Dose Monitoring:
A Tool for Improving the Quality of Care

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Clinical Imaging Physics Group

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Outline

- Motivation
- Tools for dose monitoring in CT
- How dose monitoring can improve your clinical operation
  - Establishing CTDI guidelines
  - Examples of utility of dose monitoring
  - Benchmarking dose levels vs national averages
- Future developments

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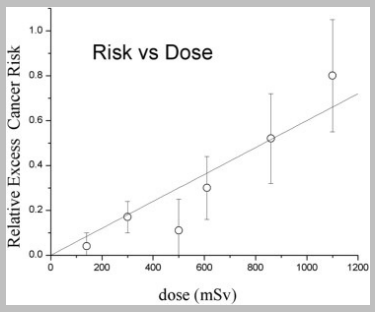
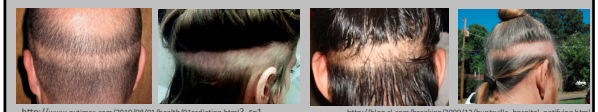
Health effects from ionizing radiation



Durand et al., Utilization Strategies for Cumulative Dose Estimates: A Review and Rational Assessment , JACR, 2012

Why monitor radiation dose?



http://www.nytimes.com/2010/08/01/health/01radiation.html?_r=1

http://blog.al.com/breaking/2009/12/huntsville_hospital_notifying.html

http://www.cleveland.com/nation/index.ssf/2010/08/radiation_overdoses_from_ct_sc.html

http://www.nytimes.com/2009/10/16/us/16radiation.html

Motivations for dose monitoring

1. Identify radiation overdoses and prevent future occurrences
2. Tool to improve the quality of care provided to your patients
3. Benchmark your institution against national averages

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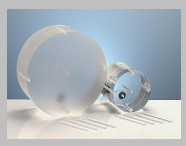
How should radiation dose be monitored?

- CTDI



How should radiation dose be monitored?

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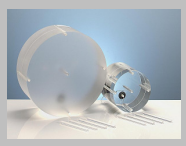
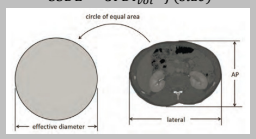


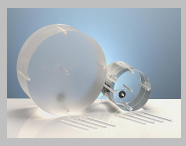
- SSDE
  - $SSDE = CTDI_{vol} \cdot f(size)$



TG 204, Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

How should radiation dose be monitored?

- CTDI



- SSDE
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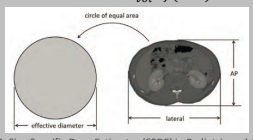
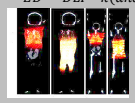


TG 204, Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

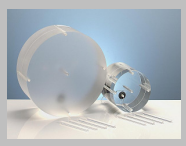
- Effective Dose
  - $ED = DLP \cdot k(anatomy)$



Li et al. Medical Physics 2010

How should radiation dose be monitored?

- CTDI



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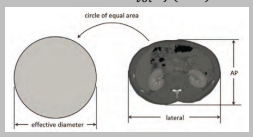

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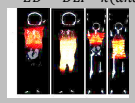
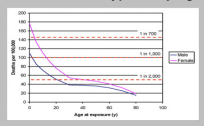


Li et al. Medical Physics 2010

- Risk Estimate
  - $\mathrm{RI} = DLP \cdot q(anatomy, age, gender)$



Fahey et al. Journal of Nuclear Medicine Technology, 2012

Measuring the effects of radiation

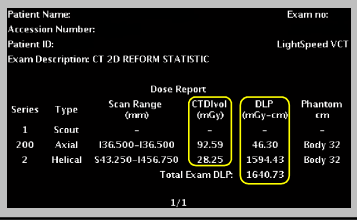
Easy to see trends

Method	Size	Organs	Age	Gender	Across modalities
CTDI					
SSDE	✓				
Effective Dose[1]	✓	✓			✓
Risk Estimate[2]	✓	✓	✓	✓	✓

1. Effective dose is only defined for reference patient, however, the concept can be modified to include a size adjustment factor.
2. Dependent on the BEIR VII data and relatively large uncertainties exist when applied to individual patients.

Optical Character Recognition

- Structured dose reports
  - Not available on all scanners
- Dose reports (screen captures)



Patient Name: Exam no:
Accession Number:
Patient ID: LightSpeed VCT
Exam Description: CT 2D REFORM STATISTIC

Dose Report

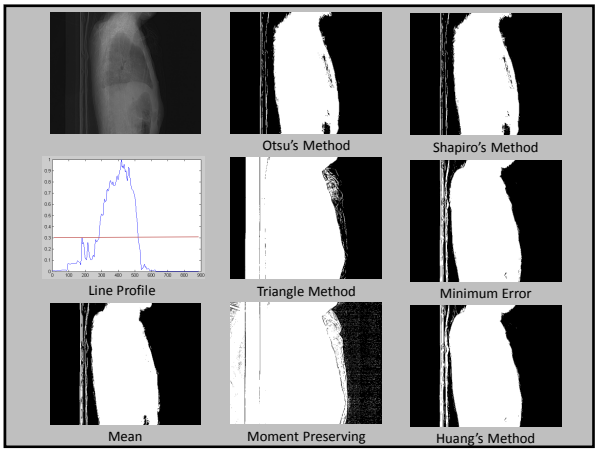
Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
200	Axial	136.500-136.500	92.59	46.30	Body 32
2	Helical	543.250-1456.750	28.25	1594.43	Body 32
			Total Exam DLP:	1640.73	

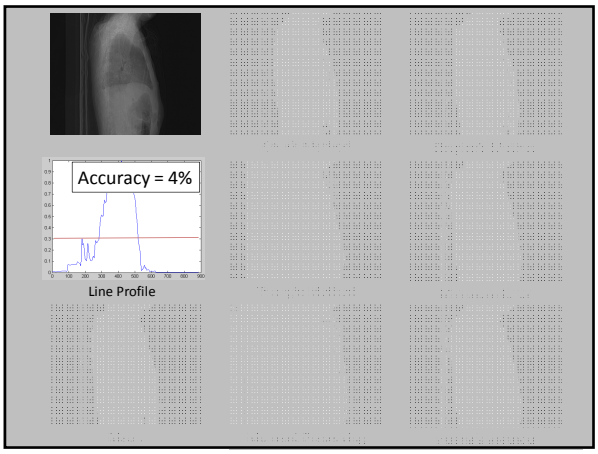
1/1

Measuring size

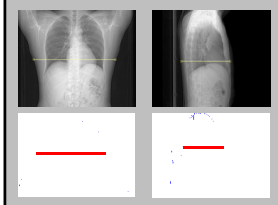
1. HU number conversion
   - Pros: Direct measure of attenuation, same range as CT scan
   - Cons: Large amounts of data, heavy cpu burden
2. Localizer pixel values
   - Pros: Less data than HU method, attenuation based, very fast
   - Cons: Conversion from PV to attenuation, edge enhancement
3. Localizer thresholding
   - Pros: Small amount of data, very fast, do not need to convert PV to attenuation
   - Cons: Not attenuation based, concerns over accuracy

* Easiest to implement on a large scale



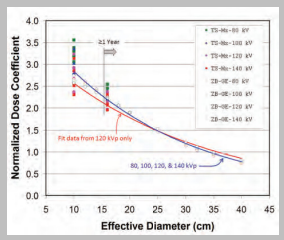


Patient size used to improve dose estimates



LAT Dim = 31.9 cm

AP Dim = 17.7 cm



Adapted from AAPM TG 204

Effective Diameter = $(\text{Lat} \times \text{AP})^{1/2}$ = 23.8 cm → Normalized Dose Coefficient = 1.55

17

Matching data to series descriptors

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S52.250-S210.375	38.12	683.81	Head 16
200	Axial	I100.000-I100.000	15.75	7.87	Head 16
4	Helical	I114.500-S189.700	22.39	785.37	Head 16

Total Exam DLP: 1477.06

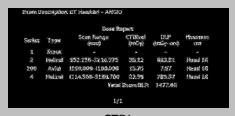
1/1

Study Description: Abd. Pelvis

Series 2: Abd. Pelvis

Series 4: Chest

Duke's radiation dose monitoring program



CTDI
DLP
Phantom
Study Description

Size
Age
Gender

Series Information
Protocol
Anatomic Region

$CTDI_{vol}$
SSDE
Effective Dose
Risk Index

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Radiation dose monitoring committee

- Consists of radiologists, physicians, medical physicists, radiation safety officers, and technologists
- Meet monthly:
  - Discuss cases that exceed alert levels
  - Evaluate current imaging protocols
  - Evaluate the use of techniques to reduce dose
  - Compare current protocols to national averages

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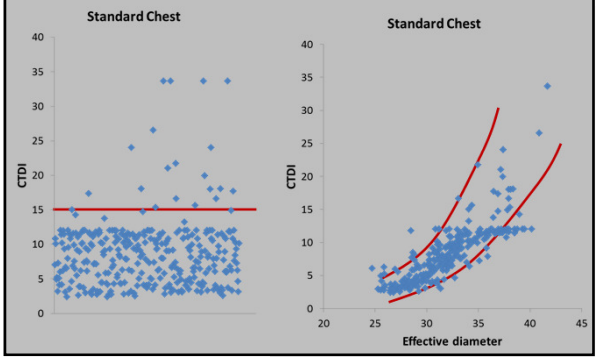
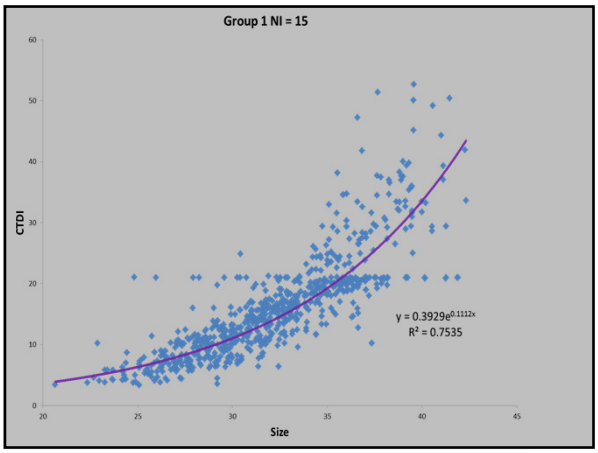
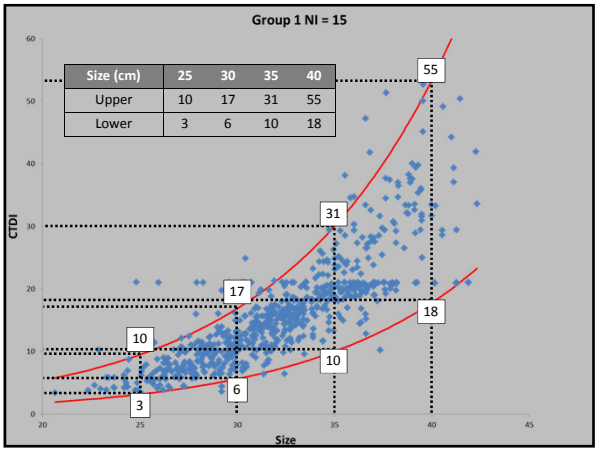
Effect of patient size

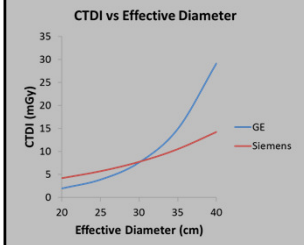


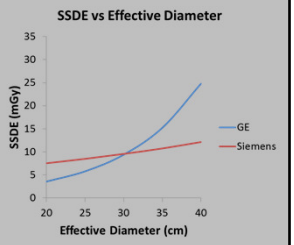




Size (cm)	25	30	35	40
Upper	10	17	31	55
Lower	3	6	10	18

Differences between scanners





Data is representative of the automatic tube current modulation algorithm
Can ***NOT*** conclude which system offers better performance

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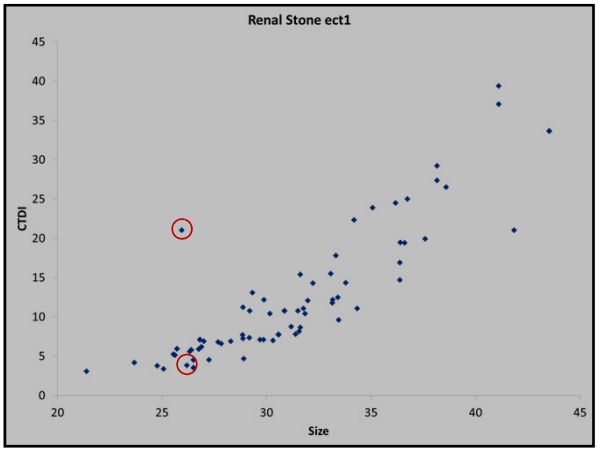
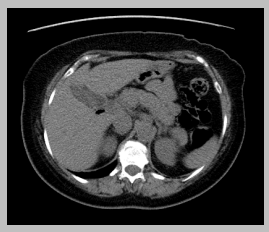


Renal Stone ect1

Low Dose

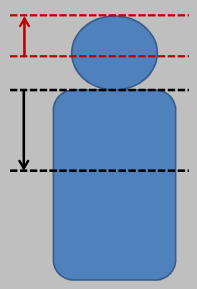


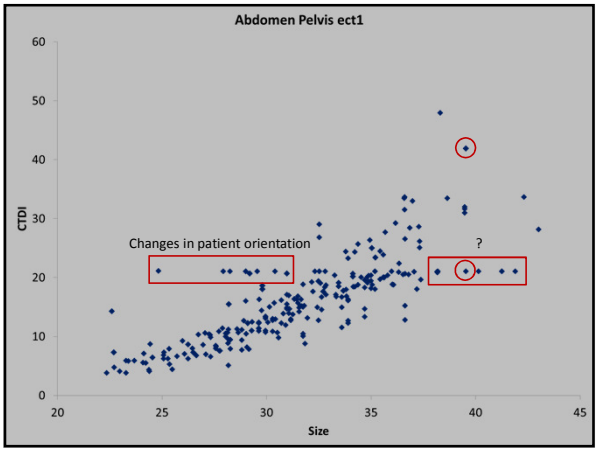
High Dose

Patient flipped from normal orientation

Changes in patient orientation

- On some scanners, **turns off AEC**
- Common reasons patient orientation is changed
  - Patient unable to lie prone
  - Combining multiple studies





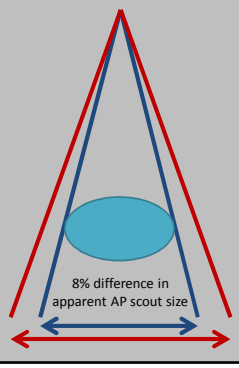
Abdomen Pelvis ect1

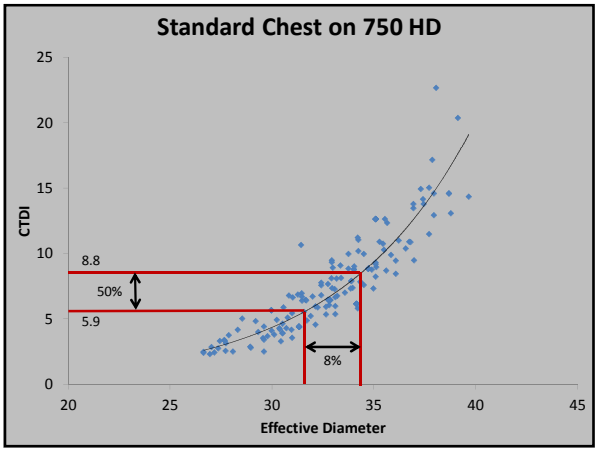
Parameter	Low Dose Series	High Dose Series
Acquisition Mode	Helical	Helical
Slice Thickness	5 mm	5 mm
kVp	120 kVp	120 kVp
Rotation Time	0.5 s	0.8 s
Tube Current	700 mA	615 mA
Collimation	40 mm	40 mm
Pitch	1.375	1.375
Noise Index	15	15

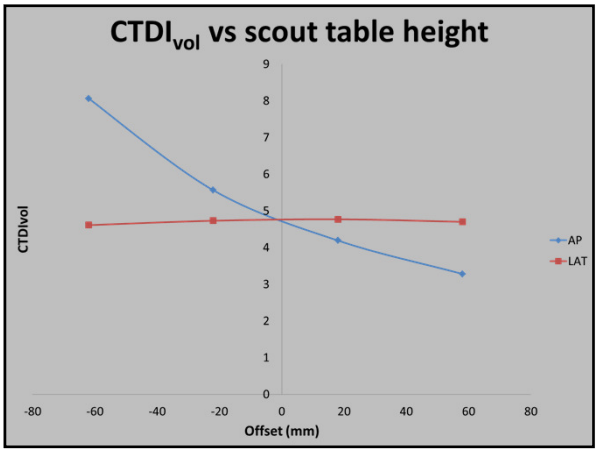
Tube rotation time increased to avoid tube current limitations

Repeat studies with different dose?

Parameter	1st Study	2nd Study
Scanner	VCT	VCT
Acquisition Mode	Helical	Helical
Slice Thickness	5 mm	5 mm
kVp	120 kVp	120 kVp
Rotation Time	0.5 s	0.5 s
Collimation	40 mm	40 mm
Pitch	1.375	1.375
Noise Index	15	15
CTDI	4.4	6.3
	45% increase in dose	
Table Height	178	112







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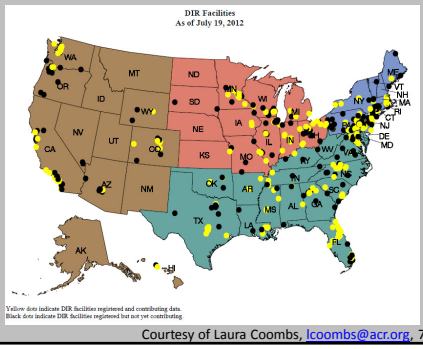
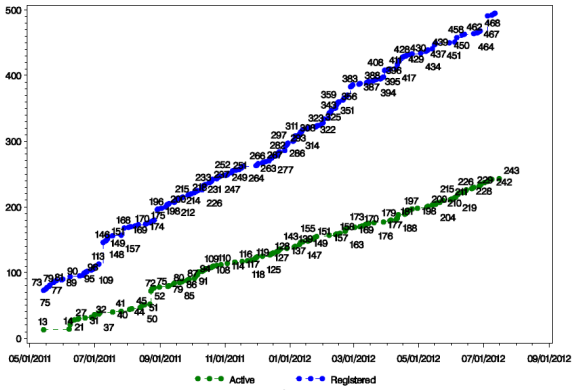
Dose Index Registry



Courtesy of Laura Coombs, lcoombs@acr.org, 703-715-4383

DIR Registration Tracking



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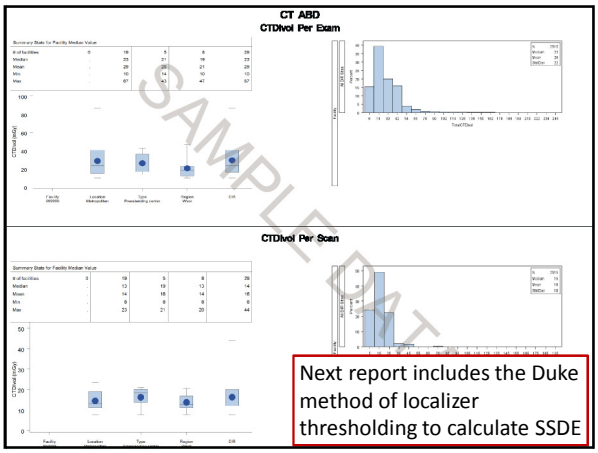

Next report includes the Duke method of localizer thresholding to calculate SSDE

DIR certified software partners

COLLEGE OF AMERICAN RADIOLOGY
NRDR DIR™ DOSE INDEX REGISTRY
SOFTWARE PARTNER

https://nrdr.acr.org/Portal/DIR/Main/page.aspx

- DOSEMONITOR http://www.dosemonitor.com/
- radiance http://radiancedose.com/
- IMALOGIX Medical intelligence at your fingertips http://www.imalogix.com/
- AWARE http://www.aware.com/medical/accurad_rem_server.html
- radimetrics http://www.radimetrics.com/default/
- imagination at work http://www.doseoptimization.com/
- radmapps http://www.radmapps.com/DIR.html

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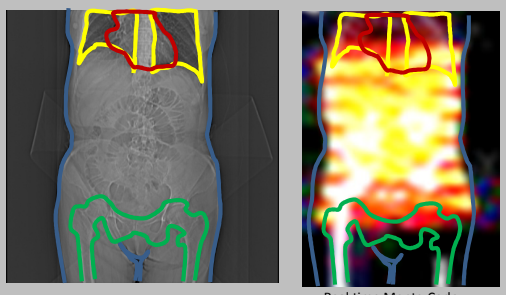
Organ segmentation



Real time Monte Carlo simulation?

Other modalities

Modality	Radiation dose metric	Challenges
Computed Tomography	CTDI, SSDE, ED, RI	Patient size, differences in technology, nomenclature
Nuclear Medicine	Injected activity, ED, RI	Patient size, pharmakinetics
Radiography	EI, ED, RI	Patient size, nomenclature
Fluoroscopy	DAP, peak-skin dose, ED, RI	Patient size, moving radiation field, not one correct fluoro time, data loss, nomenclature
Mammography	MGD, ED, RI	Patient size

One metric for all modalities?

Summary

- Dose monitoring enables standardization of radiation dose within an institution
  - Protocol, scanner, and patient size-specific CT dose guidelines
  - Improves consistency of image quality
- Examples of CT dose inconsistency caused by:
  - Changes in patient orientation
  - Tube current limitations
  - Magnification
- Benchmark radiation dose against national averages

Thank you!

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