



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)

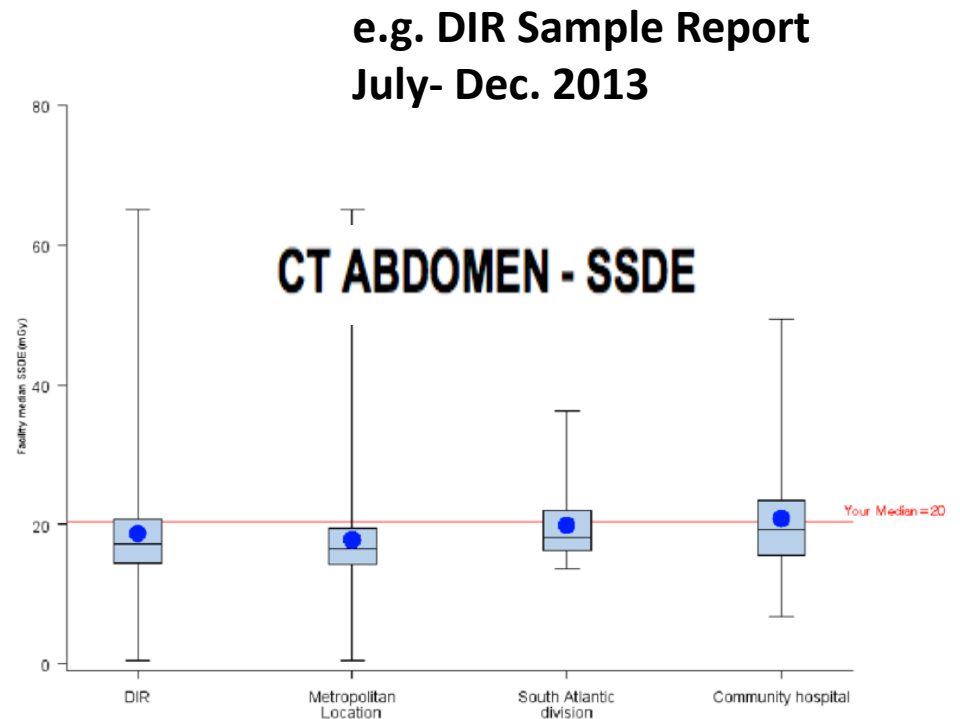
Texas (2013):

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

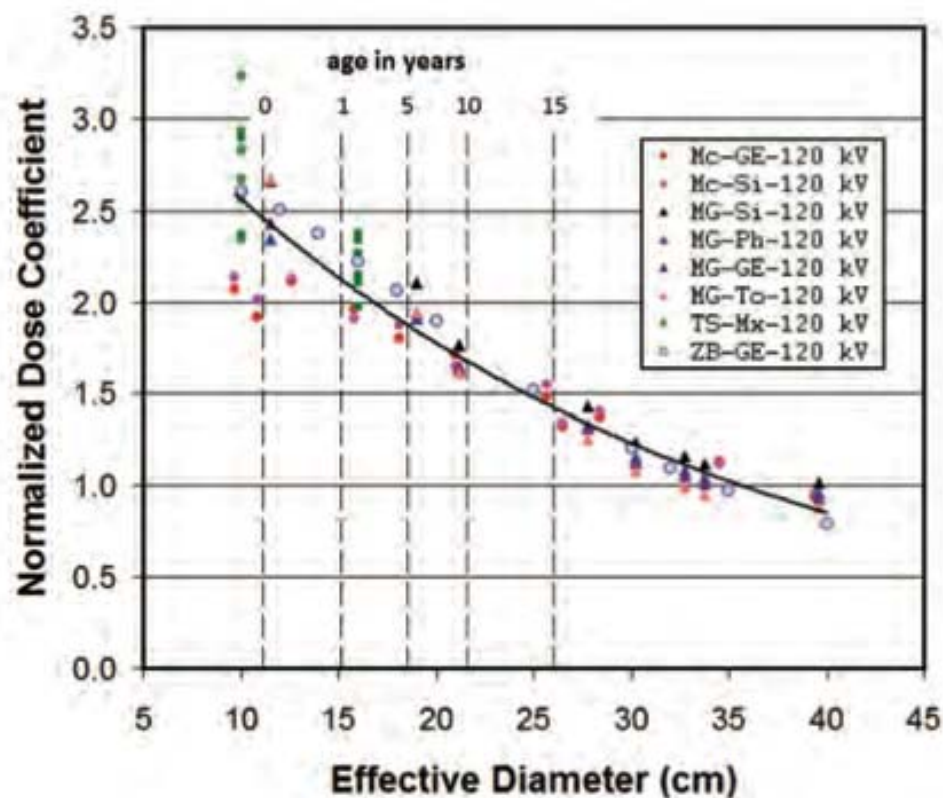


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Issues with CTDIvol, DLP and SSDE



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



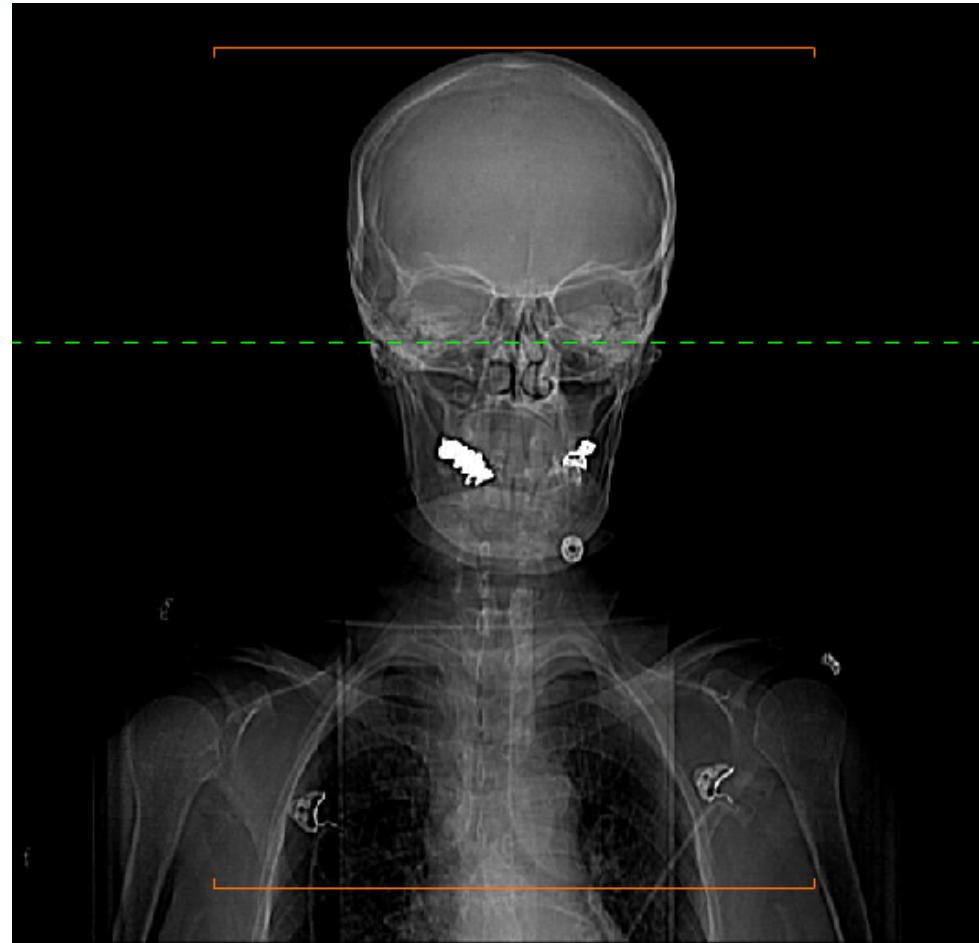
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Issues with CTDIvol, DLP and SSDE (cont'd)



**Are CTDIvol
and DLP
meaningful in
this case?**



CTA_HEAD_NECK_WO_W

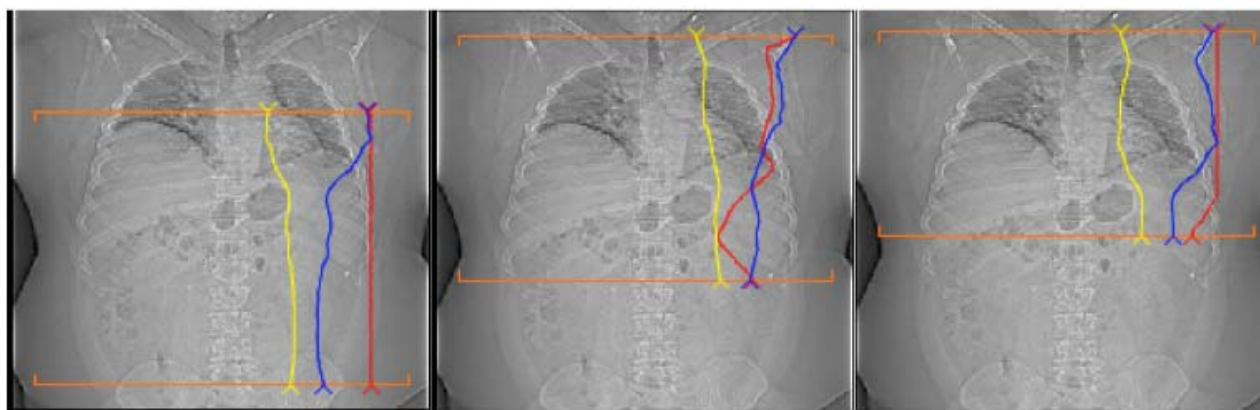
Example from database available to Bayer HealthCare

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



Meaning of Exam Level Values

CTA_CHEST_AORTA_AB_PEL_VEN (3 acquisitions)



ABD W/ AVERAGE S1

CTA AORTA S3

CHEST W/O S3 STD

Example from database available to Bayer HealthCare

Maximum? Average? Scan-length weighted average?

Organ dose?

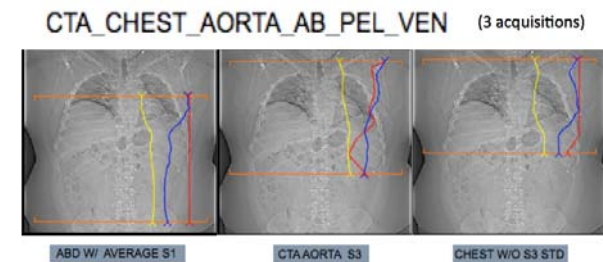
Acquisitions?
Exams



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

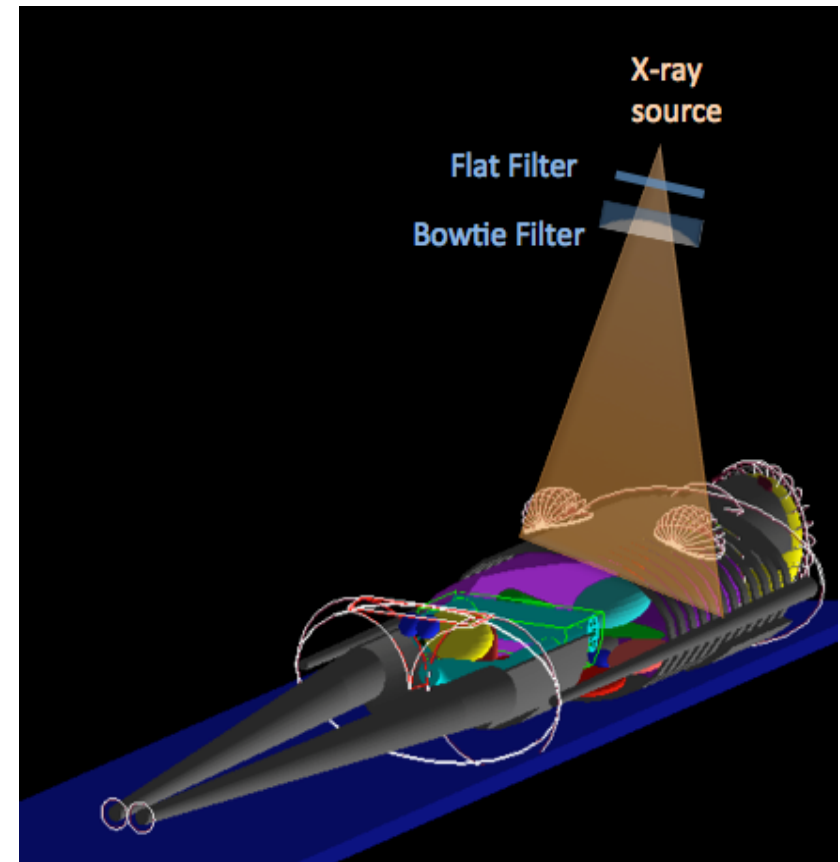
a useful dose metric
necessary for long term cancer risk studies,
especially site-specific cancers

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**

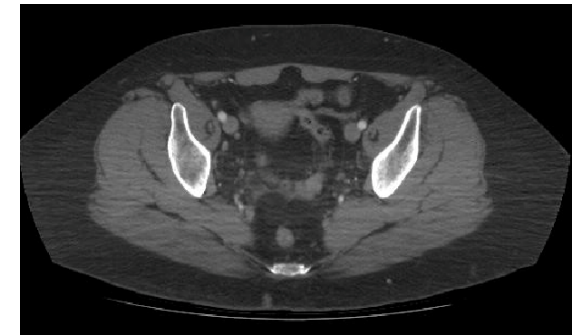
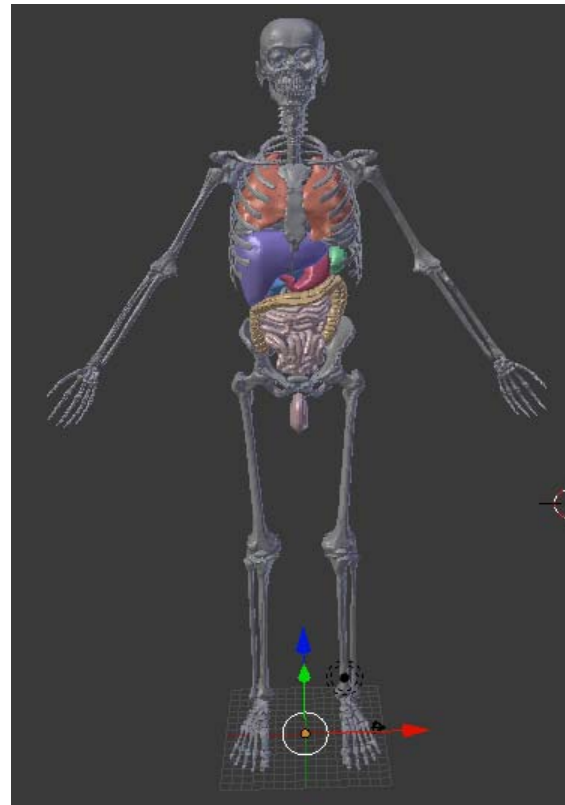
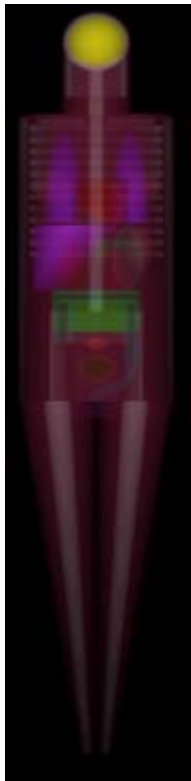


Credit: NASA and STScI

Patient modeling



We are getting better...



Example from database available to Bayer HealthCare

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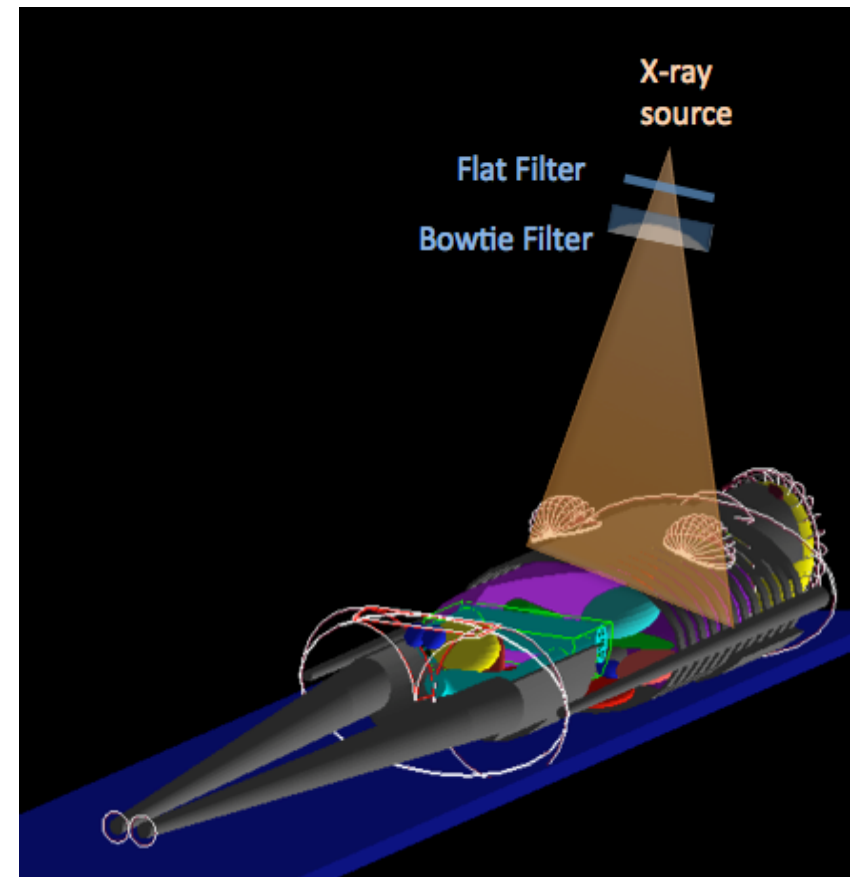
Monte Carlo Organ Dose Calculation



Three major components

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

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



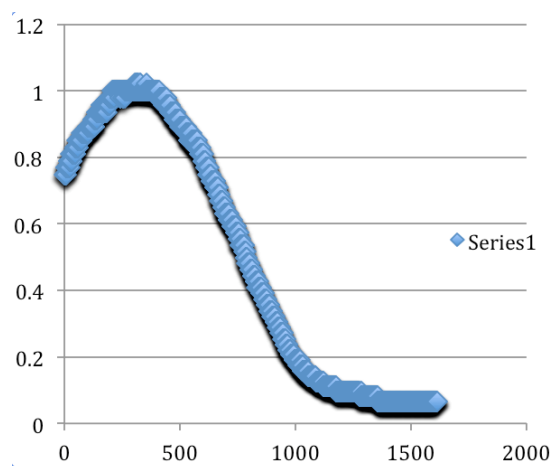
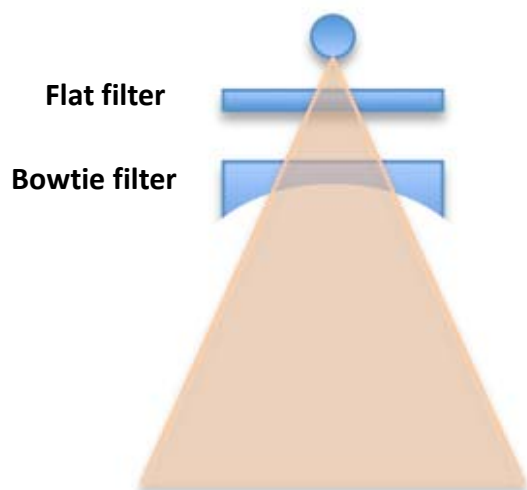
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Scanner modeling:

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

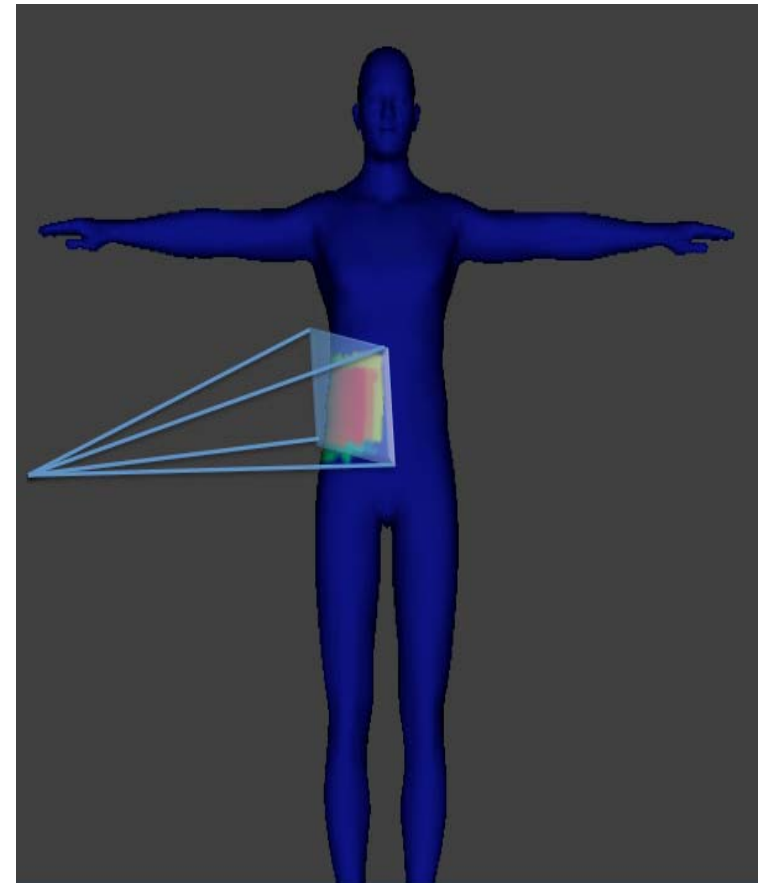


- **Shielding: come up ways to record/convey information on geometry, position, material etc., so that it can be simulated**
- **Ever improving dose reduction technique:
e.g.
x-y plane current modulation
reduced over-ranging of helical scan**

Fluoroscopy



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

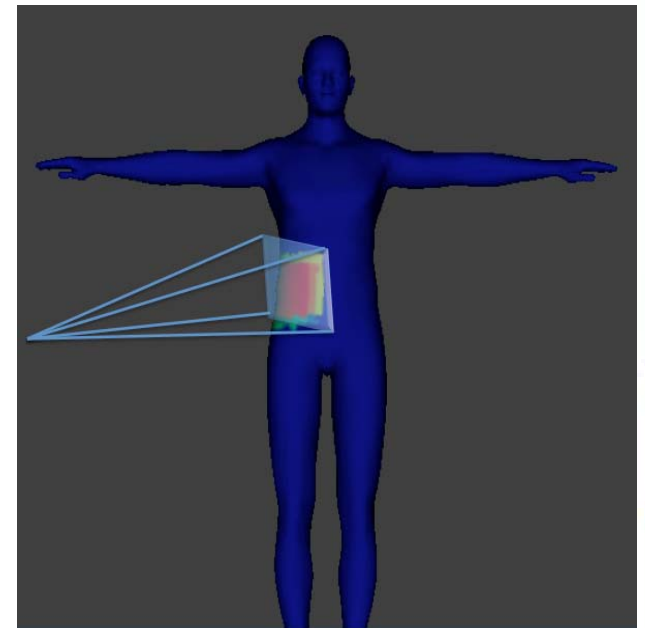


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Skin Dose Calculation



- 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-cm ²]	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	17.9	743.3	132.8
0.060000	20	71	1048	750	17.7	743.3	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.

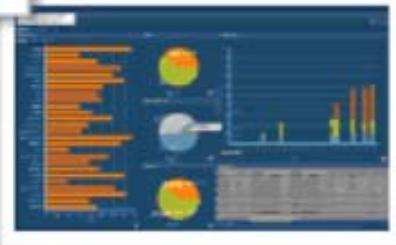
But,

need more standards to convey crucial information;

only possible with collaborations from all parties...

Managing Dose is a Team Effort

1 Order Entry



Cumulative Dose Tracking
The Patient Scorecard feature presents a meaningful and easily understood view of the cumulative dose to a patient either standalone or as part of a more complete medical record.

Radiologist

2 Protocol

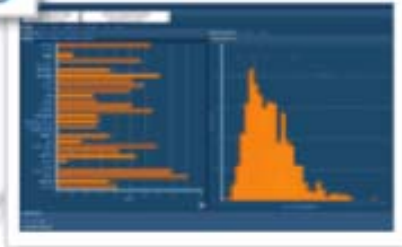


Protocol Management
The key to effective dose control starts with protocol management. Keep track of your protocols with integrated revision control and web-based access.

Manufactures

Technologist

3 Post-Examination



Examination Analysis
The Dosimetry Worksheet provides the technologist and radiologist with immediate feedback on the radiation dose delivered in an examination, and relates it to site and protocol-specific reference levels. The user can also perform "what if" scenarios with an interactive and intuitive interface.

Physicist

Referring Physician

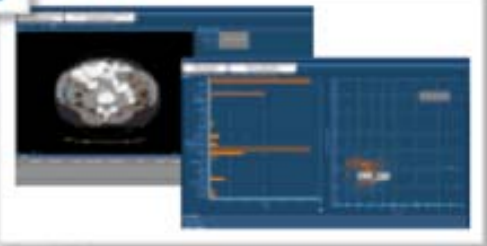
5 Reporting



Intelligent Reporting
Flexible dashboards can be customized to access the data you need without needing to become a programmer.

Administrator

4 QA/QC



Integrated Dosimetry
With tools uniquely integrated into the PACS/RIS workflow, physicists are able to monitor and ensure compliance to ALARA and other regulations and standards proactively.