Science For A Better Life

Radiation Dose Monitoring Issues

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Objectives

- Understand the limitations of current dose metrics
- Recognize the challenges of accurate dose estimates in real clinic settings
- Call for collaborations from all parties

Focusing on CT and Fluoroscopy

Why dose tracking?

- **Immediate goal: patient care, as low as reasonably achievable, improve protocols, prevent/catch mistakes**

- **Longer term goal: gather better and larger datasets to improve our understandings of radiation and cancer as well as other diseases (leukemia, lymphoma, cataracts…)**

Cancer Risk Estimates

- **NAS BEIR VII (2006)**

  Atomic bomb survivors

  Patients treated with radiotherapy or fluoroscopic procedures

Cancer Risk Estimates (Cont'd)

- **Epidemiological studies of radiation from CT exams**

e.g. "Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study" by Pearce et al. 2012

Retrospective cohort study of people younger than 22 years old that went through CT scans between 1985 and 2002 in the UK

Limitation: Dose estimated using typical scanner settings as study specific parameters for individual patients were not available

Cancer Risk Estimates (Cont'd)

- **Epidemiological studies of radiation from CT exams**

Proposed/on-going:

"Assessing Organ Doses from Pediatric CT Scans—A Novel Approach for an Epidemiology Study (the EPI-CT Study)", Thierry-Chef et al. 2013

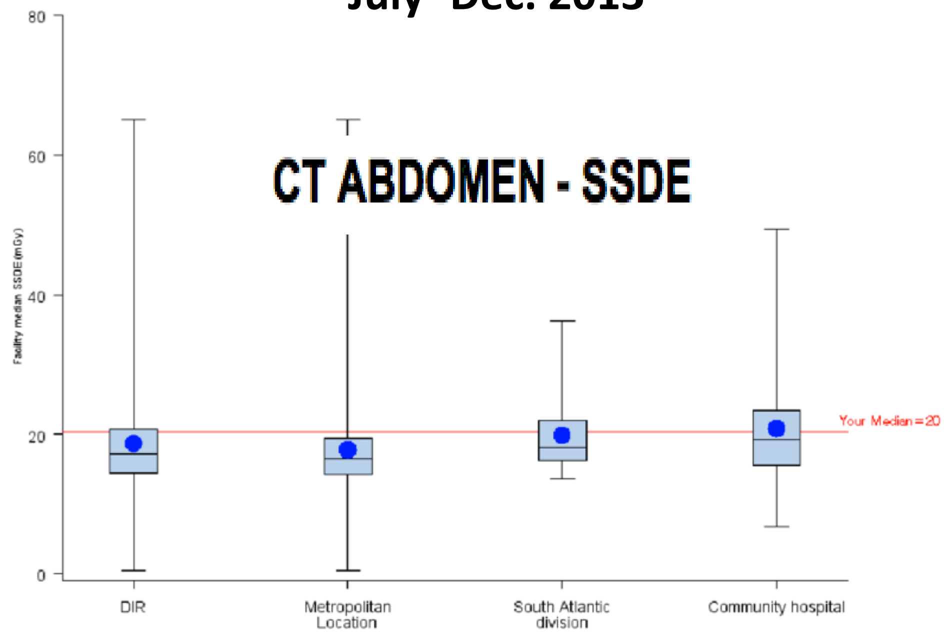
What metrics are currently being tracked?

- **Legislation**
  e.g.
  California (2010, 2012):
  CTDIvol and Dose-Length-Product (DLP)
  Texas (2013):
  CTDIvol, DLP, and Air Kerma (fluoro)

What metrics are currently being tracked? (Cont'd)

- **Dose index registry e.g. ACR DIR Benchmark on CTDIvol, DLP and SSDE (new)**
- **Commercial software partners**

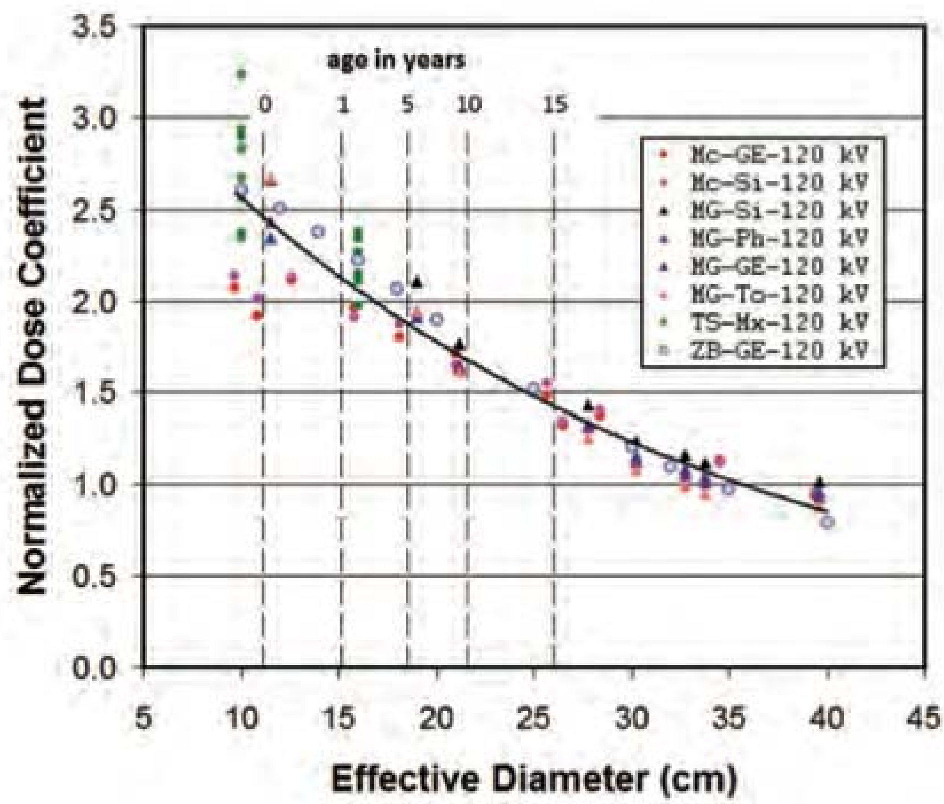
e.g. DIR Sample Report July- Dec. 2013



Issues with
CTDIvol, DLP and SSDE

CTDIvol and DLP:

Patient size issue is well recognized, and alleviated by size-specific-dose-estimates (SSDE)



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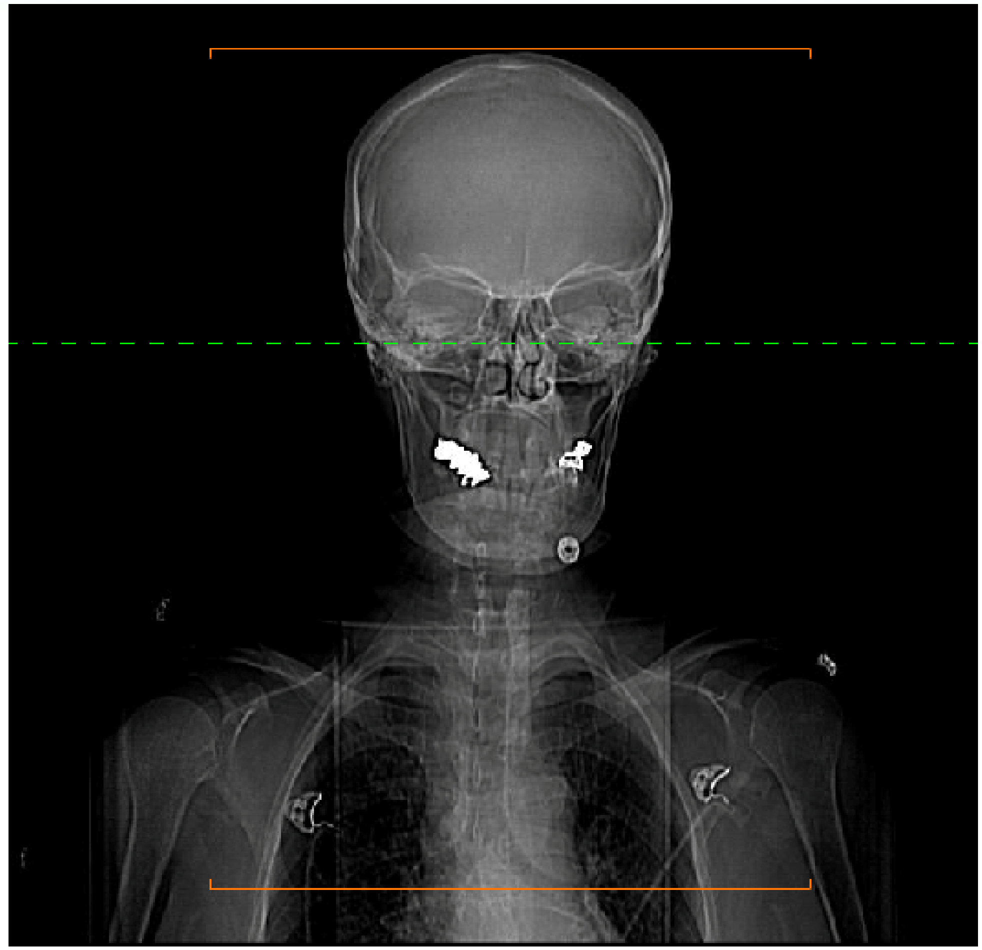
Issues with CTDIvol, DLP and SSDE (cont'd)

Are CTDIvol and DLP meaningful in this case?

CTA_HEAD_NECK_WO_W

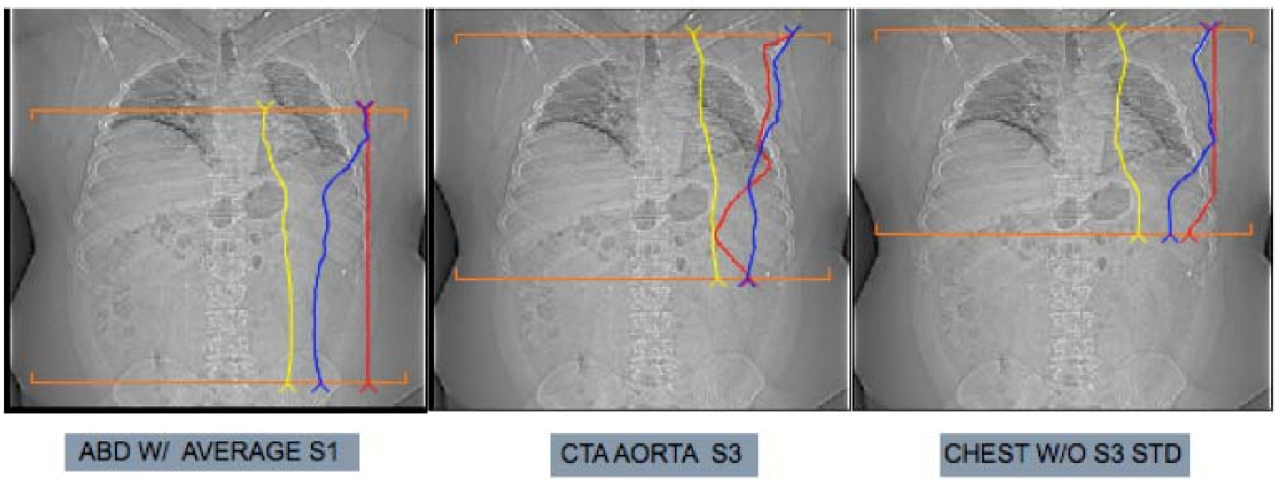


Example from database available to Bayer HealthCare

Issues with CTDIvol, DLP and SSDE (cont'd)

Meaning of Exam Level Values

CTA_CHEST_AORTA_AB_PEL_VEN (3 acquisitions)



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Maximum? Average? Scan-length weighted average?

Acquisitions?

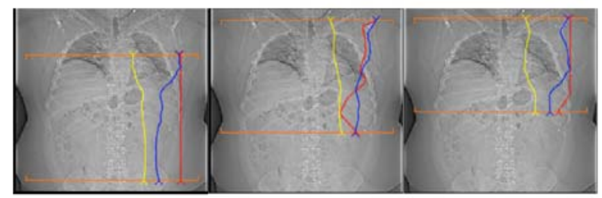
~~Exams~~

Organ dose?

Organ Dose:

energy deposited in each organ/total organ mass

Meaningful on exam level (for a specific organ, energy can be added over multiple acquisitions), and even multiple exam level.



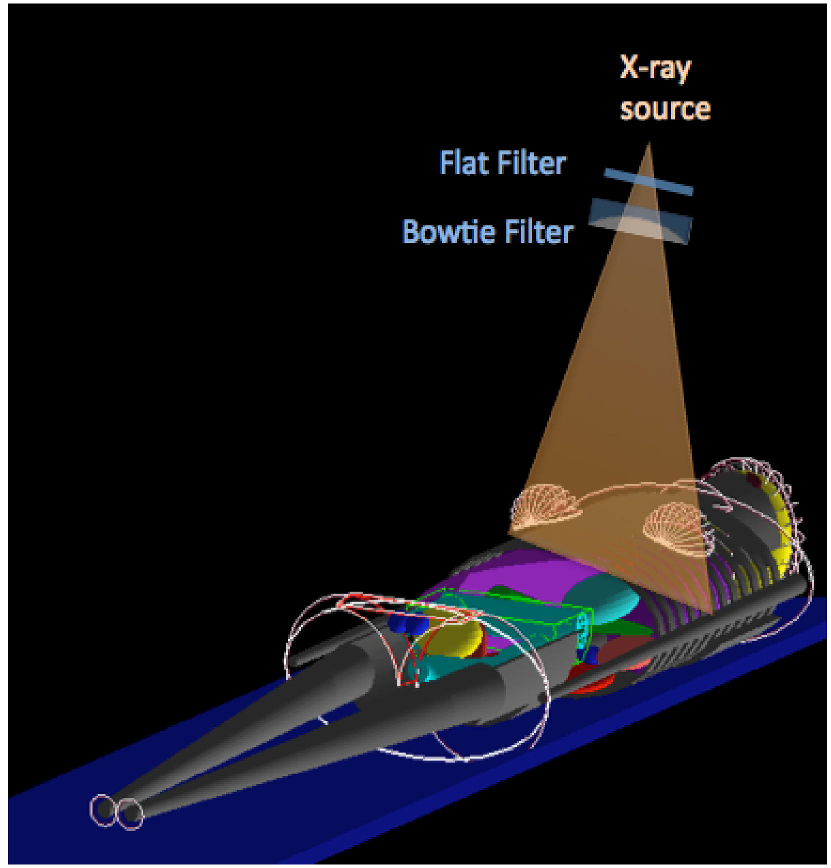
Though not meant to be used for making clinical decisions for individual patient, organ dose is

- a useful dose metric
- necessary for long term cancer risk studies, especially site-specific cancers

Monte Carlo Organ Dose Calculation

Three major components

- Patient modeling
- Scanner modeling
- Exam parameters/ scan technique



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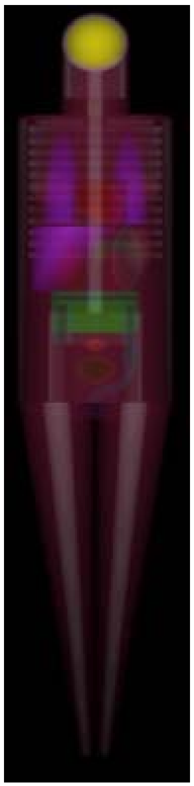
All is well, until spherical cow in the vacuum meets real clinical settings

Credit: NASA and STScI

Patient modeling

We are getting better…



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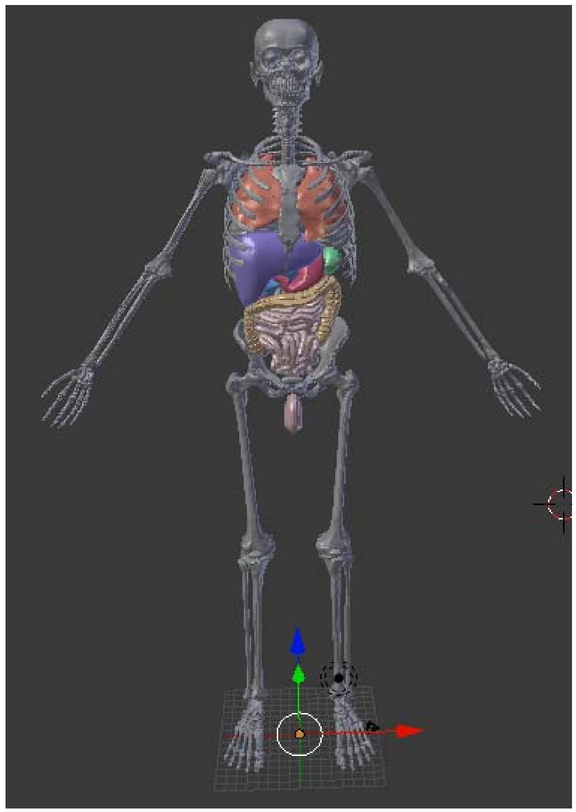

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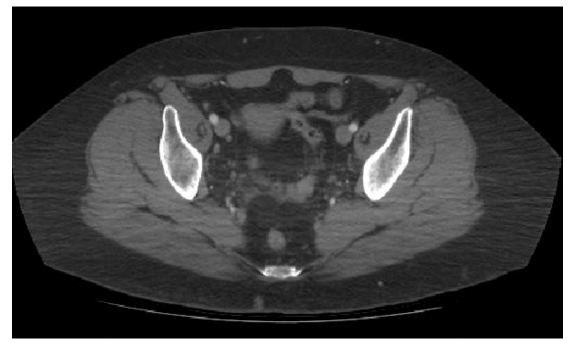

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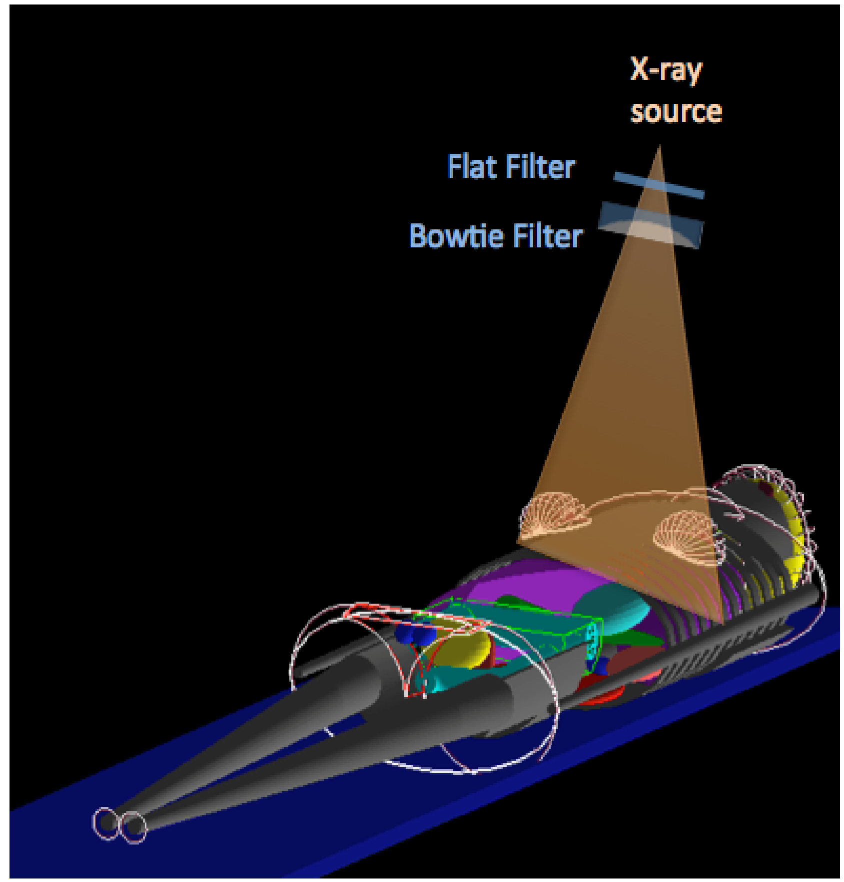
Monte Carlo Organ Dose Calculation

Three major components

- Patient modeling
- Scanner modeling
- Exam parameters/ scan technique

Not enough key information needed is captured or conveyed in a standardized way



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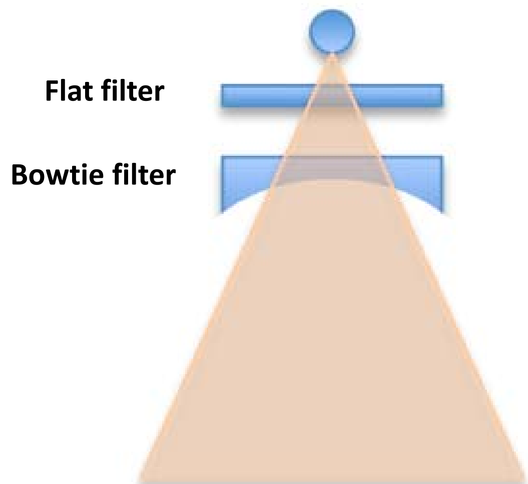
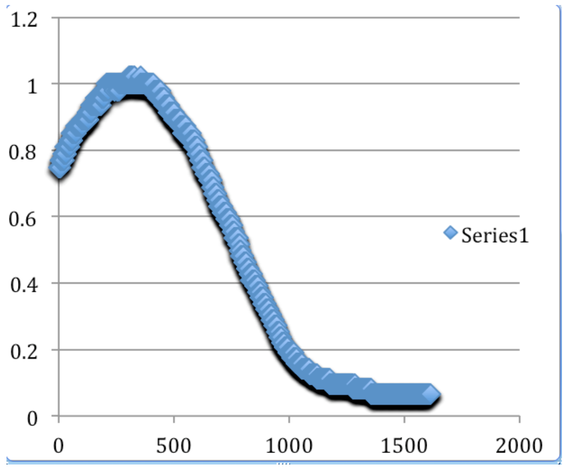
Scanner modeling:
X-ray spectrum, flat and bowtie filters (proprietary)

Infer by measuring HVL, QVL and beam profile (Turner and Zhang 2009):





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Perhaps not important before, but now, there is a need for more information on scanner characteristics for better dose estimate…

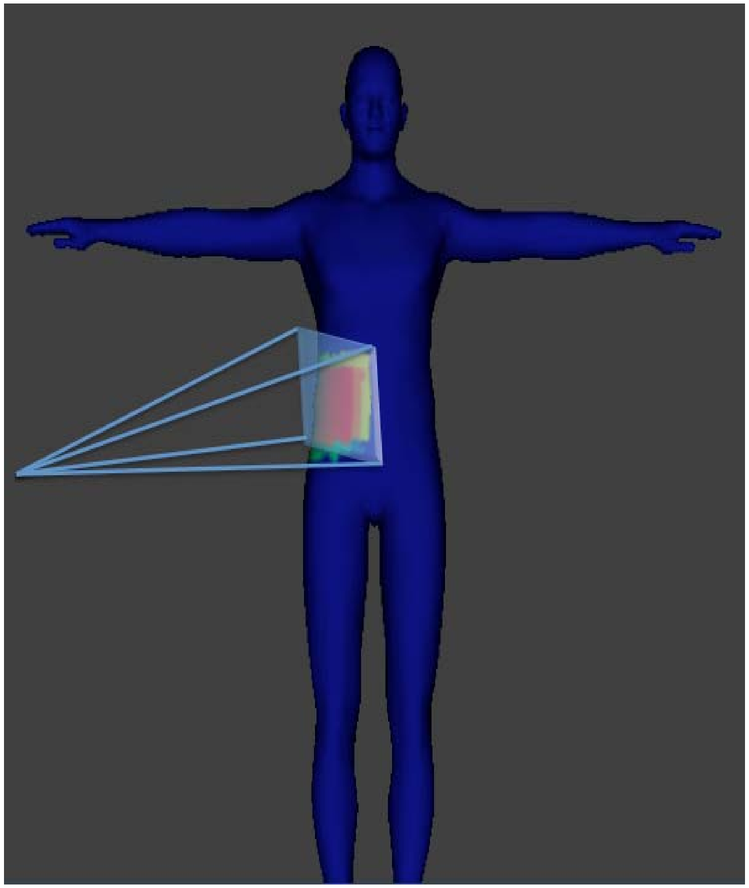
What's the best way to move forward?
Could it become part of the standard report?

Study parameters/Scan technique

- Shielding: come up ways to record/convey information on geometry, position, material etc., so that it can be simulated
- Ever improving dose reduction technique: e.g.
  - x-y plane current modulation
  - reduced over-ranging of helical scan

Fluoroscopy

- **Reference point dose**
- **Dose-Area-Product (DAP)**
- **Skin Dose**
- **(Organ dose?)**



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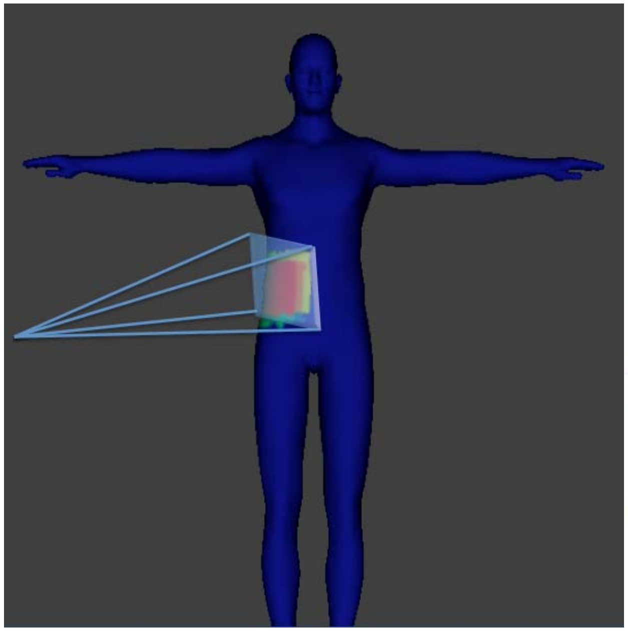
Skin Dose Calculation

- Inverse square law
  need reference point dose and source to skin distance
- Backscatter (HVL dependent)
- Table attenuation
  (HVL dependent)
- Dose_air to Dose_skin



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Challenges in Accurate Skin Dose Calculation

- Patient position on the table
- Ambiguity of table position
- Patient morphology, unlike CT, no axial or localizer for diameter estimates

Challenges in Accurate Skin Dose Calculation (Cont'd)

- Patient position on the table
- **Ambiguity of table position**
- Patient morphology, unlike CT, no axial or localizer for diameter estimates

Reference Point Dose [mGy]	DAP [mGy-cm2]	kVp	Distance Source	Distance Source	Table Longitudinal Position [mm]	Table Lateral Position [mm]	Table Height Position [mm]
0.060000	20	77	1048	750	17.9	743.3	132.8
0.050000	17	71	1048	750	[illegible]	743.3	[illegible]
0.060000	20	71	1048	750	17.7	[illegible]	132.8
0.090000	34	72	1048	750	18.4	285.9	166.9
0.12	26	71	1048	750	-64	305.7	166.9
1.84	404	71	1048	750	-64	305.7	166.9
0.42	92	71	1048	750	-51.6	370.8	166.9
0.54	117	77	1048	750	-38.1	213.1	166.9
1.09	240	76	1048	750	-35.2	178.5	166.9
0.080000	17	76	1048	750	-35.2	178.5	166.9
1.44	317	76	1048	750	-35.2	178.5	166.9

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Challenges in Accurate Skin Dose Calculation (Cont'd)

- Patient position on the table
- Ambiguity of table position
- Patient morphology, unlike CT, no axial or localizer for diameter estimates

Manual measurement?

Automated process? (e.g. Microsoft Kinect™ ?)

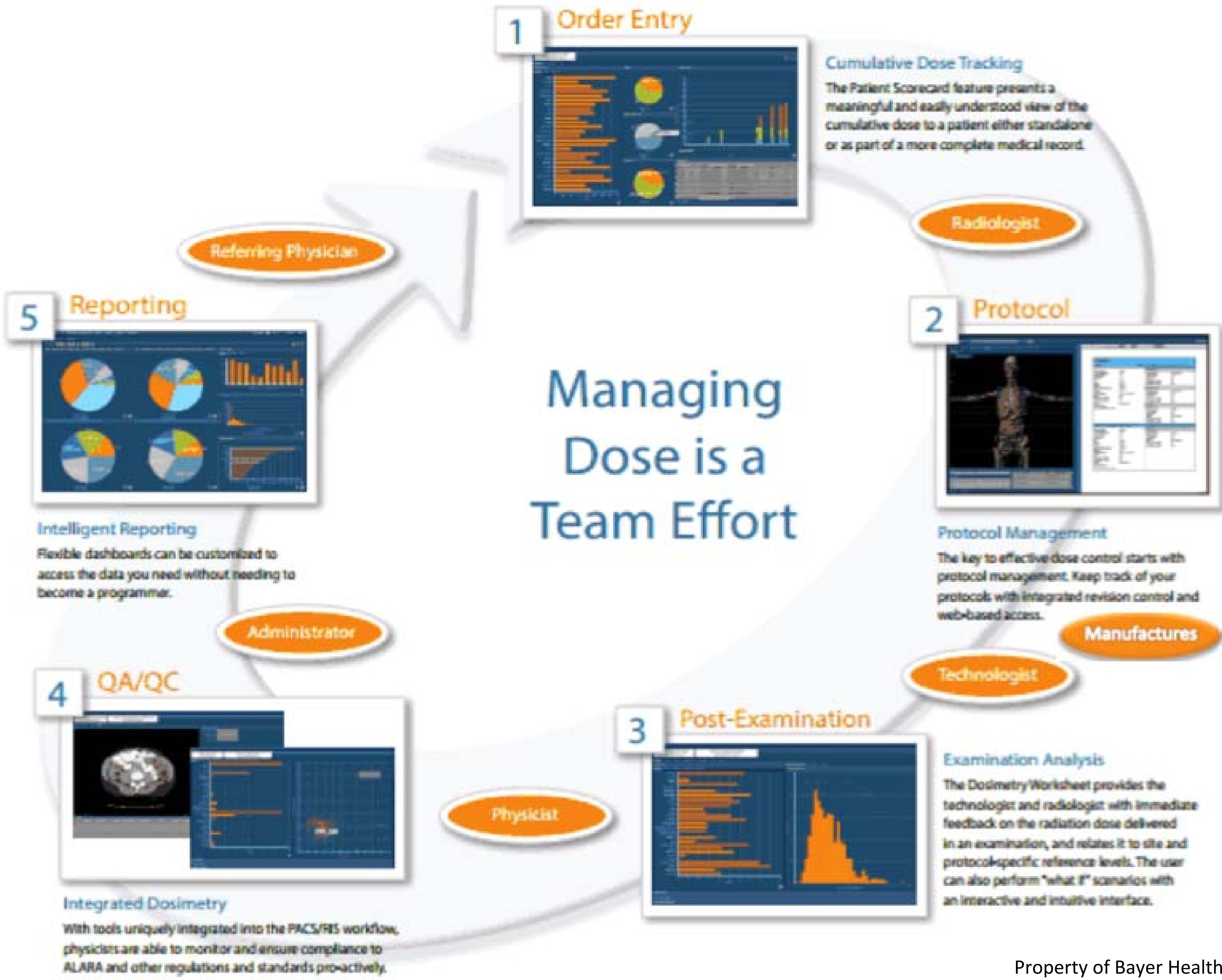
Summary

Ready to improve radiation dose tracking with more accurate dose estimates.

But,

need more standards to convey crucial information;

only possible with collaborations from all parties…



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