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Automatic exposure monitoring systems

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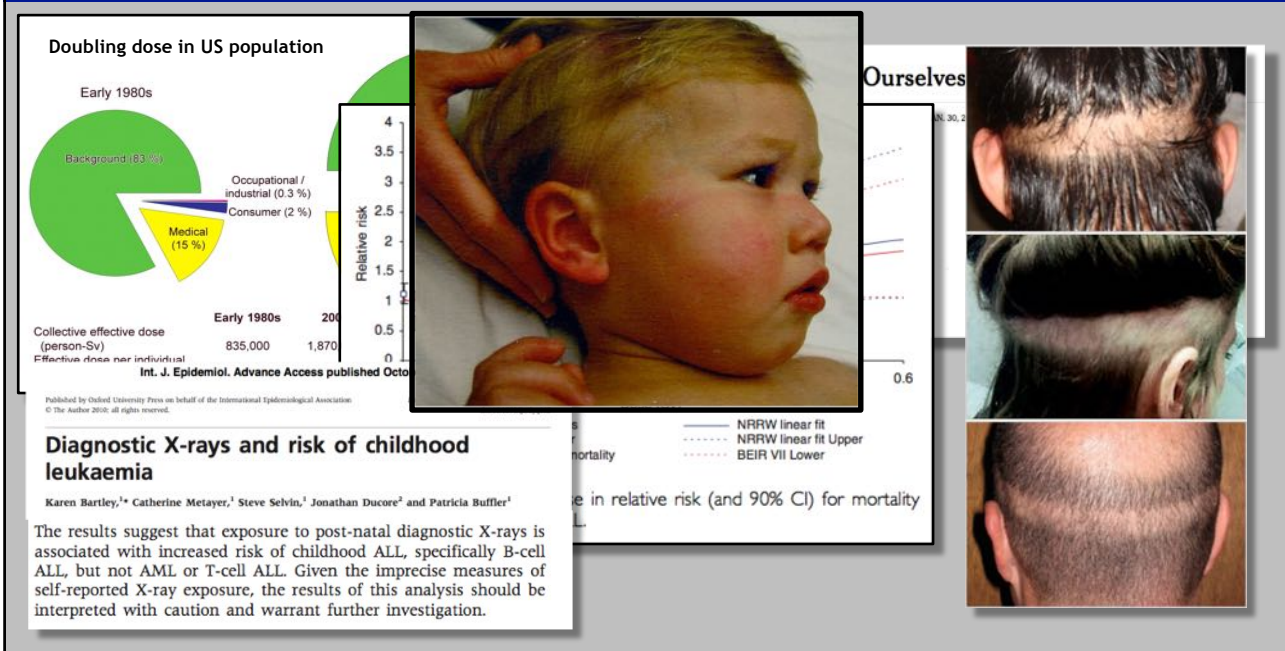
Why exposure needs monitoring (and managing)

- Operational variability
- Quality control of the actual performance

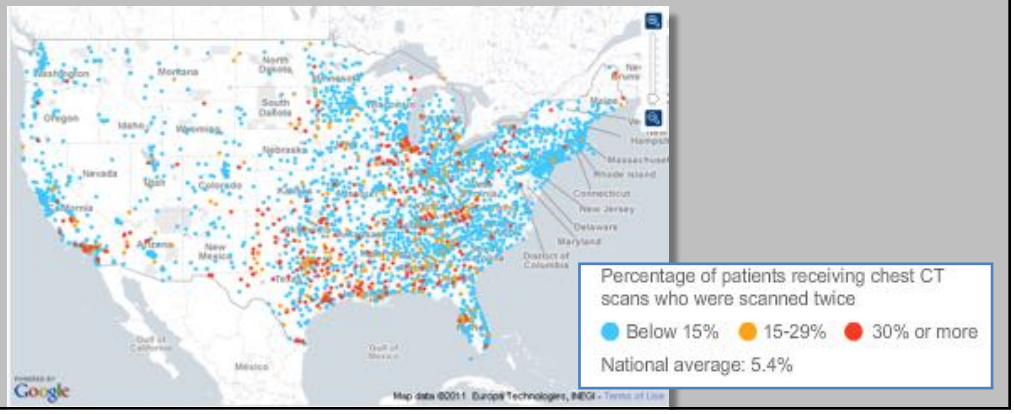
Why monitoring exposure?



Why monitoring exposure?

- Significant variability across imaging practice
  - Varying systems, imaging methods, operators, patient attributes, …
- Leading to inconsistent and suboptimal imaging causing
  - Unnecessary repeated exams (unnecessary dose and wasted utilization)

Same day repeated CT scans (per Medicare)

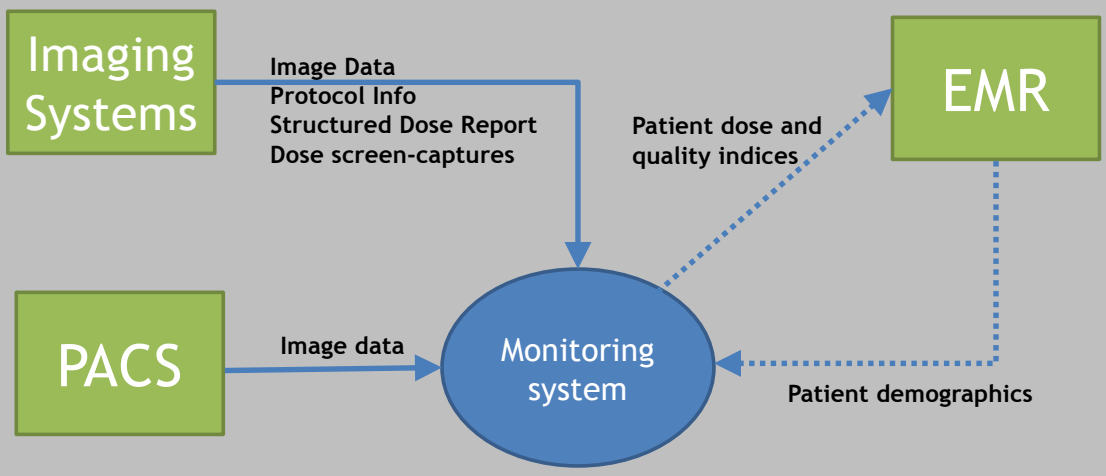


Exposure monitoring products

Exposure monitoring components

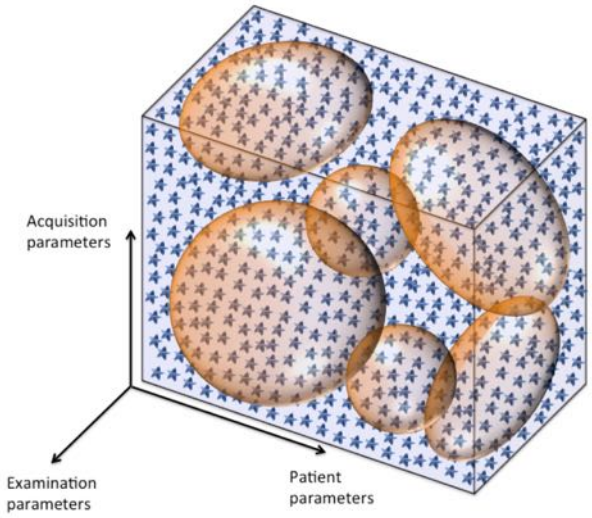
A. **Access**: Connection and collection of dose-relevant data
B. **Integrity**: Data quality and accuracy
C. **Metrology**: Meaningful quantities to monitor
D. **Analytics**: From data to knowledge
E. **Informatics**: Dose monitoring as a secure, integrated solution

Access and architecture

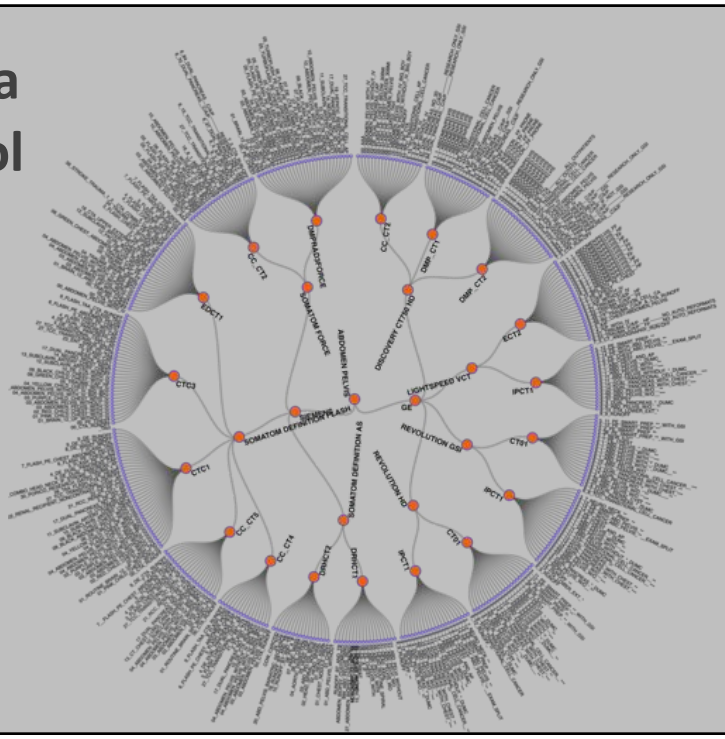


Data integrity

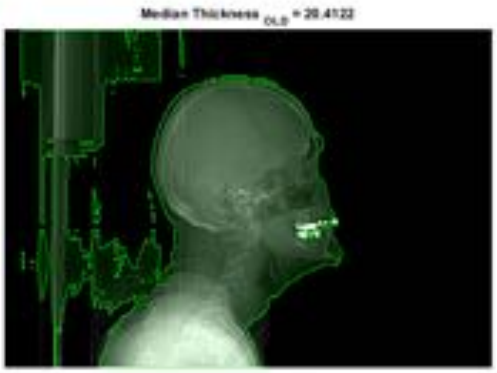
- Generalizable knowledge and analysis requires accurate classification
- Need for multi-tagging and smart binning based on needed statistics
- Lack of standardization: immense diversity in case identification and labeling



Classification of a single CT protocol



Automated Size Characterization: Adult head



20.4 cm

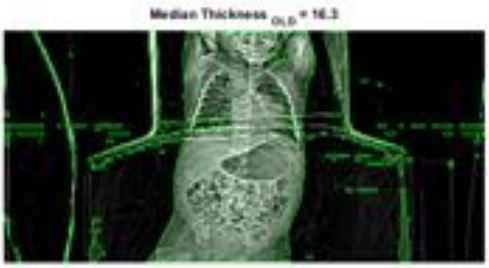
17.7 cm

Adult Body

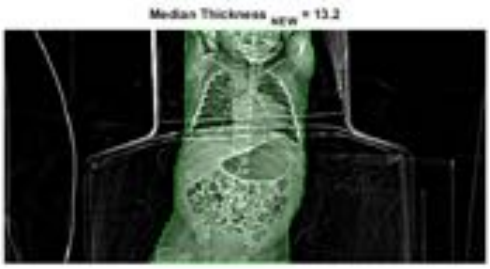
40.6 cm

47.0 cm

Pediatric Body



16.3 cm



13.2 cm

Metrology (dose and IQ)

1. **Relevant:** As much as possible, patient-/indication-centric (not modality or machine)
2. **Robust:** To ensure reliability and applicability
3. **Smart:** Maintained balance between robustness and relevance
4. **Relatability:** Surrogates relatable to clinical exam
5. **Practical:** Economic to measure

Analytics: From data to knowledge

1. **Protocol profile**
2. **Benchmarking institution against national DRLs**
3. **Defining protocol- and size-specific DRLs**
4. **Identifying outliers**
5. **Ascertaining trends over time**
6. **Ascertaining inter-system variability**
7. **Tracking protocol discrepancy**
8. **Investigating individual doses**
9. **Improving operational consistency**

Frush, Samei, Medscape Radiology, March 2015

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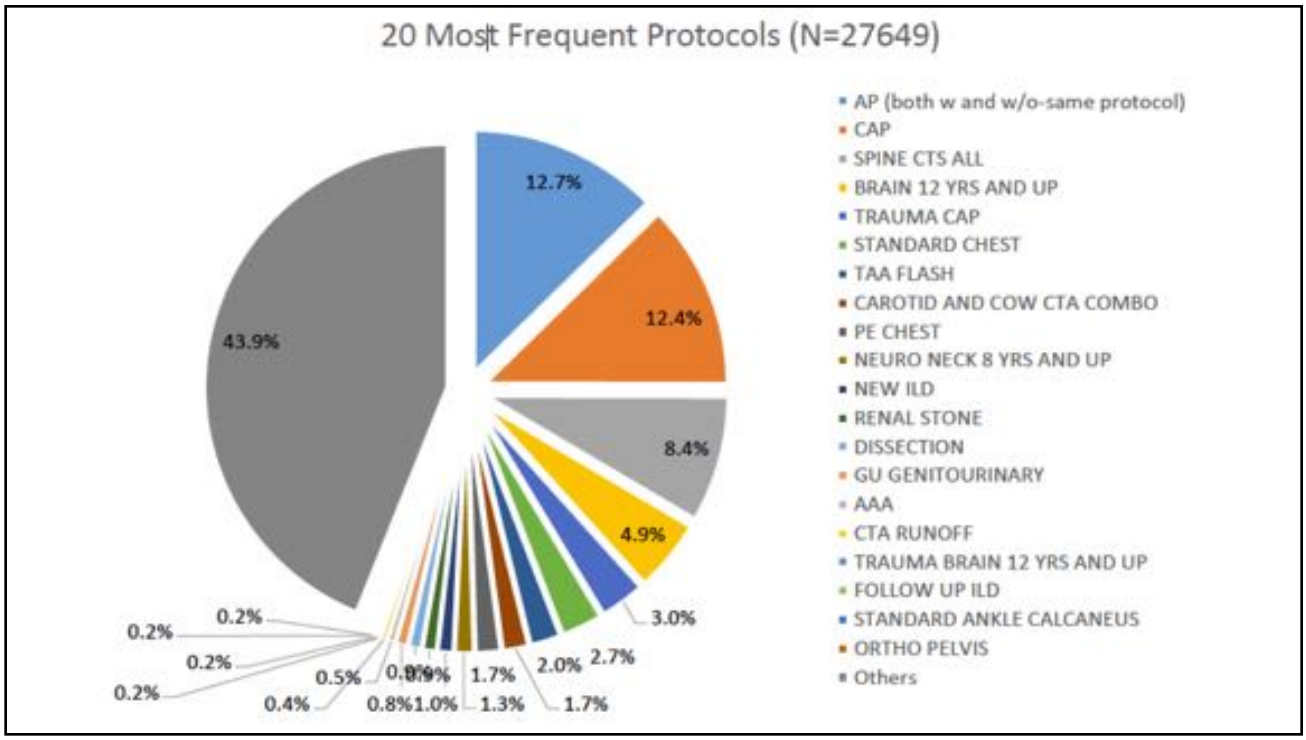

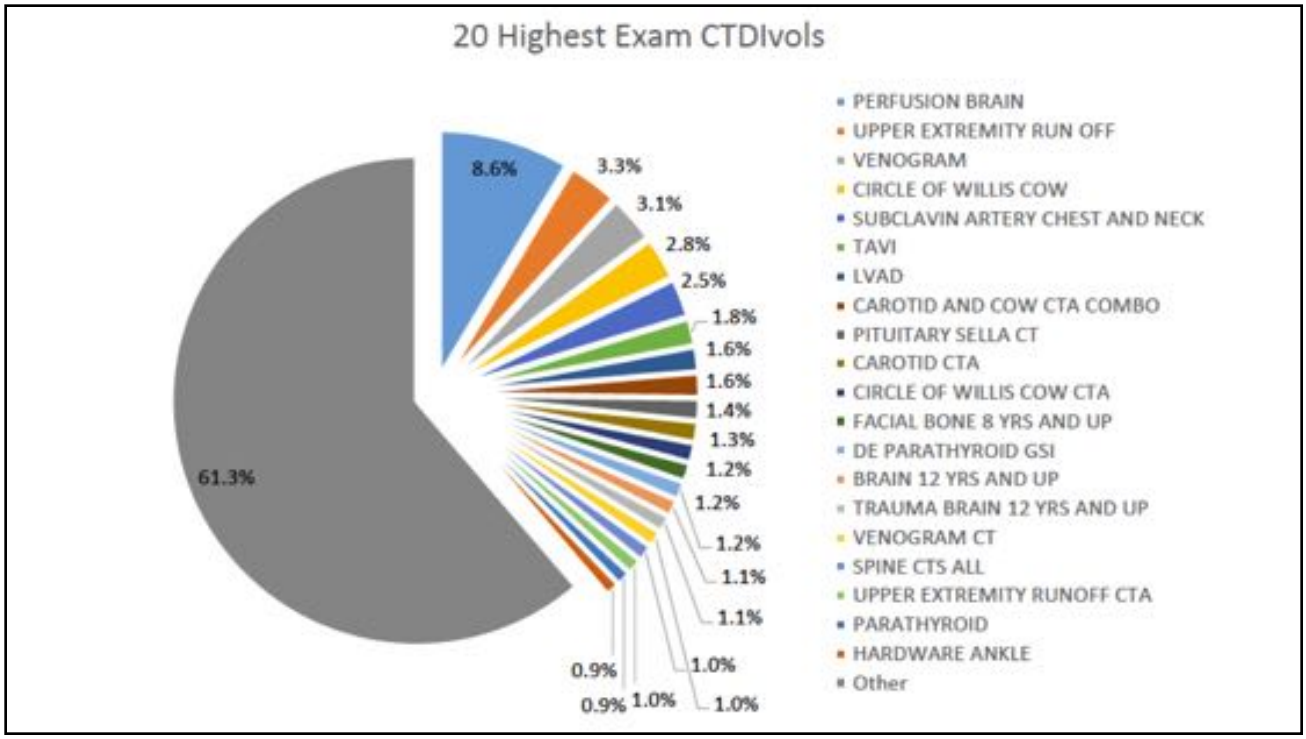

Top protocols

5 Most Frequent Protocols (N=27649)

Protocol Name	N
AP (Both W and W/O)	3502
Chest Abdomen Pelvis	3422
Spine CTs All	2332
Brain 12 Yrs and Up	1342
Trauma Chest Abdomen Pelvis	839

5 Protocols with Highest Patient Dose Series

Protocol Name	N	Median $CTDI_{vol}$ (mGy)
Perfusion Brain	1	335.4
Upper Extr. Runoff	2	128.4
Venogram	12	120.3
COW	5	108.9
Subclavin Art. Chest & Neck	1	98.5

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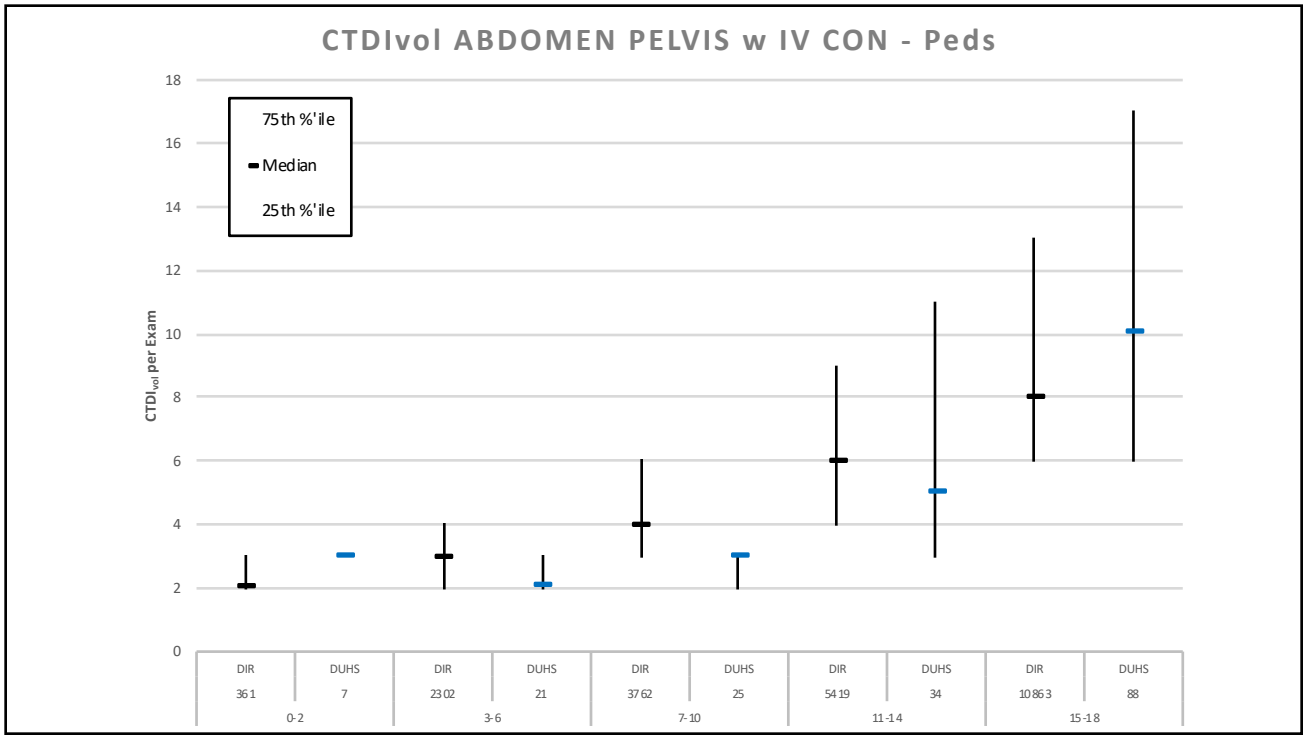
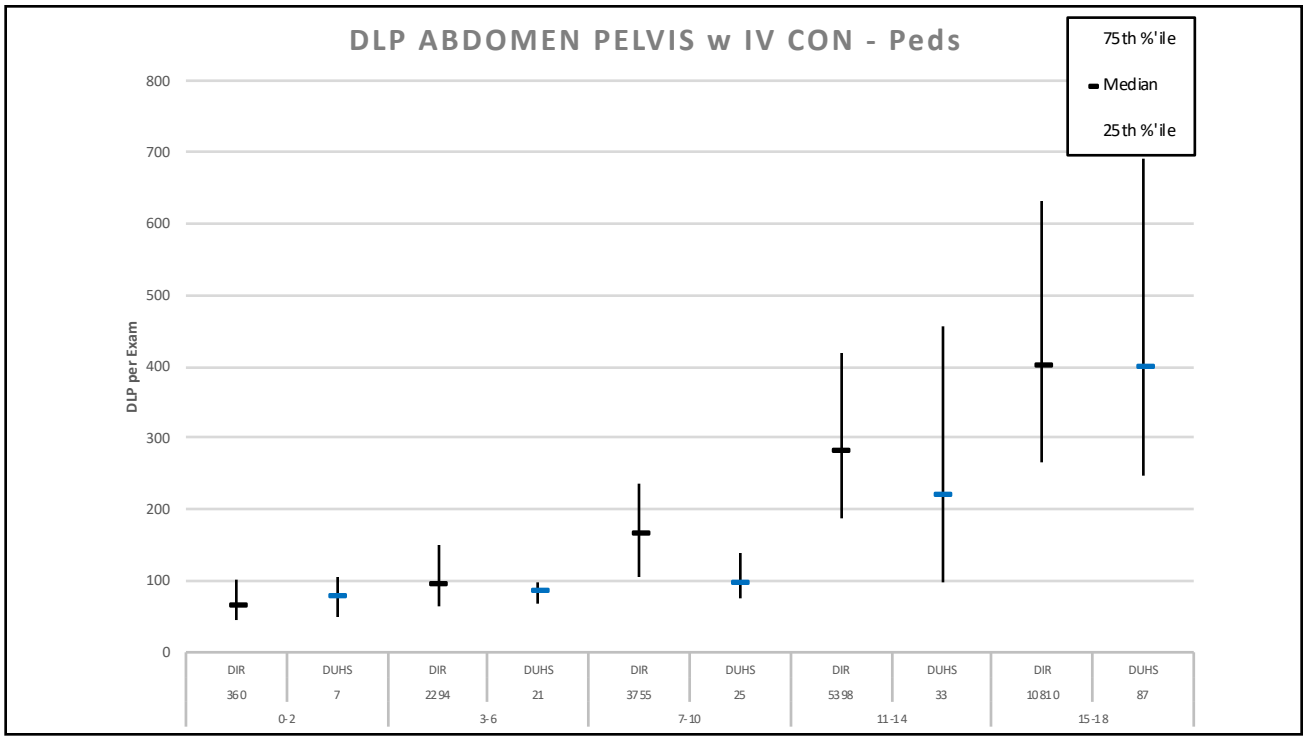
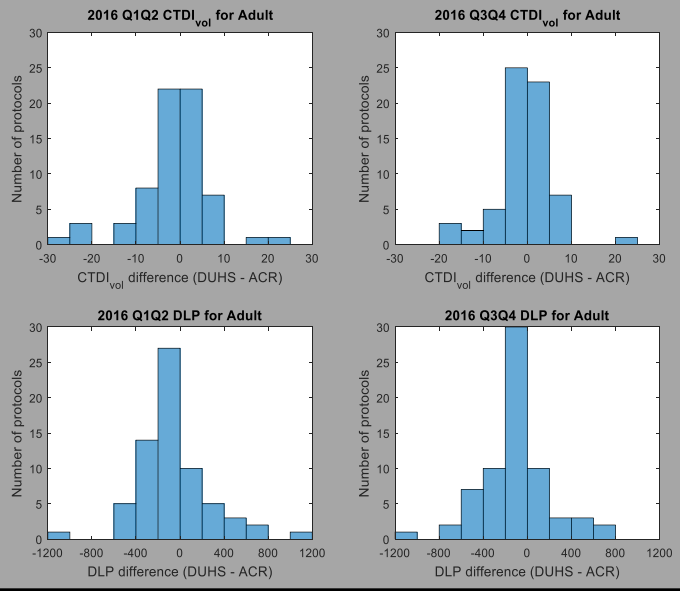
Benchmarking institution against national DRLs

- Applied to all protocols with ACR Dose Index Registry match
- Compared with 25-75% ranges
- CTDI and DLP





Benchmarking institution against national DRLs



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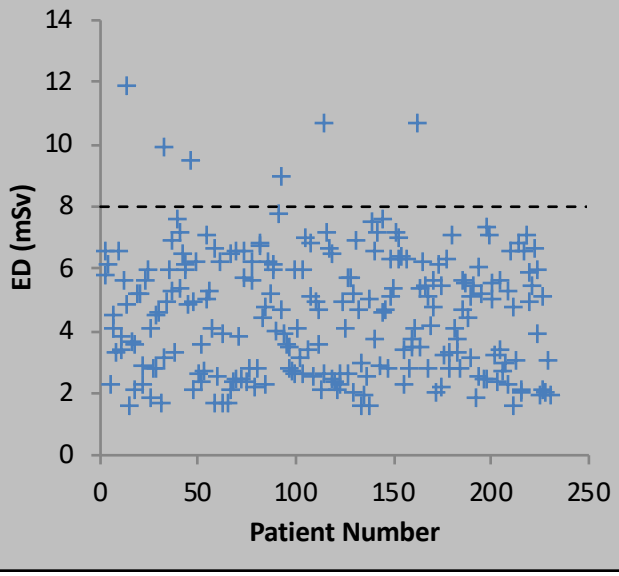
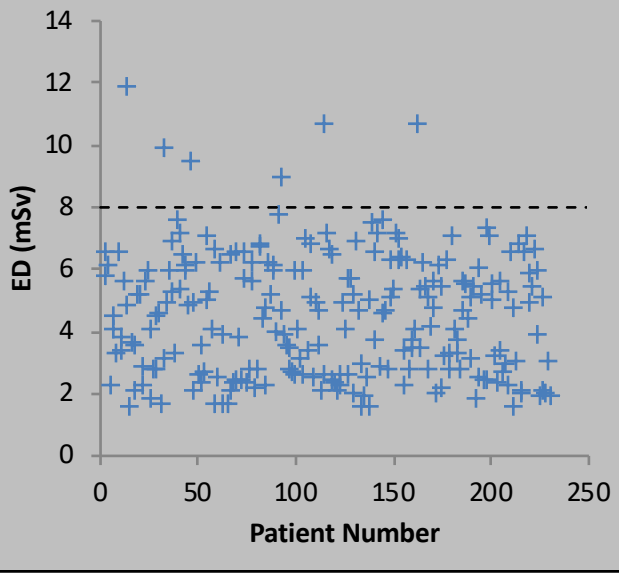
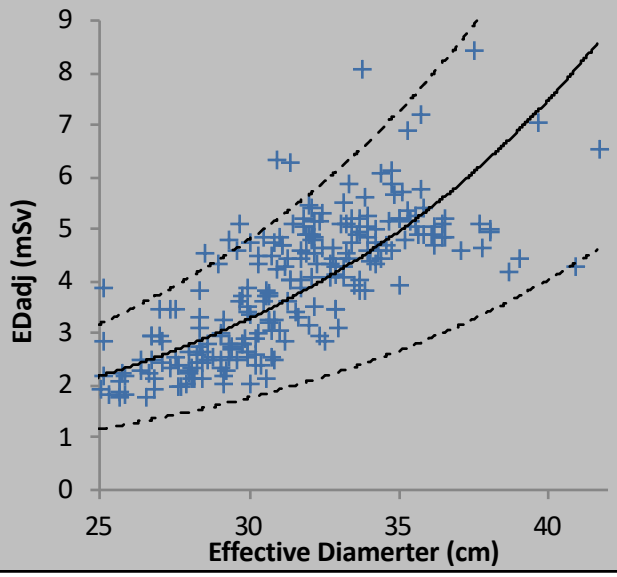
Defining protocol- and size-specific DRLs



Proper dose tracking – with size





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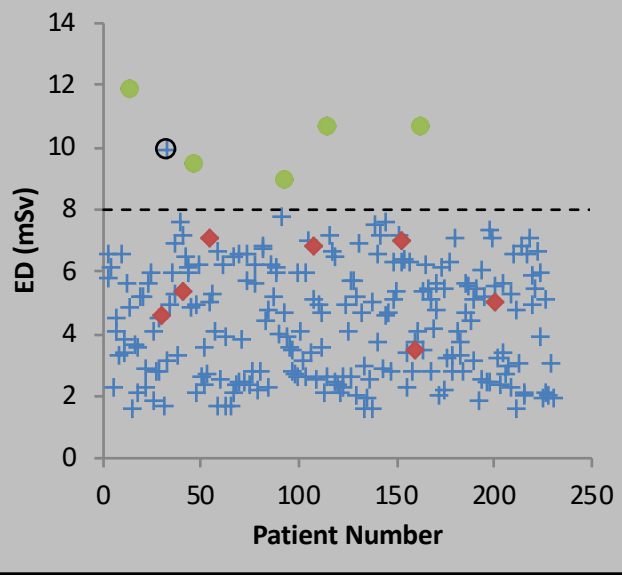
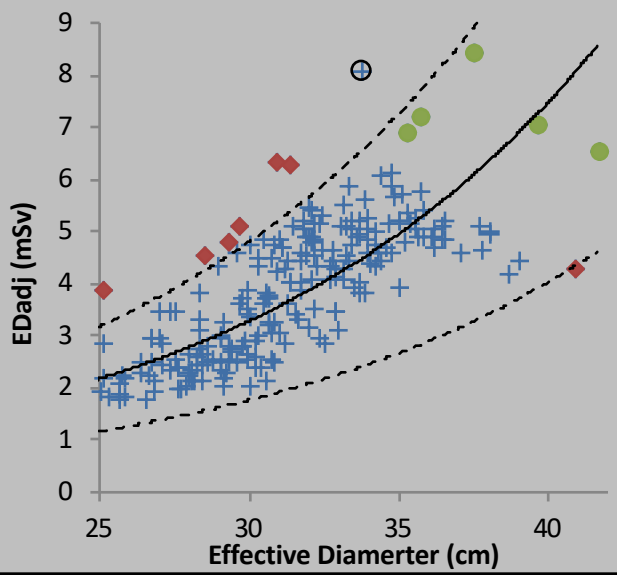




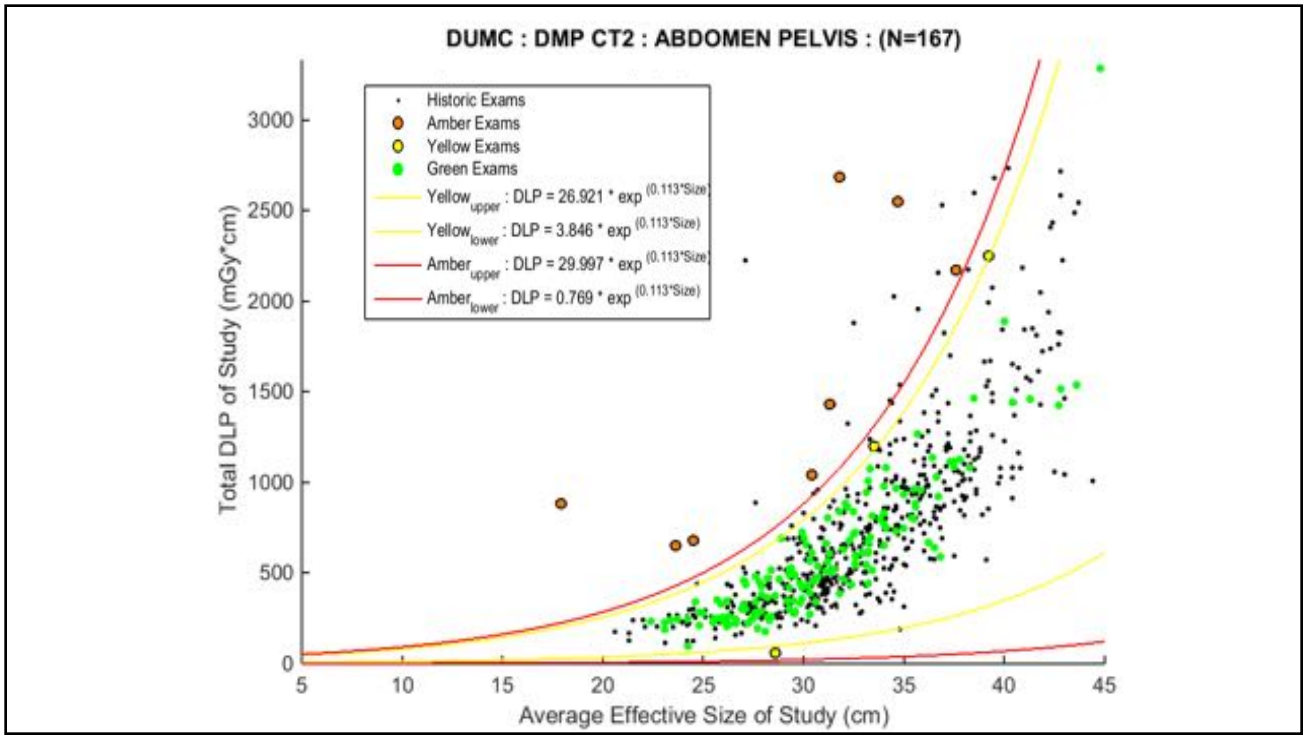
Identify Outliers

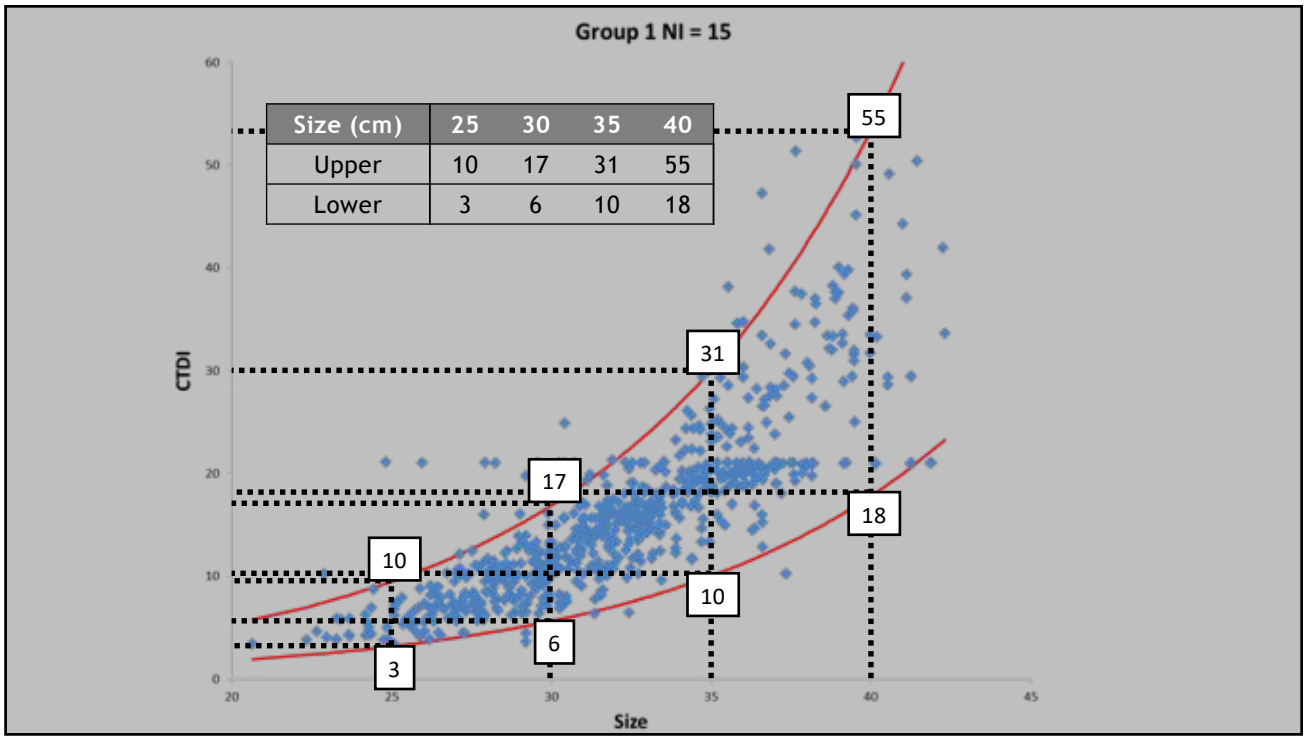
- Establish current trends wrt size
- Establish reference trends from historical data
- **Amber, outlier cases outside 1-99 percentile**
- **Yellow, warning cases outside 5-95 percentile**
- Triage the outlier list based on dose deviation:

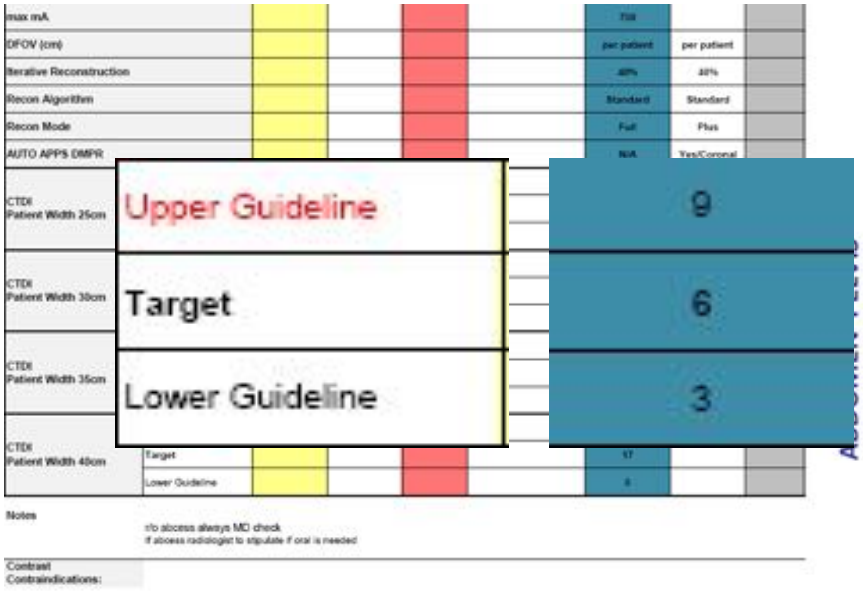
$$DD = (D_i - D_{io})/D_{io}$$

D_i = patient dose index

D_{io} = reference median dose index for patient size







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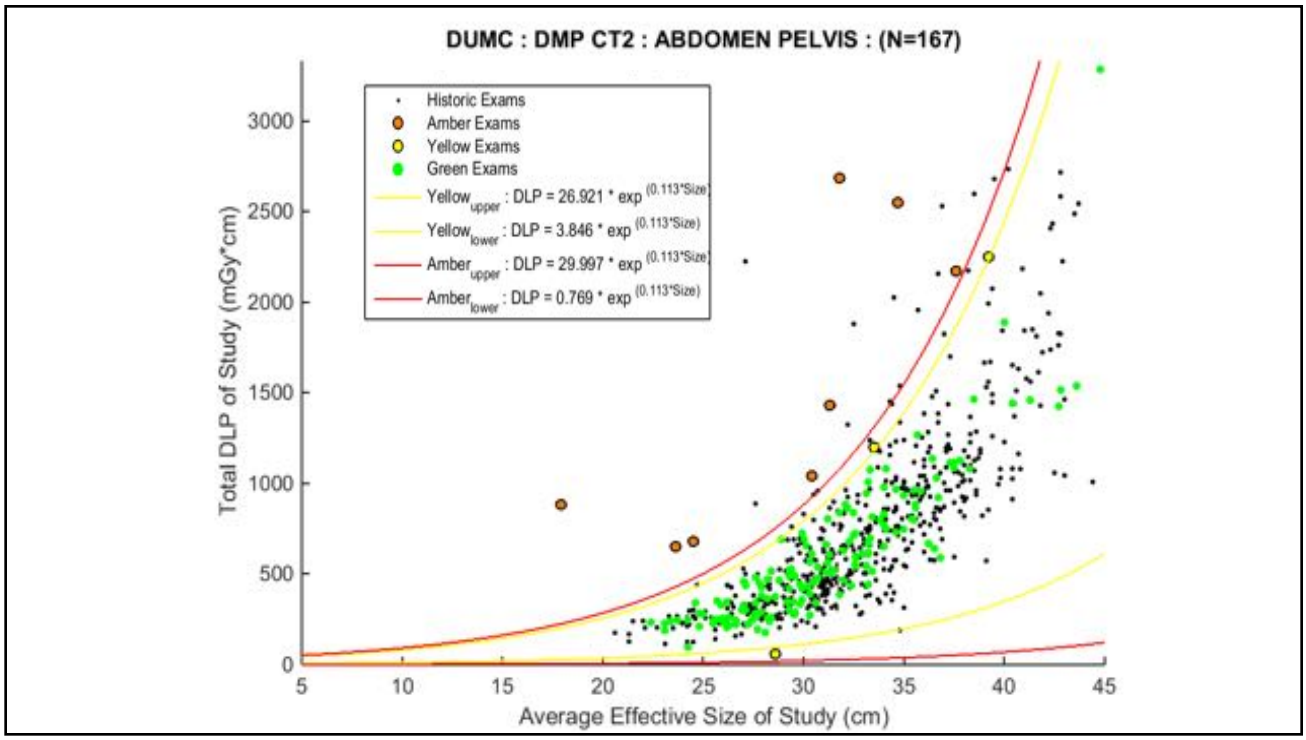
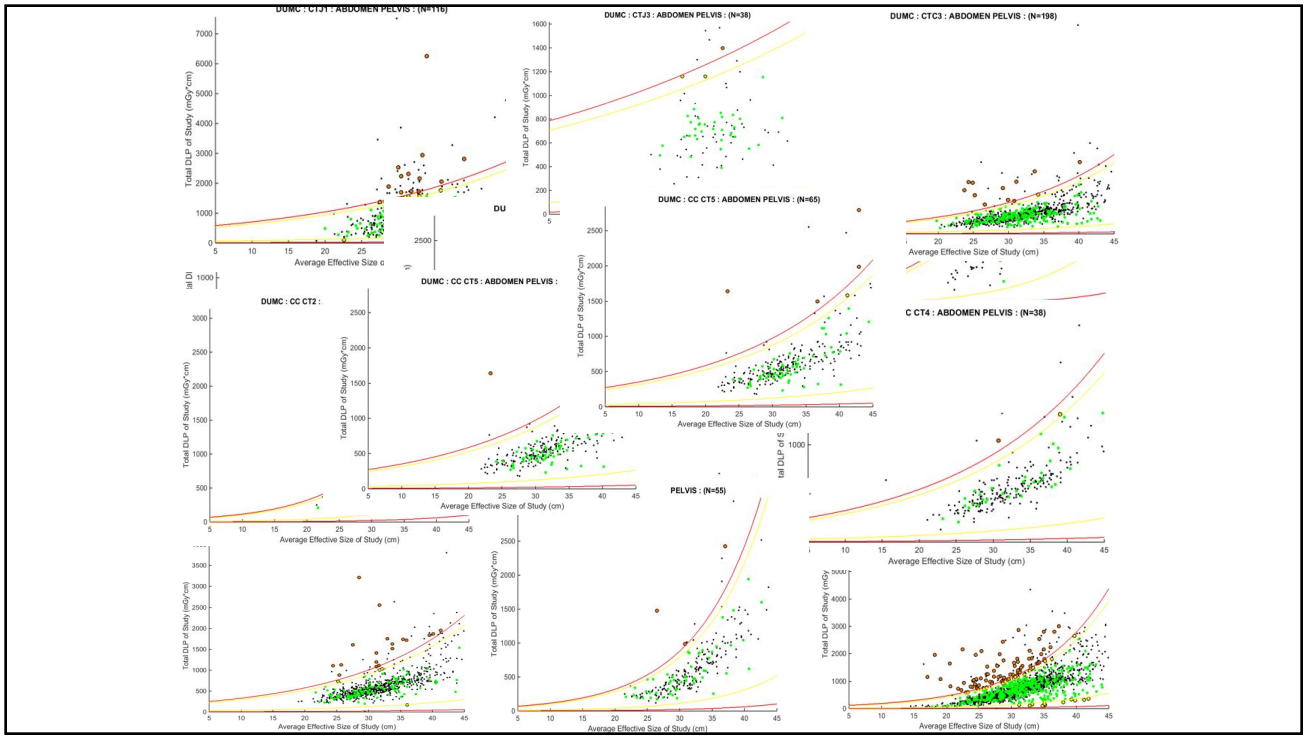
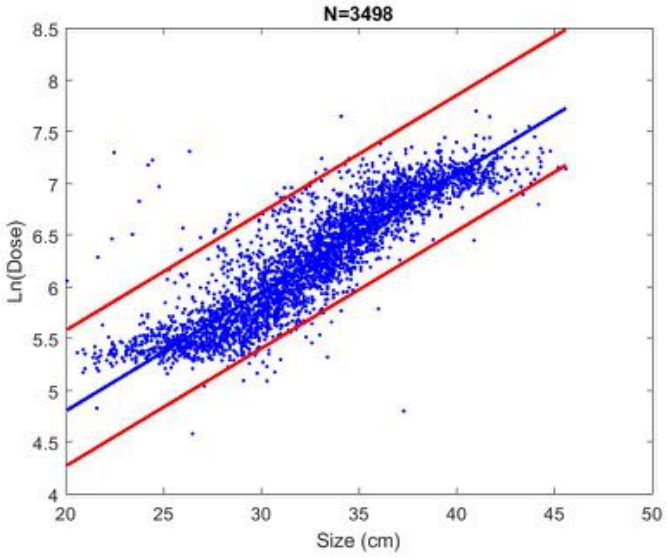




Scalarizing Variability



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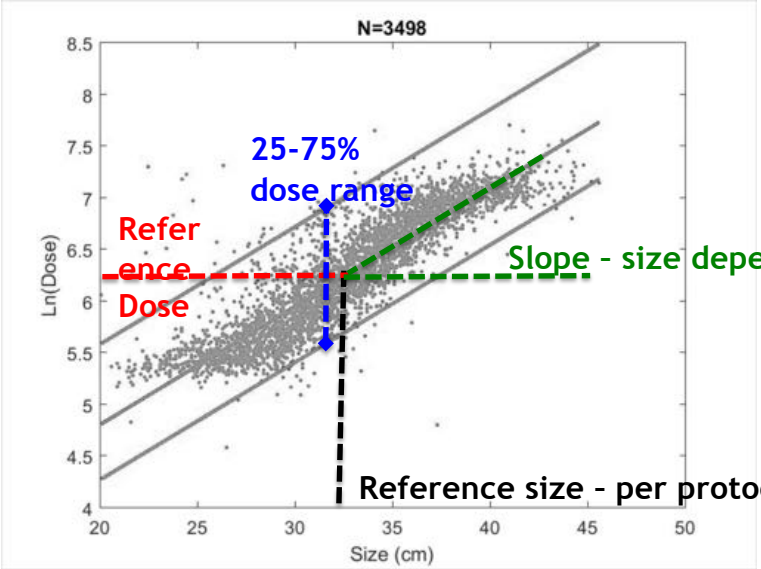
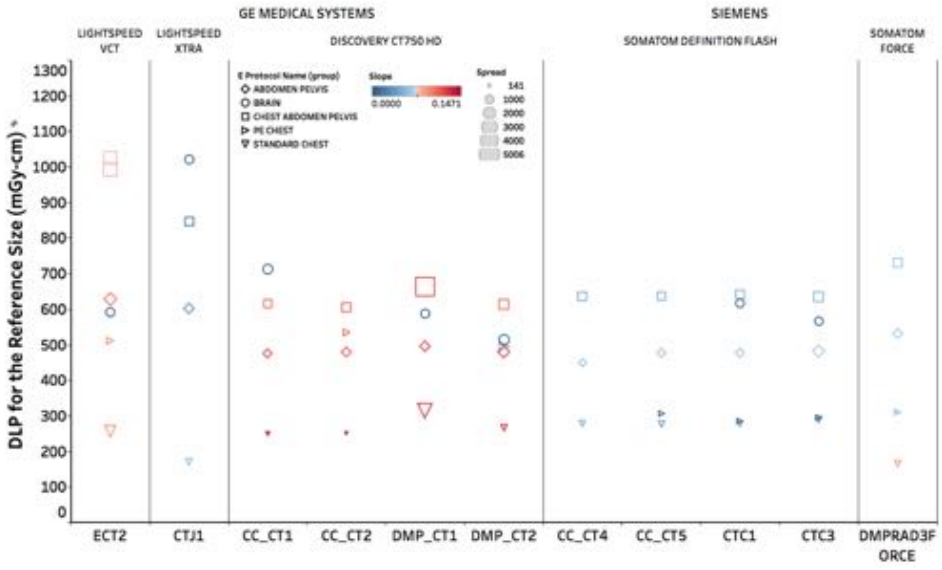


5D Illustration of Systematic Variability:

Y=dose X=system shape=protocol size=range color=slope



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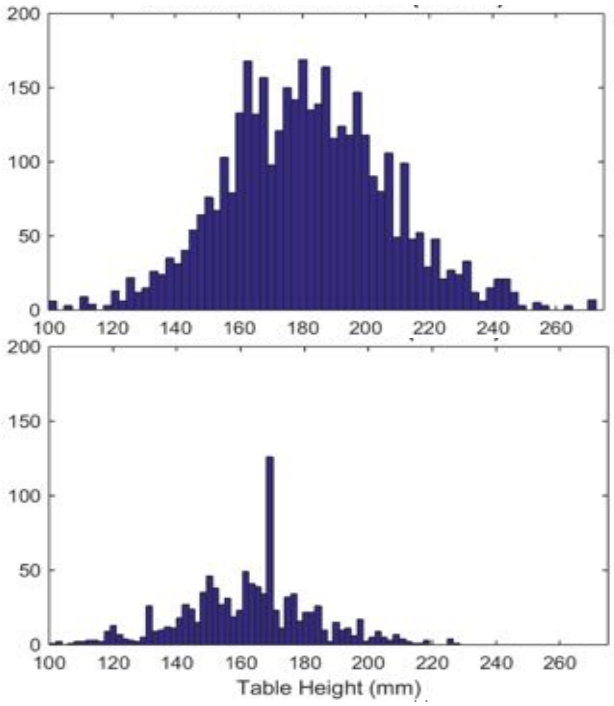
Brain 12 Yrs and Up

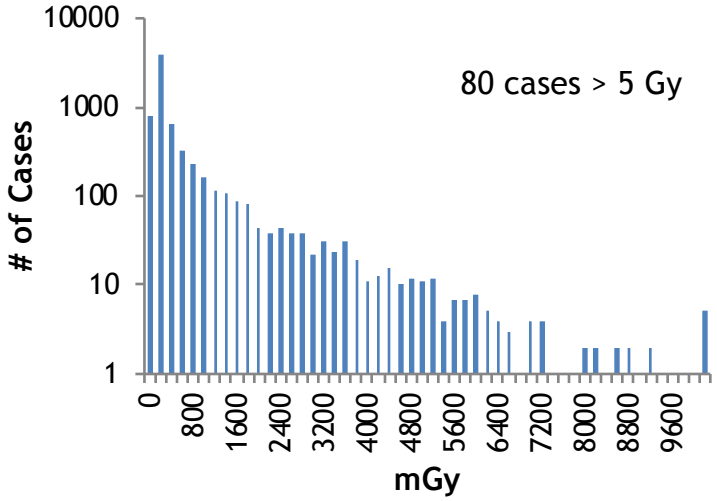
n=5480 annually (2.5% of all CT scans)

Scan parameter	Flash	750 HD	VCT	LS 16	LS Xtra
Protocol name	01_BRAIN_12_AND_UP_WITHOUT_AND_WITH_IV	1.7 BRAIN 12 YRS & UP	1.1 BRAIN 12 YRS & UP	1.1 BRAIN 12 YRS & UP	1.1 BRAIN 12 YRS & UP
Scan type	Helical	AXIAL	AXIAL	AXIAL	AXIAL
Rotation time	0.5	0.5	0.7	2	1
Pitch	0.55	1	1	1	1
Beam width	38.4	20	20	10	10
kVp	120	120	120	120	120
Slice thickness	5	5	5	5	5
Auto mA	On	Off	Off	Off	Off
mA/NI/mAsref	e225				
SFOV	FLAT	Head	Medium	Head	Head
Kernel	j45S	Standard	Standard	Standard	Standard
Iterative Level	SAFIRE 3	ASiR 40%, 80%	FBP	FBP	FBP
Matches e-protocol	No				
% of BRAIN 12YRS and UP exams	5.9%	7.8%	86.2%	0.0%	0.0%
Comments:	A few Flash protocol names, some have 1s rot time. ASiR is probably ok, official protocol changed over quarter.				

CT Table Height



Dose monitoring in fluoro



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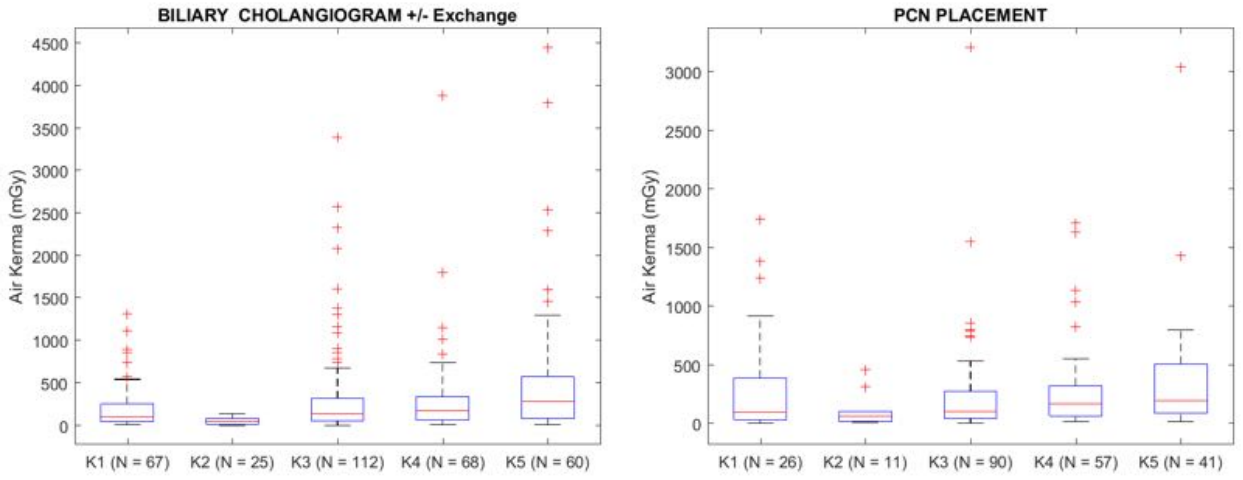
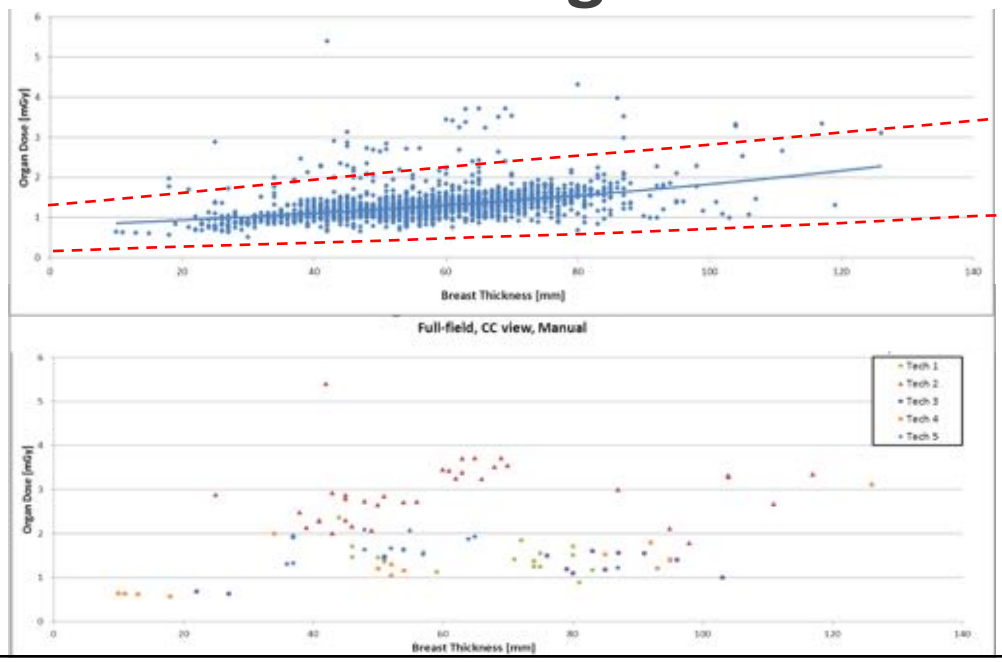
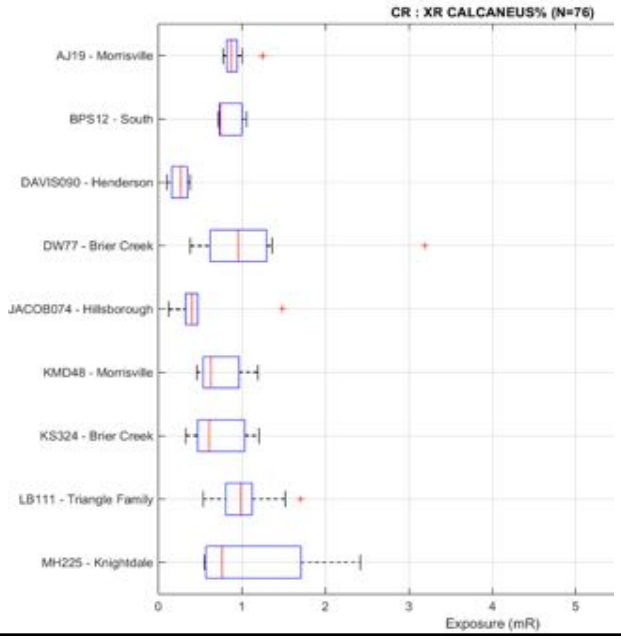
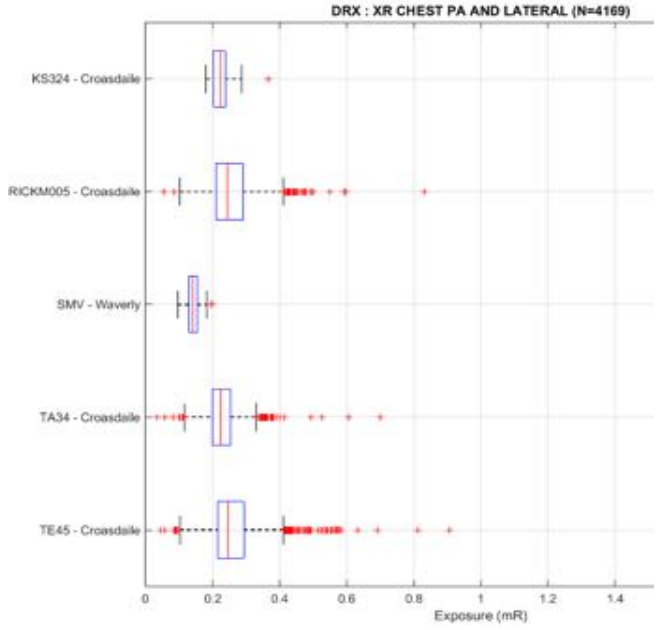


Dose monitoring in mammo



Dose monitoring in radiography





Take-home points

- Exposure monitoring is a useful tool in monitoring the quality of medical imaging practice
- Monitoring identifies overlooked issues that can/should be managed to improve practice
- Underlying purpose of monitoring
  - Assurance of appropriateness of **individual** dose
  - Followup corrective action for improved operation

Key functions of monitoring

1. Benchmarking institution against national DRLs
2. Defining protocol- and size-specific DRLs
3. Identifying and managing outliers
4. Ascertaining trends over time, users, systems
5. Tracking protocol discrepancy
6. Investigating individual doses
7. Improving operational consistency

Questions?