Radiation Dose Index Monitoring (RDIM)

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AAPM Medical Physics Practice Guideline (MPPG) 6.a.

Selection of a Radiation Dose Index Monitoring System Practice Guideline

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Note, MPPG 6.a. is still under review and waiting approval from the Professional Council and EXCOM

Disclaimer *

My employer, Texas Health Resources, utilizes GE Dose Watch product for both CT and XA dose monitoring.

My previous employer, U of Washington, has a research agreement with GE DoseWatch.

No conflict of interest to disclose, however, my personal experiences may reflect more information/detail about GE DoseWatch product. I have not used other Radiation Dose Index Monitoring (RDIM) software products; examples included in this presentation for other RDIM products are from colleagues in the field.

Topics

- RDIM Introduction
  - Motivation and overview
  - Goals and rationale
  - Potential limitations and precautions
- RDIM Software Team
- Common elements (Independent of Modality)
- Planar requirements for RDIM
- Planar QA use scenarios
- Fluoroscopy requirements for RDIM
- Fluoroscopy QA use scenarios

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RDIM Introduction

Radiation dose index monitoring (RDIM) systems may generally be identified as

- Software that passively or actively collect radiation dose indices (RDI)
- Collect data from diagnostic or image guided interventional studies using ionizing radiation
- Store RDI in a relational database along with patient demographic and study information.

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RDIM Introduction

The RDIM graphical user interface

- Allows the end user to visualize RDI by study type, patient or other category
- Used for quality assurance or patient- or study-specific investigations

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RDIM Introduction

Motivation

- Documented ionizing radiation injuries
- Recommendations from Image Gently and Image Wisely Campaigns as well as IAEA Smart Card/SmartRadTrack Project
- FDA & state dose record requirements

Cedars-Sinai investigated for significant radiation overdoses of 206 patients.

The finding prompts the FDA to issue an alert urging hospitals nationwide to review their safety protocols for CT scans.

October 10, 2009 | Alan Zarembo

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RDIM Introduction

Goals and Rationale

1. Enhance and expand existing facility QA and QC efforts
   - May aid a QMP in identifying
     - Outlier cases
     - Parameters outside pre-defined reference levels
     - Interventions with exposures above a deterministic effects threshold level
   - QA programs should consider the image acquisition and reconstruction parameters affecting dose and image quality performance

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RDIM Introduction

Goals and Rationale

2. Identify the "frequent flyer" patients
   - An individual patient has received a large number of imaging studies (i.e. multiple CT examinations; TJC fluoroscopy sentinel event, 6-month period)
   - Patient history may allow development of a patient-specific protocol under the direction of a radiologist and QMP
   - ACR Appropriateness Criteria can provide decision support and is publicly available

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RDIM Introduction

Potential Limitations and Precautions

- RDIs do not represent absorbed dose in an individual patient, rather RDIs are related to x-ray beam output or x-ray absorption at the image receptor
- Organ absorbed doses and effective dose reported by software
  - Based on standardized models of the human
  - Do not accurately represent the absorption characteristics of any single individual

Absorbed dose and effective dose estimates are beyond the scope of the AAPM MPPG 6.a.

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RDIM Introduction

Potential Limitations and Precautions

- It is not appropriate to compute a cumulative patient dose history from multiple exams.
- Avoid adding estimated doses from diagnostic studies performed over a time period longer than that required for biological repair mechanisms
  - AAPM Position Statement PP 25-A
  - Health Physicist Society *Radiation Risk in Perspective* Position Statement

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http://www.aapm.org/org/policies/details.asp?id=318&type=PP&current=true
http://www.hps.org/documents/radiationrisk.pdf

RDIM Introduction

Potential Limitations and Precautions

- It is however appropriate to assess health risks due to deterministic effects from high-dose exposures
- Alert levels for interventional fluoroscopy and dynamic CT
- Estimated peak skin dose is usually desired
- Patient record should be reviewed by a QMP for deterministic effect risk assessment

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RDIM Introduction

MPPG 6.a. recommends that organ doses and effective dose should

- Not be included in a patient's medical record
- Must not be analyzed or interpreted without the direction and involvement of a Qualified Medical Physicist (QMP)

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Which of the following is a primary rationale for the use of Radiation Dose Index Monitor Software system?

20%	a)	Tracking patients receiving low doses to determine risk estimates
20%	b)	Enhance and expand QA and QC efforts
20%	c)	Compute cumulative patient dose history
20%	d)	Calculation of absorbed dose specific to a patient
20%		

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RDIM Introduction

RDIM Software Team

- Team must include: QMP, a lead radiologist, a lead technologist, and an individual from the PACS/IT department
- Additional team members to consider:
  - Senior member of the facility administration team (e.g. CMO, Radiology Dept Administrator/Manager)
  - Physician representative from any other clinical imaging department (e.g., cardiology, EP, GI)
- Team must be responsible for selection of RDIM software
- Each member may have a variety of responsibilities in the implementation and use of the dose monitoring software

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RDIM Introduction

Purchasing an RDIM System

- Employ the same purchasing procedures they follow for any other major piece of software
- Basic assessment of
  - How the data will be used
  - Who will oversee the facility's RDIM program
  - Who will have access and at what "levels"
  - Who will implement relevant aspects of the RDIM within each modality
  - How often reviews will happen and what they will entail

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RDIM Introduction

Additional challenges to consider upon purchasing

- Cost and labor involved in set-up
- PACS and information technology (IT) issues
- Testing the software once installed – test server vs live server
- Analyses – population, modality, individual
- Identifying the type of feedback that will be provided to ordering physicians and the mechanism for communicating that feedback.

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RDIM Introduction

Using RDIM in a QA Review – Specific Questions to Consider

- How can/will the monitored data be used?
- Which indices are needed for these uses?
- What do these indicators mean?
  - Are they relevant to the overall goal?
  - How accurate are they?
  - How accurate do they need to be?
  - Is one indicator sufficient?
- Are the desired indices available for tracking?

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RDIM Introduction

Using RDIM in a QA Review – Specific Questions to Consider

- Where will they be tracked (stored and analyzed)?
- Is the imaging system compatible with the RDIM to send/receive data? If so, then how?
- Under what conditions, if any, should either estimated derived dose quantities or RDIs be summed?
- Who should have access? How much access should they have?

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The RDIM Software team must add a PACS/IT representative to the commonly assembled CT Protocol Committee, which consists of:

20%	a)	QMP and a facility or department administrator
20%	b)	QMP, lead radiologist, and lead technologist
20%	c)	Lead radiologist, lead technologist, and a facility or department administrator
20%	d)	QMP and a lead technologist
20%	e)	There is not a minimum standard for who should be on an RDIM or QC team

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RDIM Common Elements

Fundamental Functions Independent of Modality

- RDIM data may be useful in assisting the QMP in such tasks as ongoing QA, PQI projects, and patient or fetal dose estimation

1. ***Tracking of dose index*** – essential dose indices must be recorded automatically (preferred) or manually
   - Dose indices of each acquisition, including rejected images, must be recorded unambiguously
   - Essential acquisition parameters should be recorded together with the corresponding dose index data
   - If the information cannot be automatically recorded, the option of manual input by the user must be provided

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RDIM Common Elements

Fundamental Functions Independent of Modality

2. ***Notifications for dose indices outside the defined range*** – thresholds that trigger notifications to a set of end users must be configurable
   - Can be based on quality/safety assurance and regulatory compliance
   - Based on a variety of criteria, including but not limited to modality, type of exam, and patient age
   - Predetermined target users must be notified in a timely manner, typically by email
   - If PHI is included, the notification must be transmitted using a secure approach

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RDIM Common Elements

Fundamental Functions Independent of Modality

3. ***User management*** – RDIM access must be limited to a group of authorized users
   - The level of data access and system configuration must be granted according to the specific role of each user or group of users
   - Configured based on access level (all access) or limited access (e.g. by modality)

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RDIM Common Elements

Fundamental Functions Independent of Modality

4. ***Dose analysis tools*** – should assist users in utilizing the collected information, include but not be limited to:
   - Comparing dose indices of user-selected protocols across machines
   - Analyzing the trending of dose indices as a QA tool
   - Reviewing patient history which could include exams of multiple different imaging modalities

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RDIM Common Elements

Fundamental Functions Independent of Modality

5. *User interface elements* – should provide key functionalities to review the recorded dose and imaging acquisition parameters, including but not limited to
    - Navigating exams with customizable sorting options (e.g., chronologically, alphabetically, or by age)
    - Exploring detailed exam/scanning/dose information of any user-selected exam
    - Reviewing exam history of any user-selected patient
    - Categorizing dose data by modality, facility, individual device, date range, exam type, protocol type, ordering physician, performing physician or operating technologist

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Planar X-ray Specific Requirements

Dose index Monitoring for Planar X-ray
- General radiography (CR or DR), cephalometric units, and mammography
- Entrance skin air kerma (ESAK, or entrance skin exposure, ESE) – local skin dose; annually assessed by a QMP
- Replacement of film technology with CR or DR has created the need for image receptor exposure indices
    - Image receptor vendors originally developed proprietary exposure indices
    - Newer equipment complies with the IEC standard

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Planar X-ray Specific Requirements

Dose index Monitoring for Planar X-ray
- Identify outlying exposure events
- Where applicable, identifying exposure events that fail to comply with regulations or accreditation requirements

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Planar X-ray Specific Requirements

Dose index Monitoring for Planar X-ray

1. *Automatic monitoring of essential dose indices*
    - DAP, AK, and AGD for mammography must be recorded if available
    - should be able to extract DAP and reference AK (if available) for general radiography exposures
    - Capture of machine technical factors and patient demographics is also desirable. For mammography the software should be capable of extracting phantom AGD and compressed breast thickness

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Planar X-ray Specific Requirements

Dose index Monitoring for Planar X-ray

2. *Exposure Indices*
    - IEC Standard
        - RDIM software must allow entry of protocol-specific target indices (target EI), EI and DI
    - Exposure indices, manufacturer-defined
        - RDIM software must allow capture of proprietary EIs

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Planar X-ray Specific Requirements

Dose index Monitoring for Planar X-ray

3. *Notification of dose indices outside of defined range*
    - IEC Standard
        - Must allow action levels to be applied to the DI
    - Exposure indices, manufacturer-defined
        - Alert values must allow for specification of both a high and low limit (must be established by QMP) and must be unique to the exam, view, and patient habitus

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For planar imaging, which index (IEC standard) should be recorded in the RDIM software to set alerts?

20%	a)	S-number
20%	b)	Entrance skin air kerma (ESAK)
20%	c)	Target EI
20%	d)	S-number and ESAK
20%	e)	Dose-area product (DAP)

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Fluoroscopy Specific Requirements

Dose index Monitoring for Fluoroscopy
- FGI (IR, CCL, EP), general R/F, and mobile fluoroscopy
- At a minimum the exam indices to record are fluoroscopy time, air kerma (AK), and kerma-area product (KAP, historically DAP)
- When possible detailed information for each irradiation event of a procedure should be recorded so a better assessment of PSD can be performed if needed

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Fluoroscopy Specific Requirements

Dose index Monitoring for Fluoroscopy
- Given that the displayed AK may be inaccurate by up to ±35%, a QMP should assess whether a correction factor should be applied to the displayed AK
- Software should allow for unit-specific (by system) or global fluoroscopy correction factors to be assigned for accurate reporting of cumulative AK

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Fluoroscopy Specific Requirements

Dose index Monitoring for Fluoroscopy
1. ***Automatic monitoring of essential dose indices***
   - Fluoroscopy time, AK and DAP must be recorded
   - For bi-plane imaging systems, fluoroscopy RDI must be recorded separately for each tube (e.g. A/B or PA/lateral).
   - Number of irradiation events and acquisition details should be recorded. Information provided for individual event(s) should include but not be limited to: exposure time, tube position, tube angle, mode, filtration, and AK per event.

Acquisition logs can be utilized by a QMP to assess cumulative and peak skin doses

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ref. Jones & Pasciak, *Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods.* Journal of Applied Clinical Medical Physics, 2011. 12(4): p. 231-244

Fluoroscopy Specific Requirements

Dose index Monitoring for Fluoroscopy
2. ***Manual entry of dose index data fluoroscopy time entry option***
   - Optional entry of fluoroscopy dose index data should be available for systems with no dose index information displays or which have the inability to transfer such data electronically
   - For older fluoroscopy units, dose indices may not be available and/or the system might lack the capability to connect to RDIM server; a minimum record fluoroscopy time is sufficient to meet federal and state requirements

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Fluoroscopy Specific Requirements

Dose index Monitoring for Fluoroscopy
3. ***Dose Incidence Map***
   - Vendors can utilize event logs (with line-by-line history of the tube position and individual event cumulative AK) to create an 2D incidence map of AK
   - The peak AK value as reported by the vendor can then be used by a QMP in estimating the PSD

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ref. Jones & Pasciak, *Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods.* Journal of Applied Clinical Medical Physics, 2011. 12(4): p. 231-244

Fluoroscopy Specific Requirements

Dose index Monitoring for Fluoroscopy

4. ***Notification of dose indices outside of defined range***

- NCRP report 168 recommendations for
  - Patient radiation dose-management programs
  - Setting institutional substantial radiation dose levels (SRDL) for additional dose-management procedures (e.g., patient follow-up visits)
  - Regulatory and accrediting bodies – single incidence and longitudinal tracking of patient cumulative skin dose over specified periods of time (e.g., sentinel events).
- Dose monitoring software must identify single events and cumulative exposures that exceed AK thresholds

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A fluoroscopy dose exposure incidence map can be used by a QMP to:

20%	a)	Determine which critical organs may have been exposed during the procedure
20%	b)	Assess stochastic risk following the procedure
20%	c)	Estimate peak skin dose
20%	d)	Calculate the dose-area product (DAP)
20%	e)	Calculate the absorbed dose to the patient

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