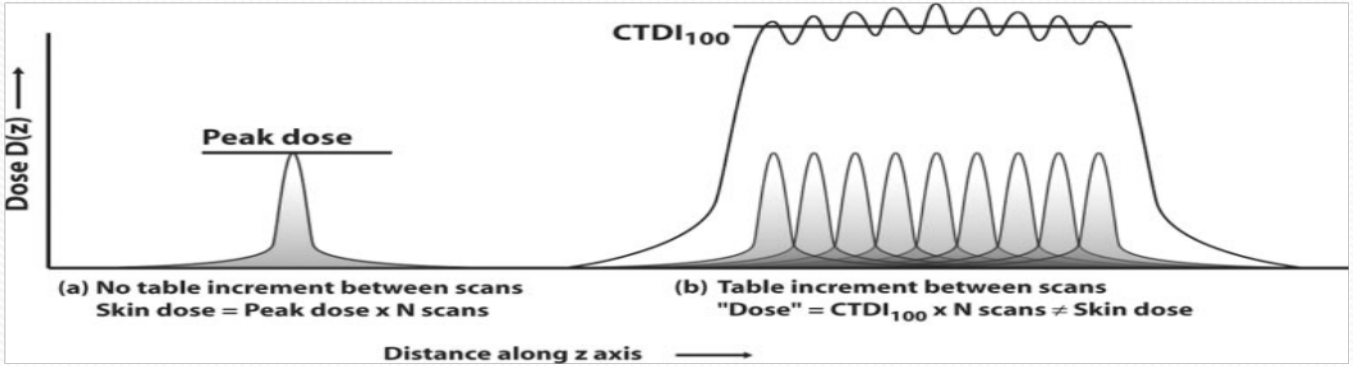
AAPM Report 204



Report also describes coefficients based on Lateral Width (from PA CT radiograph) and AP thickness (from Lat CT radiograph)

$CTDI_{vol}$ and Peak Dose (Perfusion Scans)

- $CTDI_{vol}$ is a weighted average of measurements made at periphery and center of cylindrical phantom
- Defined to reflect dose from a series of scans performed <u>w/table movement</u>



From Bauhs et al, Radiographics. 2008 Jan-Feb;28(1):245-53

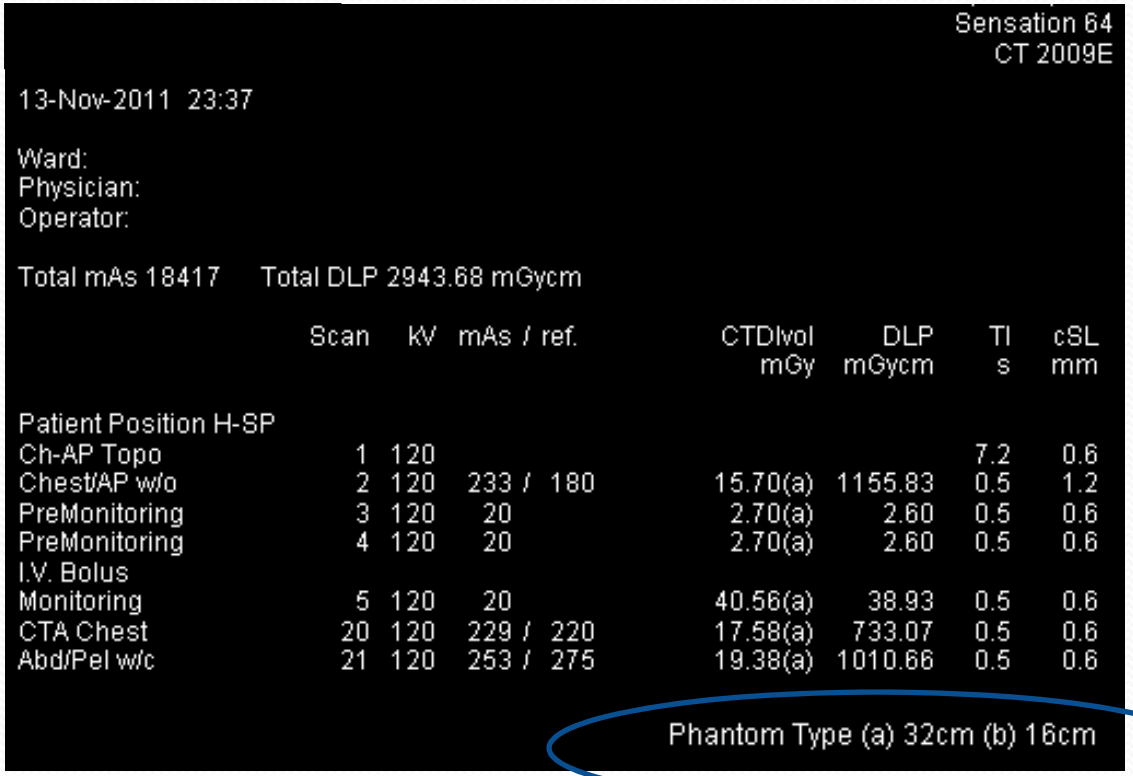
$CTDI_{vol}$ and Peak Dose (Perfusion Scans)

- $CTDI_{vol}$ is a weighted average of measurements made at periphery and center of cylindrical phantom
- Defined to reflect dose from a series of scans performed w/table movement
- Is not patient dose (not even skin dose)
- CTDIvol **OVERestimates skin dose** in cases where scan is performed with no table movement (e.g. perfusion scans)
- See article by Zhang et al, AJR Feb 2012 (in press).

Current and Future Role of CTDI/DLP

- In California there is a state law (SB 1237) that will require us (7-1-2012) to record CTDI and DLP (or the dose unit as recommended by the AAPM) in radiology reports and patient records

What's Available? How will we report this?



Sensation 64
CT 2009E

13-Nov-2011 23:37

Ward:
Physician:
Operator:

Total mAs 18417 Total DLP 2943.68 mGycm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGycm	TI s	cSL mm
Patient Position H-SP							
Ch-AP Topo	1	120				7.2	0.6
Chest/AP w/o	2	120	233 / 180	15.70(a)	1155.83	0.5	1.2
PreMonitoring	3	120	20	2.70(a)	2.60	0.5	0.6
PreMonitoring	4	120	20	2.70(a)	2.60	0.5	0.6
I.V. Bolus							
Monitoring	5	120	20	40.56(a)	38.93	0.5	0.6
CTA Chest	20	120	229 / 220	17.58(a)	733.07	0.5	0.6
Abd/Pel w/c	21	120	253 / 275	19.38(a)	1010.66	0.5	0.6

Phantom Type (a) 32cm (b) 16cm

How to convert this to a Patient Dose?
Just add $CTDI_{vol}$s?
Add DLPs?

Patient Protocol Page from Siemens S64

Tracking Patient Dose?

- How would we use $CTDI_{vol}$ (or SSDE) and DLP values?

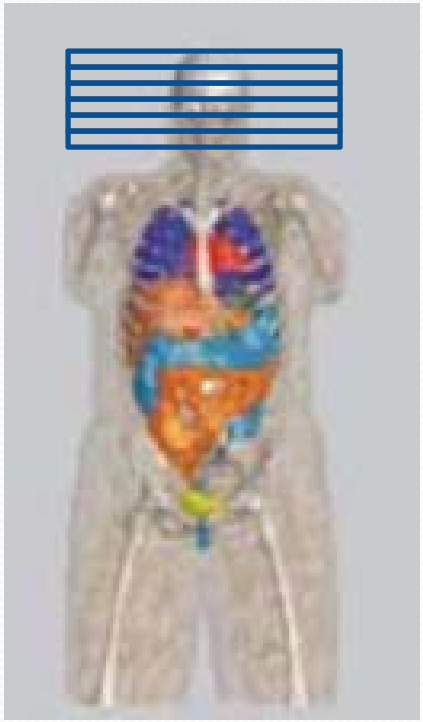
- Add them in some cases? Not add in others?
- What about different exams?

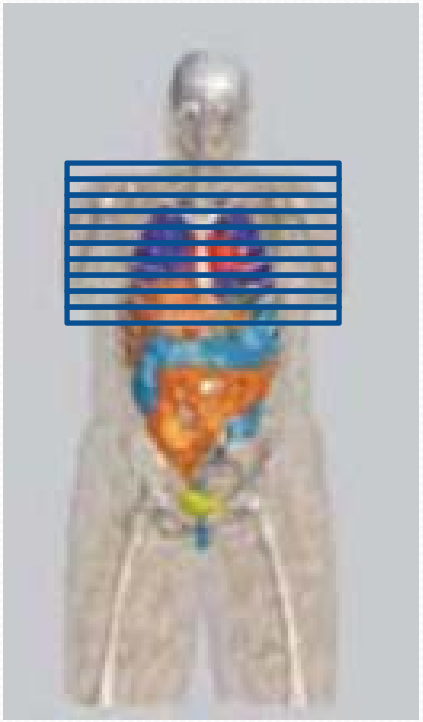
- Possible to develop rules
  - Add when same anatomic region is scanned multiple times
    - Chest pre- and post-contrast
  - Don't add when different anatomic regions are scanned
    - Head followed by Chest followed by Abd/Pel

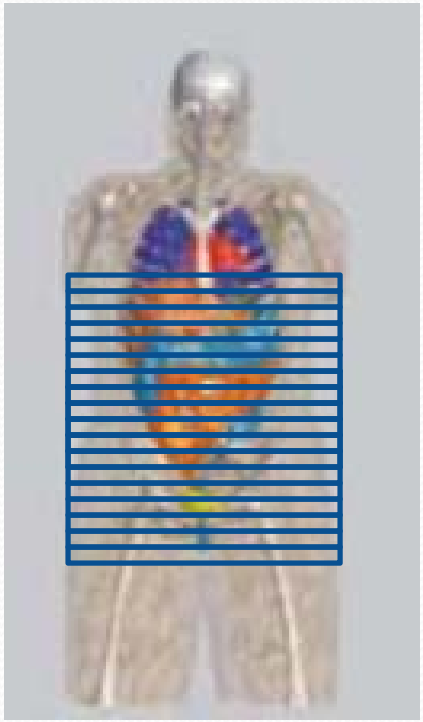
Head CT

Chest CT

Abd/Pel CT







$CTDI_1$
$SSDE_1$

+

$CTDI_2$
$SSDE_2$

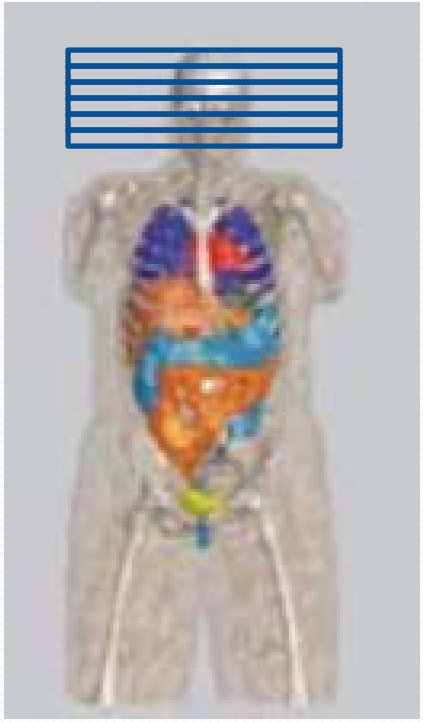
+

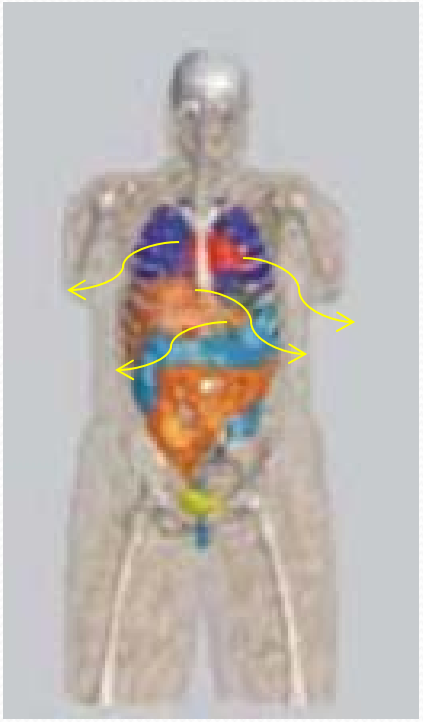
$CTDI_3$
$SSDE_3$

$= CTDI_{total}$?
$= SSDE_{total}$?

Head CT

PET





$CTDI_1$
$SSDE_1$

+

Activity

= ????

Possible Solution – Organ Dose

- Peak Dose (skin and eye lens - deterministic effects)
- Average Dose to radiosensitive organs (stochastic effects)
- These could be tracked over time
- Because they are spatially/anatomically specific, their addition (or other math operation) would be meaningful

Radiation Dose : Organ Dose

- BEIR VII report (2005)
  - Risk based on radiation dose to organ, age, gender, etc.
- ICRP 103 (2007)
  - Calculates “effective dose” based on weighted sum of organ dose
- Use dose to radiosensitive organs as a basis for estimating metrics that relate to risk

Estimating organ dose for patients

- Can We Get There?
- What will it take?
  - Detailed analysis/Monte Carlo simulation on EACH patient?

Monte Carlo Simulation Methods for Estimating Radiation Dose

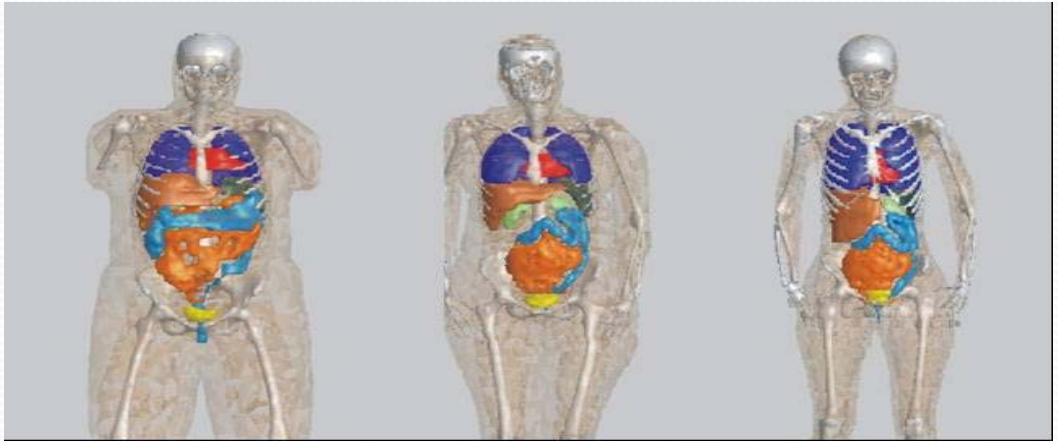
- Used in CT for some time
  - NRPB report 250 (1990)
  - GSF (now Helmholtz Zentrum Munchen (Zankl)
- Form the basis for:
  - CT Expo
  - ImPACT dose calculator
  - k factor approach (Effective dose = k* DLP), which was derived from NRPB simulated data

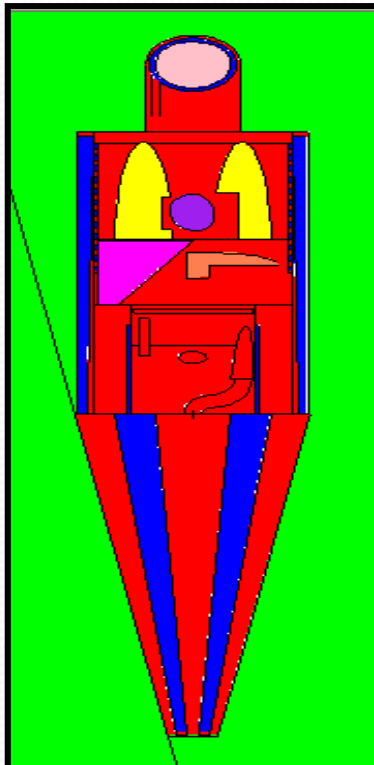
Current Approaches

- Model Scanner (e.g MDCT) in detail
- Model Patient (Geometric, Voxelized)
- Simulate Scan
- Tally Organ Dose

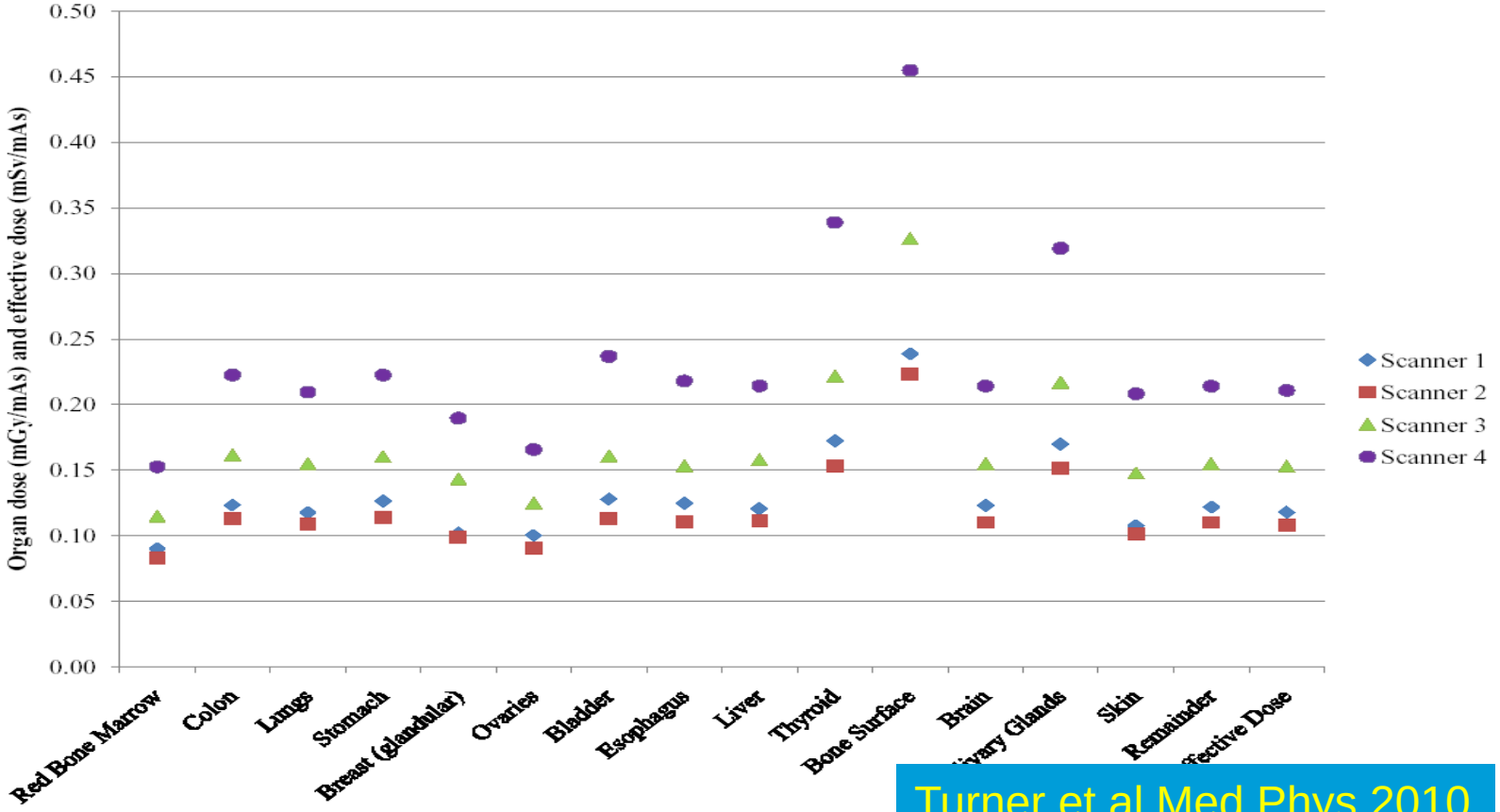
Modeling the Patient Anatomy

- Geometric
- Voxelized Models



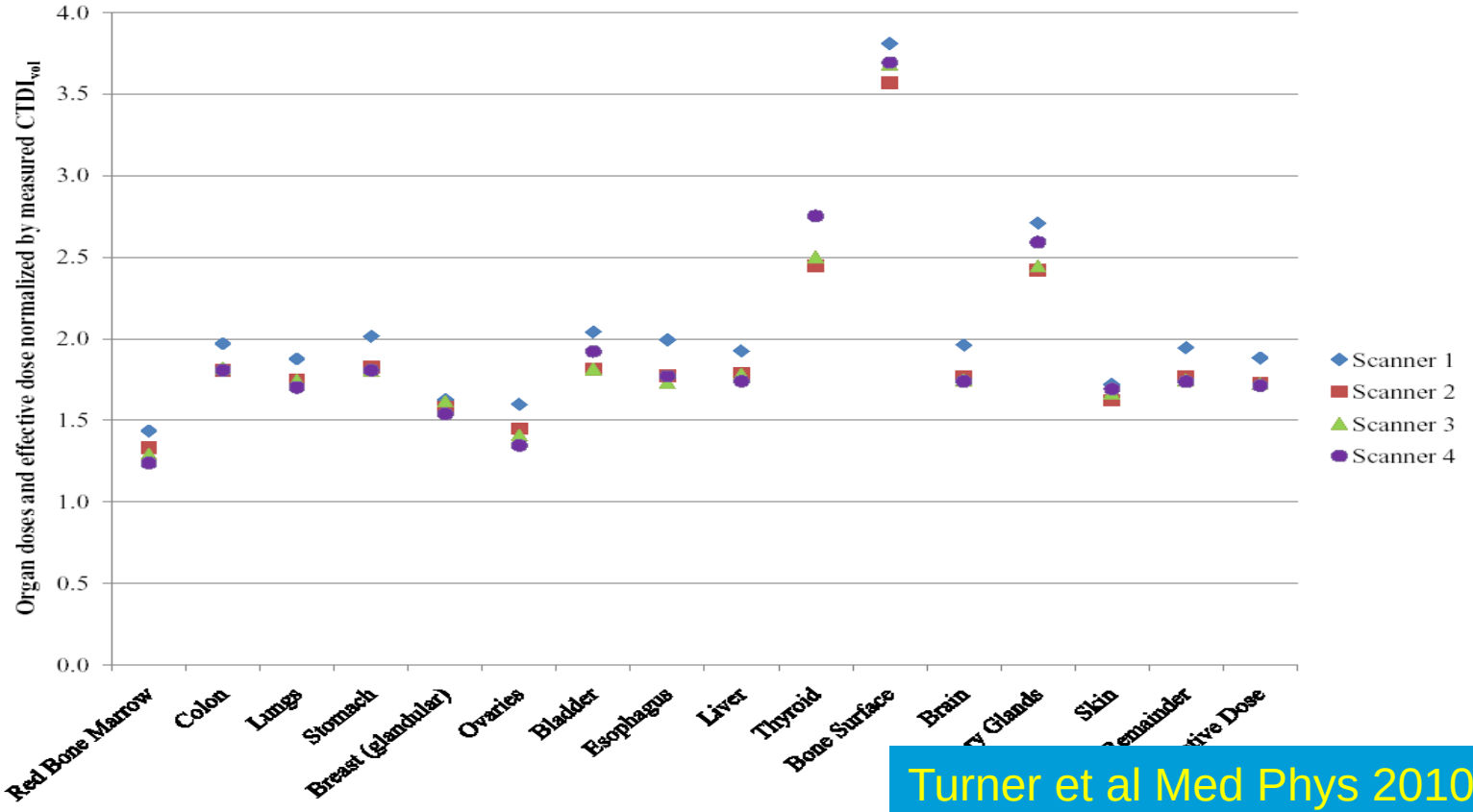


Organ dose (in mGy/mAs) and effective dose (in mSv/mAs) for GSF model Irene resulting from a whole body scan with similar parameters for each scanner



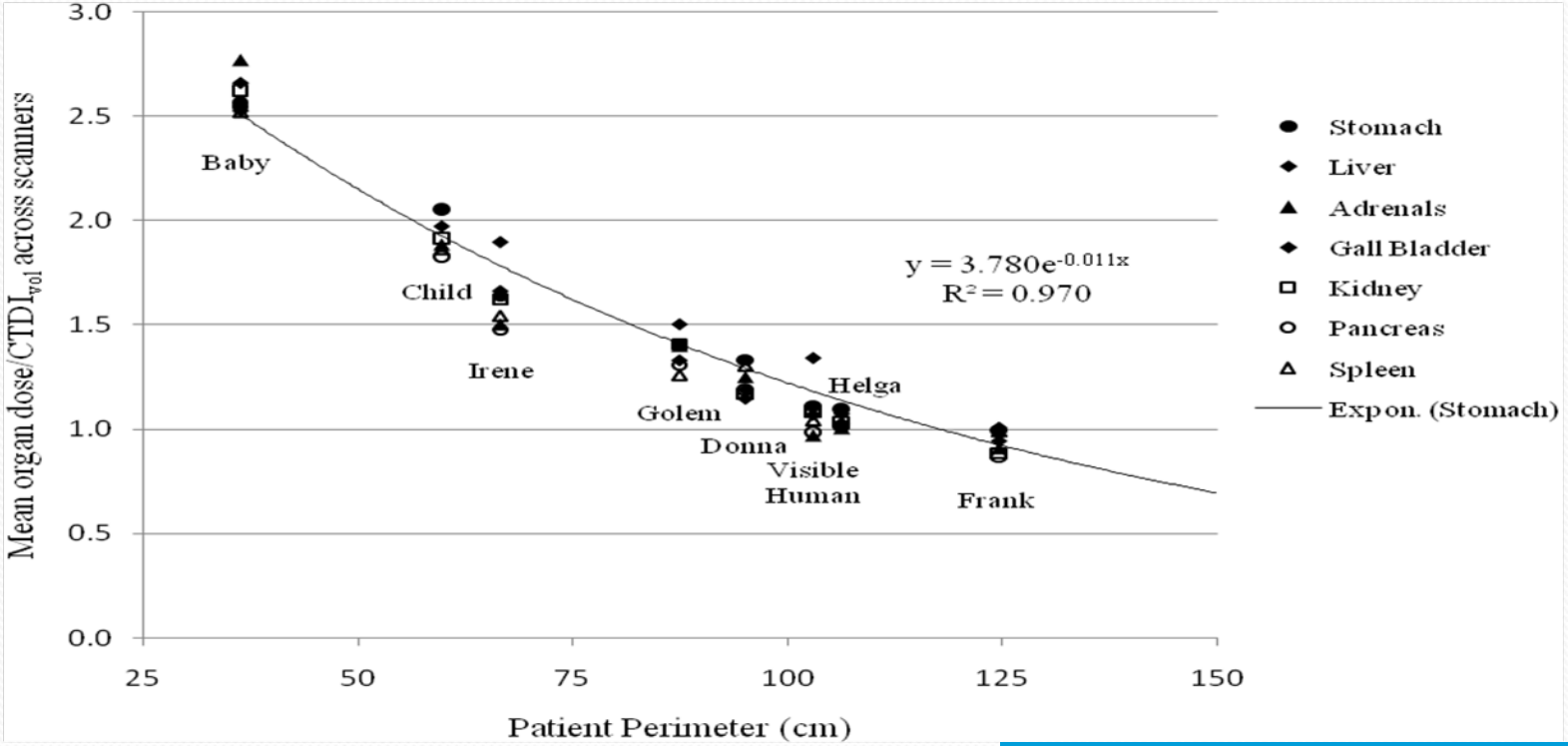
Turner et al Med Phys 2010

Organ dose and effective dose normalized by measured CTDIvol for GSF model Irene resulting from a whole body scan.



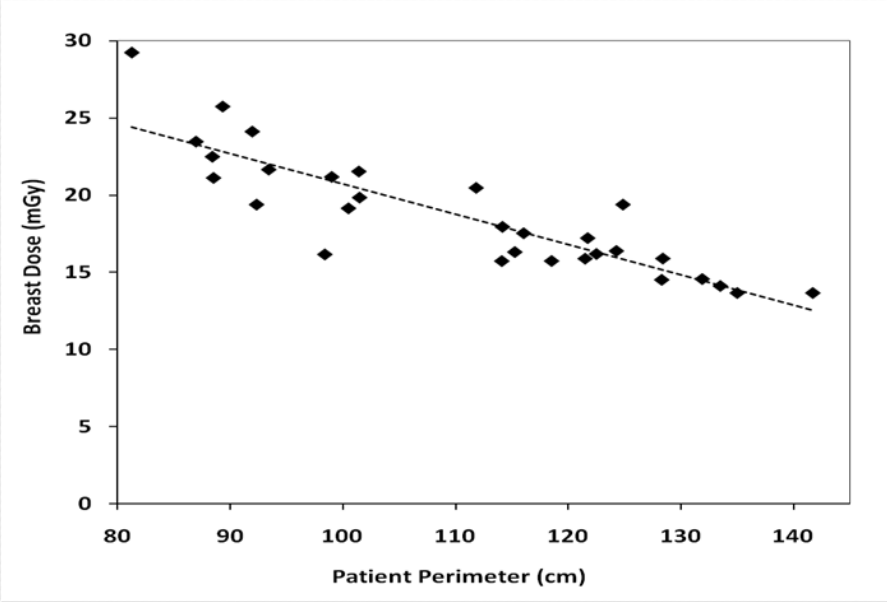
Turner et al Med Phys 2010

Normalized Organ Dose as function of Pt. Size (Abdomen Scans for each Patient)



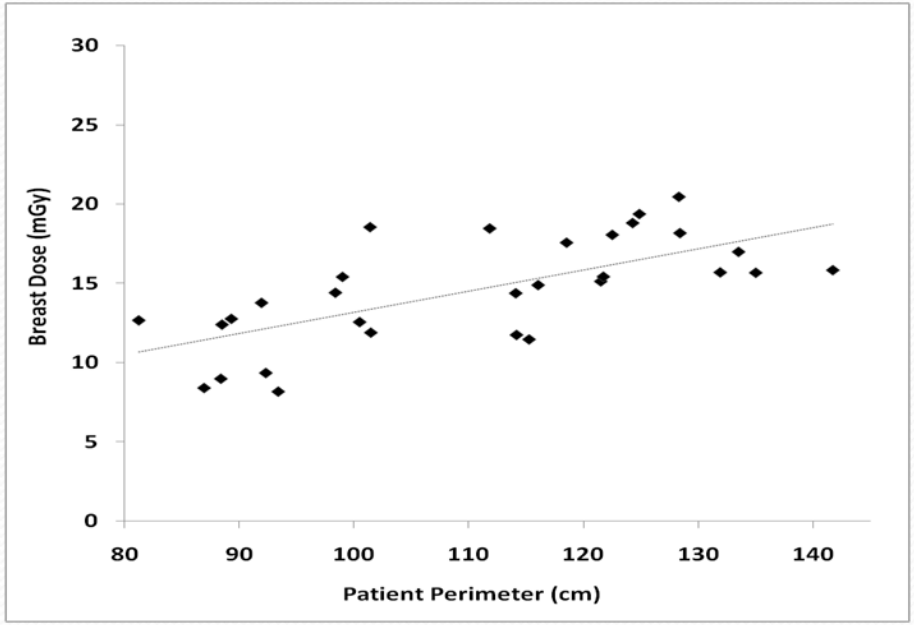
Turner et al Med Phys 2011

Angel et al, PMB Feb 2009



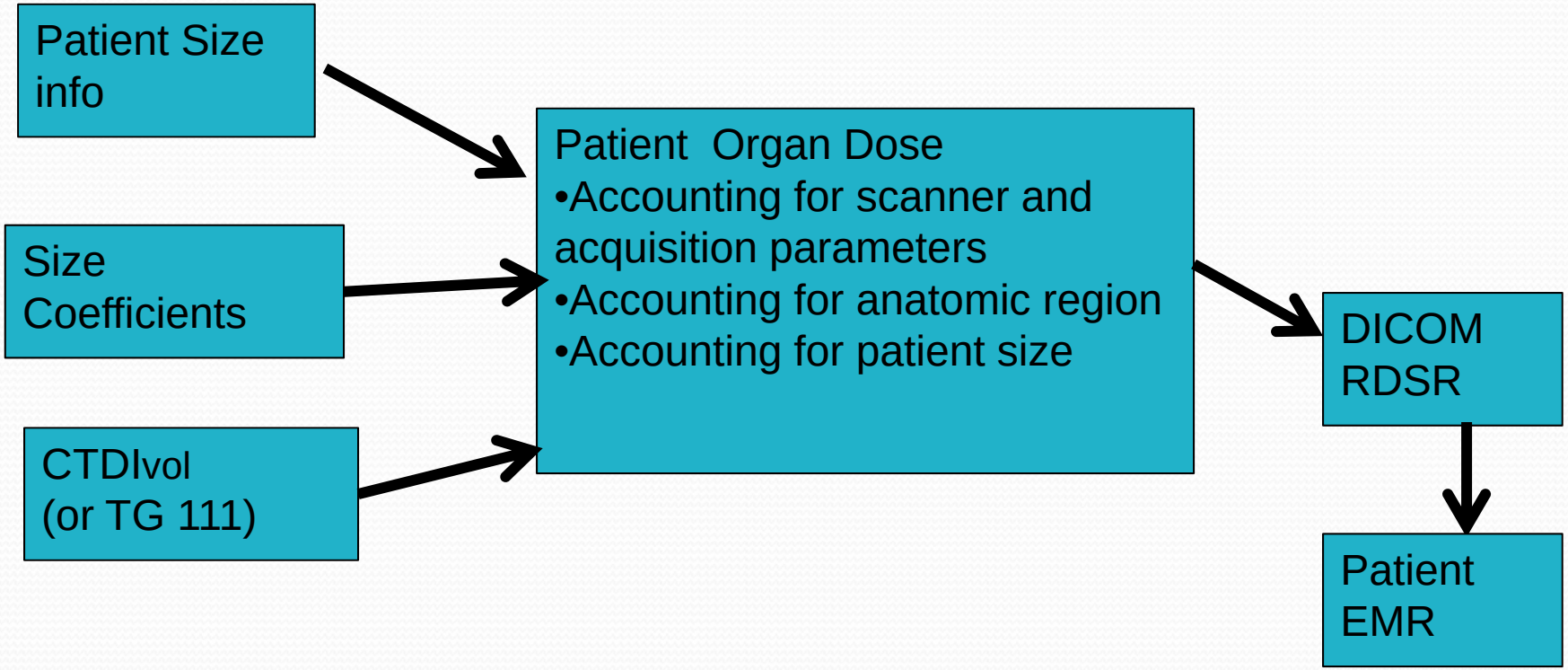
Breast dose versus patient perimeter for all 30 patient models in the fixed tube current simulations. Breast dose decreases linearly with an increase in patient perimeter (R^2=0.76).

Angel et al, PMB Feb 2009



Breast dose versus patient perimeter for all 30 patient models in the TCM simulations. Breast dose increases linearly with an increase in patient perimeter (R^2=0.46).

Future of Dosimetry?



Summary - Estimating Organ Doses

- Many Organizations suggesting that CT dose be tracked (NCI, IAEA, ACR, FDA, etc.)
- California SB 1237 requires reporting CTDIvol and DLP by 7-1-2012 (but not tracking patient dose)
- Organ Dose
  - Could be tracked across scans and across time
  - Accumulated organ dose over time

Summary - Estimating Organ Doses

- Organ Doses are meaningful indicators of Dose
- More informative than CTDI, DLP, E alone
  - Take into account differences in scanner
  - Take into account differences in patient size
  - Take into account differences in body region
  - Take into account dose reduction methods (TCM)
- Can conceivably be tracked over time in a more meaningful way that CTDI or SSDE

Summary - Estimating Organ Doses

- BEIR VII report (2005), ICRP 103 (2007) use dose to radiosensitive organs
- BEIR VII estimates risk based on organ, dose to that organ, age, gender, etc.
- ICRP 103 uses organ dose to estimate effective dose

Summary - Estimating Organ Doses

- Feasibility to obtain a reasonably accurate estimate of organ dose WITHOUT having to do detailed analysis on each patient
- Not quite ready for implementation (yet)

What Will It Take?

- Obtaining organ dose estimates in a robust fashion is not easy to do on a routine basis.
- What We Need:
  - Further develop methods in each modality that account for:
    - Source output (Nuc Med: Input)
    - Patient Factors (size, anatomy and physiology)
    - Methods to identify anatomic region/organs being exposed
  - Reporting Standards (DICOM RDSR, IHE REM)

What Will It Take?

- Cooperation between:
  - Equipment manufacturers
  - Standards organizations (e.g. DICOM, IHE, IEC)
  - Professional organizations (e.g. AAPM, SNM)
  - Users
  - Patients
  - to adopt these methods and support the implementations necessary to track patient dose in a routine fashion.

Acknowledgements

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  - Siemens Medical Solutions
  - GE Healthcare
  - Toshiba Medical Systems
  - Philips Healthcare

Reporting Dose: How To Do It Right?

- Phase 0 (We Are Currently Here):
  - Patient Protocol Page, Info. Manually Dictated into Radiology Report
- Phase 1 (We are Part of the Way Here):
  - DICOM SR, Still Manually Dictated into Radiology Report
  - Some scanners create DICOM SR, not easy to read and dictate
- Phase 2 (We WANT to be Here before July 1, 2012)
  - DICOM SR, Auto-insert into Radiology Report
- Phase 3: DICOM SR, Body Region and Size Adjusted, Auto-insert into Radiology Report
- Phase 4: DICOM SR, Body Size Adjusted, Organ Doses; Auto-Insert into Radiology Report
- Phase 5: ????