Image Gently, Pause and Pulse: Practice of ALARA in Pediatric Fluoroscopy

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ALARA

“**As Low As Reasonably Achievable**”

- General principle guiding radiation exposure
- Keep exposure to radiation dose as low as is possible for each procedure, while obtaining needed clinical information
  - = Image Optimization
Primary Learning Objective

- Review pediatric fluoroscopic procedures
  - understand the source of radiation
  - understand methods to reduce radiation
  - effect on image quality
Other Learning Objectives

- Fluoroscopy radiation units.
- Scope of pediatric fluoroscopic procedures
- Methods available for dose reduction
- Clinical settings to apply dose reduction
Fluoroscopy Radiation Units

Basic Radiation Quantities:

- Exposure & Exposure Rate
- Air Kerma & Air Kerma Rate
Fluoroscopy Radiation Units

Radiation Measurement Quantities:

- Incident Air Kerma & Rate
- Entrance Surface Air Kerma & Rate
Fluoroscopy Radiation Units

Risk Related Quantities:

- Absorbed dose
- Equivalent Dose
- Effective dose
Basic Radiation Quantities

- Exposure – expresses intensity of x-ray energy *per unit mass of air*.
  
  Units: Coulomb per kilogram (C/kg).
  Commonly used units are Roentgen or milli Roentgen, expressed as R or mR, respectively.
  
  \[
  1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}
  \]

- Exposure rate identifies x-ray intensity per unit time.
  Commonly used units are R/min or mR/min.
Air Kerma (K) – sum of initial kinetic energies of all charged particles generated by uncharged particles such as x-ray photons released per unit mass of air. Unit = Joule per kilogram, Commonly referred to as Gray/milli Gray (Gy or mGy).

1 Roentgen of exposure $\approx$ 8.7 mGy air kerma

Air Kerma Rate quantifies air kerma per unit time and is written as, $dK/dt$, that is, incremental kerma per unit increment of time.
Measurement Quantities

- Incident Air Kerma ($K_{a,i}$) – is the air kerma from the incident beam along the central x-ray beam axis at the skin entrance plane.

- Only the primary beam is considered and the effect of back scattered radiation is excluded.

  Unit = Joule per kilogram, Commonly referred to as Gray/milli Gray (Gy or mGy).

  Incident Air Kerma Rate quantifies air kerma per unit time. It is usually measured as mGy/min.
Measurement Quantities

- **Entrance Surface Air Kerma** \( (K_{a,e}) \) –
  
  It is the air kerma from the incident beam along the central x-ray beam axis at the point where radiation enters the patient and the effect of back scattered radiation is included.

  Given as \( K_{a,e} = K_{a,i} \times B \)

  \( B = \) Back Scatter Factor.

  Unit = Joule per kilogram, Commonly referred to as Gray & milli Gray (Gy or mGy).

  Incident Air Kerma Rate quantifies air kerma per unit time.
Absorbed dose – energy deposited per unit mass of a material, in our case, within tissue.

- Initially measured as rads
- Current unit based on Systeme Internationale (SI unit)

SI Unit of Absorbed Dose = Gray

- 1Gray (Gy) = 100 rad
- 1rad = 10 mGy
Risk Related Quantities

- Dose Equivalent – accounts for biological effect of type of radiation
  - For example, difference in biological effect between
    - $\alpha$, $\beta$, and $\gamma$ radiation
  - Radiation Weighting factor ($w_R$) – scaling factor used
    - $\gamma$, Xray $w_R = 1$
    - $\alpha$ ($w_R$) = 20

- SI Unit is Sievert
  - 1 Sievert (Sv) = 100 rem
  - 1 rem = 10 mSv
Risk Related Quantities

- Effective dose – accounts for radio-sensitivity of specific organs
  - Includes
    - A tissue weighting factor (w_T) for each sensitive organ
    - Each tissue included in the clinical examination (H_T)
  - Effective dose = \( \sum w_T \times H_T \), (\( \sum \)) summed over all exposed organs.

- SI Unit is Sievert
  - 1 Sievert (Sv) = 100 rem
  - 1 rem = 10 mSv
# Background Radiation Exposure

<table>
<thead>
<tr>
<th>Non-Medical Radiation Source</th>
<th>Radiation Dose Estimate</th>
<th>Equivalent Amount Background Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural background radiation</td>
<td>3 mSv</td>
<td>3mSv/year*</td>
</tr>
<tr>
<td>Airline passenger (cross-country)</td>
<td>0.04 mSv</td>
<td>4 days</td>
</tr>
</tbody>
</table>

* = estimate at sea level in US
## Medical Radiation Exposures

<table>
<thead>
<tr>
<th>Medical Radiation Source</th>
<th>Radiation Dose Estimate</th>
<th>Equivalent Amount Background Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest x-ray</td>
<td>0.1 mSv</td>
<td>10 days</td>
</tr>
<tr>
<td>Urinary tract fluoroscopy (VCUG)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Mode*</td>
<td>0.45 – 0.59 mSv</td>
<td>2 months</td>
</tr>
<tr>
<td>Optimized fluoroscope*</td>
<td>0.05 – 0.07 mSv</td>
<td>1 week</td>
</tr>
</tbody>
</table>

* Ward et al Radiology 2008;249:1002
Practical Methods to Reduce Radiation Dose to Fluoroscopy Staff & Patients
Staff Protection
Reduce Radiation Dose: Staff

- Staff dose is due to scattered radiation.
- Scattered radiation is directly proportional to Patient Dose.

\[ \text{Patient Dose} \rightarrow \text{Staff Dose} \]
Staff Protection

- Well fitted lead apron (knees)
- Leaded glasses (with sides)
- Thyroid shield
- Lead gloves
Staff protection: Hand

- Keep hands out of the beam
- Collimate
Staff protection: Shields

- Lead shield on tower
- Do not turn your back to X-ray beam if wearing front apron only
In summary: Have we:

- ... left our hands in the beam?
- ... sacrificed personal safety for expediency?
- ... turned our unshielded backs to the X-ray source?
- ... unnecessarily prolonged exposure?
- ... pushed away a protective barrier?
Patient Protection
Radiation dose is *optimized* when we use

- Least amount of radiation
  - That delivers clinically adequate image quality
Patient Positioning

- Proper patient positioning
  - Make use of Inverse square law!
  - Maximize distance between x-ray tube & patient
  - Minimize distance between patient & Image Intensifier
Control Fluoroscopic Exposures

- Choose pulsed fluoroscopy
- Choose as short a pulse width as possible
  - Typically 5 – 10 msec pulse width
Control Fluoroscopic Exposures

- Continuous fluoroscopy
  - 30 pulses per second
  - 33 msec pulse width

- Grid-controlled fluoroscopy
  - e.g. 15 pulses / sec
  - 10 msec pulse width
Control Fluoroscopic Exposures

- Increase filtration to reduce patient radiation dose
  - Balanced by need for shorter pulse widths to freeze motion

- Interposition of Aluminum and variable thickness of Copper

- Removes low energy radiation that does not reach the image intensifier
  - scattered within the patient
  - adds radiation dose
  - does not contribute to image
Control Fluoroscopic Exposures

● Remove anti-scatter grid whenever possible
  ● Removes scattered radiation
    ● Increased radiation dose
    ● Not necessary in small patients

● Avoid unnecessary magnification
Control Fluoroscopic Exposures

- Collimate to area of interest
- No need to radiate tissue that is not clinically pertinent
Control Fluoroscopic Exposures

● Use “last image hold”
  ● Whenever you need to inspect the anatomy, and do not need to observe motion or changes with time

● Use Fluoroscopy Store (FS)
  ● this method is ideal to convey and record motion, such as peristalsis, or show viscus distensibility, as in esophagram
  ● when you need information without excessive detail

[Images: Fluoro-grab and Exposure]
Control Number of Images

- Choose appropriate, patient-specific technique

- Limit acquisition to what is essential for diagnosis and documentation
  - PAUSE – Plan study ahead
  - PAUSE – think # frames / second
  - PAUSE – think magnification
  - PAUSE – think Last Image Hold
  - PAUSE – think Image Grab
Control Fluoroscopic Use

- Use fluoroscopic examination when there is a clear medical benefit.

- Use alternative imaging methods whenever possible
  - US
  - MRI
Special Pediatric Considerations

- Pediatric patient management more critical
  - Increased radio-sensitivity, small size, longevity.

- Pediatric size
  - Smaller patient leads to less scattered radiation
  - There is an increased need for magnification
Institutional Strategies to Optimize Radiation Exposure Fluoroscopy
To Start:

- An in-house diagnostic medical physicist in pediatric hospitals is optimal.
- The physicist **must** have proper training and background in Medical Physics, such as CAMPEP accredited graduate **and** residency programs.
- Proper training is key
To Start:

An Image Management committee, comprised of radiologists, technologists, administrators and medical physicists, under the direction of the department Chair, can be very helpful.

- Responsible for optimizing radiation procedures.
- Oversee the departmental QA/QC program.
- Meet criteria for accreditation, e.g. ACR
To Start:

- Oversee purchase of capital equipment and periodic hardware and software upgrades.
- Staff training on state of the art technologies.
  - Technologists, radiologists
  - Equipment, safety, physics, radiation biology
- Compliance with applicable state and federal regulations.
Dosimetry Records

- Manage fluoroscopy parameters
  - e.g., pulsed fluoroscopy, pulse rate, removable grid
- Record information related to patient radiation dose as displayed by the equipment:
  - Cumulative Dose Area Product.
  - Cumulative Air kerma/Skin Dose.
Summary

- **PAUSE** to properly plan and prepare for study
- **Activate** dose saving features of equipment
- **No** image exposures unless necessary
- **Download** image grab instead
- **PULSE** at lowest possible rate
References


