Patient Dose Tracking for Imaging Studies

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Conflict of Interest Statement

No affiliation or financial interests in any of the commercial products or enterprises discussed as part of this presentation.
Introduction to Patient Dose Tracking (PDT)

Why Patient Dose Tracking (PDT)?
What Dose Metrics are useful/attainable?
How are dose metrics obtained?
Where are dose metrics recorded?
When is PDT required?
What tools are available to assist with PDT?
Overview

• Motivation
• Dose Metrics
• PDT “Requirements”
  – Regulatory
  – Accreditation
• Strategies & Tools for PDT
• Examples of Commercial Products
Why track Patient Dose?

- Regulatory requirements
- Accreditation requirements
- Liability and Public Relations
- Research
- Quality Assurance
- Awareness & Patient Safety
- Individual Patient cumulative dose record
- PQI
Patient Dose Metrics

- **Dose**
  - Organ Dose (Gy) / Equivalent Dose (Sv)
  - Effective Dose (Sv)

- **Dose Surrogates**
  - Cumulative Exposure Time (min)
  - Entrance Air Kerma (Gy)
  - Dose Area Product (Gy-cm²)
  - Cumulative Dose (Gy)
  - Peak Skin Dose (Gy)
  - CTDI (Gy)
  - Dose Length Product (Gy-cm)
  - Size Specific Dose Estimate (Gy)
Individual Patient Dose Measurement

• Measurement of Patient Dose – Difficult
  – Dosimeters
  – Computational Predictions

• Dose Surrogates – Easier to obtain
  – Easier measurement
  – Difficult interpretation for radiation detriment
  – Not uniformly defined or applied

• Depend on biological endpoint
The dosimetry parameter that best represents the stochastic radiation detriment to a patient is:

- **23%** a. Cumulative Dose
- **17%** b. CTDI\text{vol}
- **13%** c. Dose Area Product
- **30%** d. Dose Length Product
- **17%** e. Effective Dose
Answer: e. Effective Dose

Requirements & Recommendations

- **Federal**
  - 21CFR 803: Reporting of skin damage to fluoroscopic equipment manufacturers
  - FDA Recommendations for Interventional Procedures

- **States**
  - CA, TX, OH......?
  - Fluoro and CT

- **Other**
  - Individual Health Care Systems
    - Veterans Health Administration & NIH
  - American College of Radiology, Dose Index Registry
  - The Joint Commission
Sample Recommendations for Dose Metrics

- **California:** Effective Dose, Skin Dose
- **Texas:**
  - Reference Levels
  - Fluoro: Air kerma, or other estimates of skin dose
  - CT: $\text{CTDI}_{\text{vol}}$, DLP
- **VHA:**
  - Cumulative fluoro time
  - Cumulative air kerma or skin dose
  - Dose-area-product
• Recorded PDT Metrics likely dictated by regulatory and accreditation bodies
Requirements: California

- Senate Bill 1237
- Report to DHS scans that are repeated or wrong body part resulting in:
  - Effective Dose > 0.05 Sv
  - Dose > 0.5 Sv to any organ or tissue
  - Shallow dose to skin > 0.5 Sv
- Some exceptions
- Implementation: Reference levels for CTDIvol and DLP
- Exam and patient specific
  - i.e. Cumulative CTDIvol of 650 mGy for any expected to exceed skin reporting threshold of 500 mSv
Requirements : Texas

• 25 TAC 289.227 – Effective May 1, 2013
• Radiation Protocol Committee for
  – Fluoroscopically-Guided Interventional Procedures
  – CT Systems
  – Methods to monitor radiation output
  – Establish Reference Levels for radiation output
  – Actions for when reference level is exceeded
  – Do not need to determine patient dose for each procedure
Requirements: Texas

- Fluoroscopy
  - Make and maintain a record of radiation output information so the radiation dose to the skin may be estimated....
  - To include:
    - Cumulative air kerma or dose area product (if available on system) or
    - Fluoro mode, Cumulative exposure time & number of recorded exposures.

- CT
  - Make and maintain a record of radiation output information so the radiation dose to the skin may be estimated....
    - CTDIvol and DLP (if system capable of calculating and displaying) or
    - AAPM TG 111 Recommendations
Proposed: Ohio

- Fluoro: Interventional, cardiac cath pediatric, pregnant patients
- Record cumulative air kerma or DAP for each exam
or
- Mode of operation, Cumulative fluoro exposure time, and number of radiographs
The State of Texas requires monitoring of patient doses for

- 17% a. Radiography and Fluoroscopy
- 30% b. Fluoroscopy and CT
- 30% c. Radiography and CT
- 17% d. Fluoroscopy only
- 7% e. CT only
Answer: b. Fluoroscopy and CT

Proposed: The Joint Commission

- Prepublication Standards: Diagnostic Imaging Services Requirements; Provision of Care, Treatment, and Services (PC) – Effective July 1, 2014

- PC.01.02.15 ; C5
- For ... diagnostic CT... documents in the patient’s medical record the radiation dose (CTD\text{vol} or DLP) on every study produced during a CT examination.

- PC.01.02.15 ; C6
- For... diagnostic CT.. The interpretive report of a diagnostic CT study includes the CTD\text{vol} or DLP radiation dose. The Dose is either recorded in the patient’s interpretive report or included on the protocol page.
– Only applicable for systems calculating and displaying radiation doses.

– Not applicable to systems for rad therapy treatment planning or dental cone beam CT
Proposed: The Joint Commission

• Prepublication Standards: Diagnostic Imaging Services Requirements; Performance Improvement (PI) – Effective July 1, 2014

• PI.02.01.01; A6
• The hospital compiles and analyzes data on patient CT radiation doses and compares it with external benchmarks, when such benchmarks are available.
  – i.e. collection of data where pre-identified radiation dose limits are exceeded.
Observations on proposed TJC standards

- Draft requirement for electronic transmission of protocol identifying radiation dose to PACS was removed from the standard.

- Expect a parallel set of Fluoroscopy standards in Phase 2 – 2015 Implementation.
Effective July 1, 2014, The Joint Commission accreditation will require documentation of each patient’s radiation dose (CTDI$_{vol}$ or DLP)

- 10% in the patient medical record.
- 33% by electronic transmission to the EMR.
- 20% by electronic transmission to the hospital’s electronic PACS.
- 20% for diagnostic CT and dental cone beam CT systems.
- 17% by a diagnostic medical physicist.
Answer: a. in the patient medical record.

Ref: TJC Prepublication Standard PC.01.02.15
Generation & Recording of Dose Metrics

• Measured vs Predicted
  – DAP: measured
  – Cumulative Air Kerma/Skin Dose: Measured
  – CTDI: Predicted
  – DLP: Predicted

• Recording Methods
  – Manual
  – DICOM Radiation Dose Structure Report RDSR
    Or other electronic transfer formats
  – Optical Character Recognition (OCR) from images
Formats & Imaging Modalities

- DICOM Radiation Dose Structured Report
  - RDSR
- DICOM Modality Performed Procedure Step
  - MPPS
- IHE profile Radiation Exposure Monitoring

Digital Modalities these are typically provided for:
- CT
- Fluoro:
  - Interventional Radiography
  - Cardio-Vascular
  - Mobile C-Arms
- Radiography
- Mammography
Options for Legacy Equipment

- Manual entry / Logs
- Image Headers
- OCR from Images
Dose Tracking Applications

• Cumulative dose tracking throughout a health system (multiple modalities and procedures).
• Analysis to optimize image quality and minimize patient risk
• Compliance and Reporting:
  – Internal
  – Patients
  – Governing & regulatory authorities
Patient Dose Tracking

- Threshold dose notifications
- Cumulative dose history prior to exams
Trend Analysis

- Dose comparisons as a function of
  - Modality
  - Protocol
  - Sites
  - Patient populations
  - Time
  - Etc.
Compliance Reporting

- Periodic Summary Reports
- Customized Diagnostic Reference Levels
Communication with other systems

- PACS
- RIS
- HIS
- EMR
- ACR DIR
Dose tracking software systems can integrate dose information from each of the following methods except:

- 40%: a. DICOM MPPS
- 17%: b. DICOM RDSR
- 10%: c. IHE Profile REM
- 20%: d. NEMA OS-3-2012
- 13%: e. OCR
Answer: d. NEMA OS 3-2012

Ref: Manufacturer Websites listed at end of presentation
Commercial Solutions for Dose Tracking

• Broad range of capabilities
  – Basic information recording
  – Advanced analysis and interactive notification

• Multi-modality

• Transmission of dose information from imaging device or PACS

• Integration with PACS, RIS, & EMR

• Analysis and Reporting
Commercial PDT Tools

• Basic

• Custom

• Dedicated System
Basic Dose Tracking

- Integrated with an existing system
- Example: Meditech
  - Integrated information system
  - Many aspects of health care
  - Includes a RIS and interfaces with PACS
  - RDSR’s flow into Meditec
  - Subsequently recorded in patient record
Custom Applications

• Designed to meet specific needs

• Example: Primordial
  – Customized applications in radiology
  – Provide wide variety of Radiology services
  – Departmental workflow, communications, QC,...
  – Integration of PACS, RIS, and EMR

  – Radiation Dose Monitoring – Customizable Application
Dedicated Dose Tracking Software

Integrate dose metrics from imaging systems or PACS

typical formats: DICOM RDSR preferred

Integrate with PACS, RIS, EMR

Analysis capabilities

Selection of Reference Doses

Automated notification
Examples of Dedicated Dose Tracking Systems

- DoseMonitor (PACS Health)
- DoseTrack (Sectra)
- DoseWatch (GE)
- RADAR360 (MedPhys360)
- Radimetrics/eXposure (Bayer)
Common Features

- DICOM or IHE standards for interfaces
- Single server web-based applications
- Interface with multiple modalities
  - CT, Mammo, DR, Interventional vascular, Cardiac angiography, mobile C-arms
- HL7 Interface with PACS
- Customization for Ref. dose alerts
- Provide Near-time dose feedback
- Upload to ACR Dose Index Registry
- SSDE Prediction – Based on patient EMR data
by PHS Technologies Group

- 2012
- Single server, browser based design
- Direct integration with RIS, EMR, ACR DIR
- Supports CT, Mammo, DR, IV, CA
Features and Capabilities:

• Patient historical dose repository
• Customizable alerts and notifications
• Dose data exportable to dictation
• Reporting – sort by
  – Technologist
  – Procedure
  – Physician
• 8000 studies over 6 months
RADAR360 by MedPhys360

- Radiation Dose Analyzing & Reporting
- Queries PACS for CT data
- CTDI & DLP Analysis
- Protocol Management
- Pediatric Techniques Evaluation
- Customizable – designed to be affordable
DoseTrack by Sectra

• Cloud based dose monitoring
• Supports CT, Mammo, DR, IV, CA
• Alerts when thresholds exceeded
  – i.e. User defined Dose Reference Levels
• Fluoro cumulative dose maps
• Analysis:
  – Patient specific
  – Dose profiles for imaging systems
  – Comparison of individual performance
Radimetrics (eXposure) by Bayer

- Stand alone system- in house server
- Integrates with PACS & RIS

- Patient Score Card
  - Cumulative dose tracking

- CT Dosimetry Prediction
  - Monte Carlo simulation engine
  - Organ doses
  - Effective dose
  - Protocol evaluation
• Protocol Management
  – Supports multiple scanners
  – Tracks & authorizes revisions
  – Set uniform dose reference levels
    (CTDI, DLP, E, Organ Dose)

• Reporting
  – Customizable dashboard
  – Select items of items of interest
  – Patient Scorecard integrates with most EMR systems

• Productivity
  – Monitoring & Analysis of equipment utilization
  – Integrates with Contrast dose management tools
DoseWatch – GE HealthCare

- Multi-modality
- Not vendor specific
- Centralized system- web-based interface
- Integrates with RIS and EMR
- Tracking and statistical analysis
  - Identifies dose outliers
  - Email notification
DoseWatch

• Reporting
  – By device, operator or protocol
  – User defined thresholds
  – Email notifications

• Trend analysis
  – Baselines for procedures
  – Benchmark for improvements/optimization
DoseWatch

- **Legacy systems**
  - Extracts dose info from OCR on dose report images

- **CT : Size Specific Dose Estimate (SSDE)**
  - Per AAPM TG 204
  - Based on scout images

- **Fluoroscopy: Incidence Map**
SSDE

CTD\textsubscript{vol} : 11.59 mGy

LAT = 239.45 mm

AP = 159.27 mm

LAT + AP = 398.73 mm

Effective Diameter = 19.53 cm

f_{ssd} = 1.78

SSDE : 20.63 mGy

Off Isocenter Shift

Table Height = 115.5 mm

Delta X = 24.55 mm

Delta Y = 25.5 mm

Max Patient Width = 331.09 mm

Max Patient Thickness = 187.64 mm

mA Modulation

Mean mA = 180 mA

Min mA = 180 mA

Max mA = 180 mA
Cumulative Dose Incidence Map

- Frontal
- Lateral
- Both

Color Legend:
- > 5.0 Gy
- 4.5 - 5.0 Gy
- 4.0 - 4.5 Gy
- 3.5 - 4.0 Gy
- 3.0 - 3.5 Gy
- 2.5 - 3.0 Gy
- 2.0 - 2.5 Gy
- 1.5 - 2.0 Gy
- 1.0 - 1.5 Gy
- 0.5 - 1.0 Gy
- < 0.5 Gy

RAO: -15°
CRA: -15°

Estimated worst entrance surface air kerma

Grid Coordinates:
- ROA:
  - 9.94
  - 1.52
- CRA:
  - 0.46
  - 0.62
  - 0.44
- LAO:
  - 4.76
  - 0.74
  - 0.46
- CAU:
Effectiveness & Advances

• Demonstrated reduction in patient doses
  – Even without extensive analysis
• Seamlessly satisfy recording requirements
• Management of doses, equipment, training
• Endless PQI possibilities

• Development of Real-Time Dose Monitoring
  – Fluoroscopy
  – Real-time integration & body mapping of fields using RDSR
Real-Time Skin Dose Mapping

- RDSR – Radiation Dose Structured Report
- Collaboration with UF, UF Health Jacksonville and Columbia University Medical Center in NYC
- PI: Wesley Bolch, Ph.D.
The cumulative dose incidence map provides:

13%  a. A planar representation of the surface air kerma distribution

20%  b. A summary of the DAP per study

23%  c. A visualization of cumulative organ doses through the body

13%  d. The variation of a facility's cumulative delivered dose over time

30%  e. A correlation of the number of studies performed with cumulative dose
Answer: a. a planar representation of the surface air kerma distribution.

Ref: Manufacturer Websites listed at end of presentation
Summary

• Evolving Industry
  – Expect increasing numbers & advanced capabilities
• Products are readily customized to users needs
• Patient population or individual based applications
• Valuable QA tools
• Support regulatory focus & compliance
• Dose metrics not uniform across modality
  – Unavailable for legacy equipment
  – Integration of patient dose ?
• Integrate with other systems (PACS, EMR, RIS, HIS...)
• Difficult to track across health care systems
References

- The Joint Commission: Prepublication Standards: Diagnostic Imaging Services Requirements ; Provision of Care, Treatment, and Services, Dec 2013.
- 2014 Ambulatory Care, Critical Access Hospital, and Hospital Comprehensive Accreditation Manual – March 2014.
Commercial Product Web-Sites and Descriptions

- http://www.dosemonitor.com/
- http://www.radimetrics.com/
- http://www.sectra.com/medical/
- http://www.primordialdesign.com/
- http://medphys360.com