Dose Monitoring Fundamentals: Card Cath, IR, Nuc Med, CT, Gen or Mobile Fluoro, Direct Radiography

Keith J. Strauss, MSc, FAAPM, FACR
Clinical Imaging Physicist
Cincinnati Children’s Hospital Medical Center
Associate Professor
University of Cincinnati School of Medicine
Dose Monitoring Fundamentals

- Goals
- Requirements
- Radiation Risk
- Dose Metrics
- Challenges
Goals

- Improve performance across population of patients
  - Maintain/Improve image quality
  - Manage ( Increase/reduce) patient doses
- Comparison of results to:
  - DRLs
  - DRRs
Goals

- Diagnostic Reference Range (DRR)
  - Upper bound at 75\textsuperscript{th} percentile (DRL)
  - Lower bound at 25\textsuperscript{th} percentile

- Image quality of numerous studies evaluated by 6 pediatric radiologists
  - Unacceptable cases occurred in studies below the 25\textsuperscript{th} percentile of patient dose\textsuperscript{1}

\textsuperscript{1}Goske MJ, et. al. “... Abdominal ...”, Radiology. 2013 Jul;268(1):208-18

Strauss, KJ, et. al. “... Chest ...”, Radiology. 2017 Feb 17:161530
Goals

- Tied to departmental
  - QA procedures
  - QC procedures
Goals

- Improve care for individual patient
  - Justification of each study involving ionizing radiation
  - Alter planned approach of ‘heavy’ dose examination based on patient’s exam history
    - Alter skin ports used.
    - Alter duration skin ports with significant radiation history are used for upcoming exam.
Requirements

● National
  ● The Joint Commission 2015
    ● Patient radiation doses during
      ▪ CT
      ▪ Nuclear Medicine

Studies must be tracked, reviewed, and followed up.
Data placed in medical record.
Requirements

● **State**
  ● California: Enter into patient’s medical record
    ● CT: CTDI$_{vol}$ and DLP
  ● Texas
    ▪ CT: Skin dose
    ▪ Fluoro: Skin dose
  ● Ohio: Future fluoro skin dose requirements
Risks

● **Stochastic**

  ● Cancer induction
    ● Risk of the 30\textsuperscript{th} head CT (50 mGy) for the same patient is no greater than risk for 1\textsuperscript{st} head CT.
    ● PROVIDED the 30\textsuperscript{th} head CT is properly justified, there is no reason it should be discouraged or denied.

  ● A comprehensive dose monitoring program is not required to properly track this concern!
Risks

- **Deterministic**
  - (tissue effects) skin erythema or worse
  - > 2,000 mGy threshold for single exam
    - CT perfusion studies
    - Complex Interventional Procedure
Risks

- **Deterministic**
  - Cumulative effect from multiple exams
    - 60 head CTs at 50 mGy each spread over time should not result in erythema
      - Doses add, but not arithmetically
        - $5 + 5 + 5 < 15$
    - Multiple skin ports on patient’s back result in a maximum skin dose $<<$ cumulative dose for the exam
      - Peak Skin Dose
Risks

- *Deterministic*
  - Cumulative effect from multiple exams
  - Be cautious
    - Peak Skin Dose ~ Cumulative exam dose
    - Someone else may have contributed to the patient’s radiation history!
      - Tipping point dose << Threshold dose
Dose Data Base Systems

- Numerous different systems available
  - DoseMonitor (PACS Health)
  - DoseTrack (Spectra)
  - DoseWatch (GE)
  - RADAR360 (MedPhys360)
  - Radimetrics/eXposure
  - PEMNET (Clinical MicroSystems)
Dose Metrics

- Dose index of choice must reside in the Radiation Dose Structured Report Available on all new equipment
  - Eliminates proprietary issues between different vendors of imaging equipment
  - Should be compatible for all patient dose Monitoring Systems
Dose Metrics

- **Air Kerma (AK) mGy**
  - Formally skin exposure (Roentgens)
  - Not applicable to:
    - CT
    - DR (applicable, but typically not provided)
    - Nuc Med
Dose Metrics

- **Kerma Area Product (KAP) \( \mu \text{Gy} \cdot \text{m}^2 \)**
  - Air Kerma at the entrance plane of the patient multiplied by the area of the x-ray beam at same plane
  - Not applicable to:
    - CT
    - Nuc Med
Dose Metrics

- **Size Specific Dose Estimate (SSDE) mGy**
  - Estimate of the average dose to the patient’s anatomy at the center slice along the scan length (z direction) during a CT exam of the patient’s trunk
  - Applies to CT scanning only
    - Currently not defined for heads—this will change soon
    - IEC Standard being created to result in SSDE display on all future CT scanners for heads and trunk exams!
Dose Metrics

- Critical Organ Dose (mGy)
  - Estimate of the dose to the patient’s organ receiving the largest dose from an injection of a radiopharmaceutical
  - Applies to Nuclear Medicine scanning only
Dose Metrics

- **Exposure Index (EI number)**
  - Dose index of the radiation dose received by the patient during Direct Radiography
  - Applies to DR imaging only
  - Is dependent on:
    - Radiation output of x-ray unit
    - Region of anatomy imaged
    - Selected image processing
Challenges

- Accuracy of displayed dose indices
  - AK and KAP: $\pm 35\%$ from manufacturer
  - QMP should calibrate all displays of AK and KAP
  - These units are not accurate, but are consistent
    - Dose displays maintain their accuracy over time or completely fail
  - QMP can provide correction factor for AK or KAP display which should be accurate to $\pm 10\%$
    - TG190 published by AAPM for physicists to follow
Challenges

- Consistency Between Vendors
  - Units of KAP are confusing
    - IEC: Gy·cm$^2$
    - Gy·mm$^2 = $ Gy·cm$^2 \times 100$
    - **Displays:** Gy·mm$^2 = \mu$Gy·m$^2 = $ cGy·cm$^2$
    - Oddball Display: mGy·cm$^2$?

- mGy·cm$^2 \times 10 = $ Gy·mm$^2 = \mu$Gy·m$^2$
Challenges

- CTDI\textsubscript{vol} and DLP
  - Both of these dose indices are doses to \textit{standardized phantoms}
  - We want doses to patients of multiple sizes
  - CTDI head and body standardized phantoms crudely model an adult head and an adult body
    - Error assuming CTDI is an adult patient dose is small
    - Assuming CTDI is a pediatric patient dose \textit{under-estimates} small patient dose by up to 250%!
Challenges

- Setting up a comprehensive dose data base system is not trivial
  - Time consuming
- Collecting the data is just the first step
- Data requires analysis to be useful
  - Annual Sample Sizes:
    - ~ 12,000 CT exams
    - < 10,000 IR & Cath exams
    - ~ 15,000 General Fluoroscopic
    - ~ 150,000 DR exams
Challenges

- Effectively using data
  - Large Quantity of data
  - Analytics needed for effective analysis
  - Incorporating into QA and QC program identification of problems
    - Operator
    - Imaging equipment
    - Appropriateness of standards within department
Conclusions

- Comprehensive Dose Monitoring program can positively impact patient care
- Implementation is not trivial
- Ongoing use requires careful management
  - Just because something can be done does not mean it should be done!