Informatics Tools for Recording/Tracking Dose

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Co-Chair, DICOM Standards Committee
Past Chair, IHE Radiology Planning Committee
Standards & Tools
Learning Objectives

1) DICOM Radiation Dose SR (RDSR)
   - capturing procedure dose information

2) IHE Radiation Exposure Monitoring Profile (REM)
   - coordinating the capture and management of RDSR objects
   - applying in a radiology practice.

3) "CT dose screens"
   - porting legacy scanner data into RDSR

4) MITA CT Dose Check (XR-25)
   - pre-scan dose pop-ups on the CT console

5) IHE Integration Statements & DICOM Conformance Statements
   - specifying these standards & features when purchasing and integrating radiology systems.
Headers & Screen Shots

- Useful but **limited**
- Missing details
- Not machine-readable
- Duplication issue
- Size issue

<table>
<thead>
<tr>
<th>Series</th>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTDIvol (mGy)</th>
<th>DLP (mGy·cm)</th>
<th>Phantom cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scout</td>
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<td>2</td>
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<td>$15.750-1G50.250</td>
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<td>Total</td>
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Exam Description: CT HALS/THORAX/ABDOMEN

Patient Name: [Name]
Accession Number: [Accession Number]
Patient ID: [Patient ID]
Exam no:
Discovery CT750 HD
**DICOM RDSR**

### Radiation Dose Structured Report Object

<table>
<thead>
<tr>
<th>NL</th>
<th>Rel with Parent</th>
<th>VT</th>
<th>Concept Name</th>
<th>VM</th>
<th>Req Type</th>
<th>Condition</th>
<th>Value Set Constraint</th>
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<tbody>
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<td>CONTAINER</td>
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</table>
DICOM Dose Reports

- “SR Objects” – DICOM Structured Reports
  - Easily ingested (and regurgitated) by PACS

- Granularity: “Irradiation Event”
  - & Accumulated Dose over Study, Series

- Templates:
  - CT, Projection X-Ray (Mammo, Fluoro, DR/CR)
  - PET/NM (WIP)

- Not addressed: RT
Key Measurements

- **CT Dose**
  - DLP, CTDIvol, kVP, mA, sec, ...
  - Effective Dose [ Optional; Reference estimation method ]
  - SSDE (CP-1170) [ Optional; see AAPM 204 ]

- **Projection X-Ray Dose**
  - DAP, Dose@RP, kVP, mA, sec, ...
  - Fluoro Dose, Fluoro Time
  - CR/DR: Exposure Index, Deviation Index

- **Mammography Dose**
  - AGD, Entrance Exposure@RP, kVP, mA, sec, ...
  - Compression, Half Value Layer

Other Details in Dose SR

- Full Patient / Order / Study Details
- Unique ID for each Irradiation Event
- Equipment ID, Ordering Doc, Performing Tech

- Patient Size, Orientation, Anatomy Imaged
- Imaging Geometry

- X-Ray Filtering & Collimation Details
- Anode Target Material
- Calibration, Phantom, Dosimeter, Patient Model
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IHE REM Profile

Radiation Exposure Monitoring
IHE in One Slide

- IHE helps vendors implement & test functions that span multiple systems

- Profiles are implementation guides
  - how to use existing standards
  - to address a specific problem scenario

- Connectathons are test events
  - managed testing of Profile implementations

- IHE helps users purchase & integrate multi-system solutions
  - list required IHE Profile support in RFPs
Using SR Dose Reports

- **Radiation QA**
  - Periodically Query / Retrieve Reports from Archive
  - Set policies/standards and flag deviations
  - Set goals for improvement and track progress
  - Implement protocol changes and compare difference in dose

- **Regulation**
  - E.g. Automatically insert dose metrics into diagnostic reports

- **Patient Impact Evaluation**
  - e.g. if Patient identified as pregnant post-facto

- **Dose Mapping**
  - Store data in realtime from Modality to Mapping Workstation
Using SR Dose Reports

- **National Registries**
  - Anonymize and submit Dose Reports to Registry
  - Compile Population Risk Estimations
  - Derive Dose Reference Levels (DRLs)
  - Provide Site-Site Comparisons

- **Individual Dose Record**
  - Collect Dose Reports over time

- **Clinical Trials**
  - Collect Dose together with Images
  - Demonstrate both improved detection & reduced dose
## Legacy Dose Extractors

<table>
<thead>
<tr>
<th>Series</th>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTD\text{vol} (mGy)</th>
<th>DLP (mGy cm)</th>
<th>Phantom cm</th>
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<td>1</td>
<td>Scout</td>
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<td>Total Exam DLP: 555.72</td>
<td>1/1</td>
</tr>
</tbody>
</table>

Patient Name: 
Accession Number: 
Patient ID: 
Exam Description: CT HALS/THORAX/ABDOMEN

Exam no: Discovery CT750 HD
Legacy Extractor

- What if you can’t get REM?
- Extractors create (partial) REM objects
  - Based on OCR of dose screens
  - Based on image header contents
  - Based on MPPS
- Likely incomplete but still useful
- Allows use of uniform infrastructure (RDSR)
- Current focus: CT, some XA
Example Extractors

- Open Source
  - “Dose Utility” - dclunie.com
    - by David Clunie (PixelMed)
  - “Radiance” - radiancedose.com
    - by Tessa Cook (Hospital of U of Pennsylvania)
  - “GROK” – dose-grok.sourceforge.net
    - by Graham Warden (Brigham and Women's Hospital)

- Also
  - ACR Triad Site Server (included in ACR participation)
    - by Mythreyi Chatfield (ACR)
  - ... and a growing number of commercial products
MITA XR-25

CT Dose Check

Dose Notification
Predicted DLP of 981 mGy-cm
Exceeds Threshold …
MITA CT Dose Check Initiative

- **Goals**
  - Enhance dose awareness (CTDI/DLP)
  - Help to avoid excessive radiation events
  - Provide data to sites for QA

- **MITA has published the standard (XR-25)**
  Manufacturers worked to ensure
  - Uniformity
  - Speed of implementation
  - Breadth of deployment

* [http://www.nema.org/standards/xr25.cfm](http://www.nema.org/standards/xr25.cfm)
Dose Notification

- Pop-up message
  - Notifies technologist that dose *for a current scan element* will exceed a trigger value
  - Tech may:
    - confirm and proceed, or
    - go back and adjust scan parameters
  - System records audit trail
    - Predicted dose, Notification value, Date/time, diagnostic reason, etc.

- Clinical sites set values that will trigger a notification
  - Can set DLP and/or CTDI_{vol} values for each scan element
    - e.g. head without contrast
  - Defined by the clinical site for their patient population
Dose Alert

- **Pop-up message**
  - Alerts technologist *cumulative* dose for current study will exceed a trigger value:
    - CTDI\text{vol} (summed at each patient location)
    - DLP (summed over the current study)
  - Tech may:
    - enter their name, (& a password if configured), confirm and proceed, or
    - go back and adjust scan parameters

- **Clinical sites set values that will trigger an alert**
  - Can set DLP and/or CTDI\text{vol} values
    - System must allow at least one global value
  - System tracks accumulated CTDI\text{vol} at each patient location & accumulated DLP
  - System checks predicted accumulated dose indices when protocols are saved & when scans are ready
Default Values

- The FDA has suggested an alert value for CTDIvol of 1000 mGy.
- AAPM suggested notification values
- Can be changed at local site
- Consider behavior modification vs alert fatigue

### Table 1: Notification Values recommended by the AAPM Working Group on Standardization of CT Nomenclature and Protocols

<table>
<thead>
<tr>
<th>CT Scan Region</th>
<th>CTDIvol Notification Value (mGy)</th>
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<tbody>
<tr>
<td>Adult Head</td>
<td>80</td>
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<tr>
<td>Adult Torso</td>
<td>50</td>
</tr>
<tr>
<td>Pediatric Head</td>
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</tr>
<tr>
<td>≤2 years old</td>
<td>50</td>
</tr>
<tr>
<td>2 – 5 years old</td>
<td>60</td>
</tr>
<tr>
<td>Pediatric Torso</td>
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</tr>
<tr>
<td>≤10 years old (10-cm phantom)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25</td>
</tr>
<tr>
<td>≤10 years old (32-cm phantom)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10</td>
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<tr>
<td>Brain Perfusion (examination that repeatedly scans the same anatomic level to measure the flow of contrast media through the anatomy)</td>
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<tr>
<td>Cardiac</td>
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<tr>
<td>Retrospectively gated (spiral)</td>
<td>150</td>
</tr>
<tr>
<td>Prospectively gated (sequential)</td>
<td>50</td>
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</tbody>
</table>

<sup>a</sup> As of January 2011, GE, Hitachi and Toshiba scanners use the 16-cm-diameter CTDI phantom as the basis for evaluating dose indices (CTDIvol and DLP) displayed and reported for pediatric body examinations.

<sup>b</sup> As of January 2011, Siemens and Philips scanners use the 32-cm-diameter CTDI phantom as the basis for evaluating dose indices (CTDIvol and DLP) displayed and reported for pediatric body examinations.
Audit Trails

- Pop-up Overridden? System must record:
  - Dose Notification
    - Predicted dose, Notification value, Date/time, Diagnostic reason
  - Dose Alert
    - Predicted dose, Alert value, Date/time, Diagnostic reason, Operator name

- RDSR has fields to record all these details
  - May choose to record even if not overridden

- Triggers vs DRLs
  - 75\textsuperscript{th} percentile \rightarrow popups on 25\% of scans
  - See AAPM guidance
Dose Tracking in Products

- **IHE REM**
  - Testing: IHE Connectathon (2013: 32 vendors passed REM)
  - [http://connectathon-results.ihe.net](http://connectathon-results.ihe.net)
  - Product: IHE Integration Statement (2013: 41 products)
  - [http://product-registry.ihe.net](http://product-registry.ihe.net)

- **DICOM RDSR**
  - Product: DICOM Conformance Statement

- **NEMA XR-25**
  - Vendor commitment; most new products
Ask for it

- RFPs / Purchase Requirements
  - ... shall support IHE REM as the Acquisition Modality actor ...
  - Ask to see IHE Integration Statements & DICOM Conformance Statements

- Installation / Acceptance
  - Discuss activation / configuration

- Upgrades
  - Some models can be upgraded
Takeaway

Data Collection
- New/recent Modalities
  - IHE REM / DICOM RDSR to capture dose data
- Legacy strategies
  - Dose extractors to generate RDSR data

Analysis
- IHE REM – Dose Information Reporter for local analysis
- ACR Dose Registry to compare to benchmarks

Prevention
- CT Dose Check for configurable pre-scan alerts