medical informatics and patient dose management with FGI

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Opportunities

- Paper/electronic logs: Fluoro time, $K_{a,r}$ and $P_{KA}$
- Procedures of ‘interest’ not communicated
- Tedious calculations for PSD
- Physicists lack procedure/equipment use knowledge
- Need Procedure Specific PSD/ $K_{a,r}$
- Need Physician Procedure Data
- Need FGI ALARA Program
- Need multi-episode PSD

Educational Objectives

- Describe Informatics based tools for peak skin dose monitoring with FGI
- Understand how the use of Informatics can assist with Clinical Medical Physics activities:
  - Meet Regulatory and Accrediting Agency requirements
  - Assist with Physician QA Goals
  - Monitor of FGI ALARA Practices
- Use DMAIC for data driven Dose related QA

CONCLUSION

...All medical radiation doses should be tracked and considered to determine if an increased deterministic risk exists.
**DMAIC ‘Basis of Six Sigma’**

"duh-may-ick"

- **Define** – metric or goal (i.e. limit prob of skin damage)
- **Measure** – ‘peak skin dose’ (using Informatics)
- **Analyze** – Cause and Effect relationships (i.e. complex procedure, too high technique, steep angles, etc.)
- **Improve** – optimize protocol (specific ALARA protocol settings, announce dose levels, physician education)
- **Control** – use process controls (Control Charts)

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**Informatics/DMAIC Approach to PSD Management**

- **D** Define the goal and metrics
- **M** Simulate patient/equipment environments
- **M** Model for PSD calculation
- **A** Analysis of Results
- **I** Improvement (ALARA Program)
- **C** QA Monitoring ‘shine a light’ *

* Timely data are more likely to be acted upon!

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**Define ‘Peak’ Skin Dose**

- $D_{\text{skin,max}}$ – the most highly-irradiated skin region

Compute $D_{\text{skin}}$ from $K_{a,r}$:

- Validated Vendor $K_{a,r}$
- Backscatter
- Mass-energy absorption coefficient ratio $\text{tissue:air}$

* Table and pad attenuation
* Equipment/patient specific information
* Account for locations of the x-ray beam/patient
* Actual source-skin entrance distances
C-arm Reference Point Location

- $K_{a,r}$ – total air kerma at the reference point
- 15 cm from isocenter toward x-ray tube
- Reference point ~ patient’s entrance surface

Getting Information! – $K_{a,r}$ Is KEY!

- Images only show limited portion of $K_{a,r}$
- May not be transferred to PACs
- **Need cumulative $K_{a,r}$**
  - Exam Protocol
  - Dose Report
  - Manual entry (several vendors)
- Equipment after 2006 has $K_{a,r}$
- DICOM Radiation Dose SR is ‘emerging’!

DICOM Radiation Dose SR

<table>
<thead>
<tr>
<th>Tag (Group, Element)</th>
<th>NAME</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0040,A730-0040,A300-0040,A30A</td>
<td>Fluoro Dose Area Product Total (Gy/m²)</td>
<td>0.00614</td>
</tr>
<tr>
<td>0040,A730-0040,A300-0040,A30A</td>
<td>Fluoro Dose (RP) Total</td>
<td>0.2267</td>
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<tr>
<td>0040,A730-0040,A300-0040,A30A</td>
<td>Total Fluoro Time(s)</td>
<td>2504</td>
</tr>
<tr>
<td>0040,A730-0040,A300-0040,A30A</td>
<td>Acquisition Dose Area Product Total (Gy/m²)</td>
<td>0.00624</td>
</tr>
<tr>
<td>0040,A730-0040,A300-0040,A30A</td>
<td>Acquisition Dose (RP) Total</td>
<td>0.2564</td>
</tr>
<tr>
<td>0040,A730-0040,A730-0040,A124</td>
<td>Irradiation Event UID</td>
<td>1.2556.8268.402.1200...</td>
</tr>
<tr>
<td>0008,1030</td>
<td>Performing Physician’s Name</td>
<td>Physician</td>
</tr>
</tbody>
</table>
DICOM RD SR
Patient having 287 separate ‘events’

Simple Geometry or assume $K_{a,r}$ is > PSD

$K_{a,r} = 5$ Gy
Machine correction = 0.85
BSF = 1.4
Tissue/Air = 1.06
Ref Pt/Skin = '0'
Table/Pad = 0.7
PSD = 4.4 Gy

Both Fluoro AND Acquisitions needed!
Dosimetry: Virtual (reference) Patients

Patient: Supine, Head First

Dosimetry: Virtual Equipment

Patient: Prone
Patient: Supine, Feet First

Patient: Right Side

Patient: Left Side

C-Arm Primary Angle (+)
C-Arm Primary Angle (−)

C-Arm Secondary Angle (+)

C-Arm Secondary Angle (−)

Table Lateral – “Image Context”
A point calculation of air kerma to a 0.01×0.01m² radiated region

Square shape field of view

With three points on each triangle face, we can construct the four faces of the pyramid such as \( Ax + By + Cz = D \), where \( A, B, C, D \) are coefficients. As an example, for the plane consisting of sources \( (x_{c1}, y_{c1}, z_{c1}) \) and \( (x_{c4}, y_{c4}, z_{c4}) \), coefficients of plane are as follows,

\[
A = y_{Spot} \times (z_{Spot} - z_{c4}) + z_{Spot} \times (x_{Spot} - x_{c4}) + x_{Spot} \times (y_{Spot} - y_{c4})
\]

\[
B = z_{Spot} \times (x_{Spot} - x_{c4}) + x_{Spot} \times (y_{Spot} - y_{c4}) + y_{Spot} \times (z_{Spot} - z_{c4})
\]

\[
C = x_{Spot} \times (y_{Spot} - y_{c4}) + y_{Spot} \times (z_{Spot} - z_{c4}) + z_{Spot} \times (x_{Spot} - x_{c4})
\]

\[
D = -x_{Spot} \times y_{Spot} \times z_{Spot} + x_{Spot} \times y_{Spot} \times z_{c4} + y_{Spot} \times z_{Spot} \times x_{c4} + z_{Spot} \times x_{Spot} \times y_{c4} - x_{Spot} \times y_{Spot} \times z_{c4} - y_{Spot} \times z_{Spot} \times x_{c4} - z_{Spot} \times x_{Spot} \times y_{c4} + x_{Spot} \times y_{Spot} \times z_{c4} + y_{Spot} \times z_{Spot} \times x_{c4} + z_{Spot} \times x_{Spot} \times y_{c4}
\]

Compute: Dose to each 1 cm² point in defined region
Sort $D_{\text{skin}}$ - 'define' Peak Skin Dose

Table:

<table>
<thead>
<tr>
<th>ID</th>
<th>Gender</th>
<th>Procedure</th>
<th>KAP air kerma (cm²)</th>
<th>Number of scans</th>
<th>Number of Fluoro</th>
<th>Peak skin dose</th>
<th>Total area radiated (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>f</td>
<td>IR Emobilization (non-Neuro)</td>
<td>245.7</td>
<td>180</td>
<td>162</td>
<td>4.3 Gy</td>
<td>1068</td>
</tr>
</tbody>
</table>

Analysis: Why would PSD be $> K_{\text{air}}$?
Skin Dose ‘angled views and patient size’

Analysis: FGI Protocols (need standardization)

<table>
<thead>
<tr>
<th>IR Unit 1</th>
<th>IR Unit 2</th>
<th>IR Unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vas Upper Extremities</td>
<td>Vas Mesenteric</td>
<td>Aorta</td>
</tr>
<tr>
<td>Vas Pelvis</td>
<td>Vas Upper Extremity</td>
<td>Mesenteric</td>
</tr>
<tr>
<td>Renal</td>
<td>Lower Extremity</td>
<td>Vas Mesenteric</td>
</tr>
<tr>
<td>Vas Renal</td>
<td>Vas Lower Extremity</td>
<td>Chemo Embolo</td>
</tr>
<tr>
<td>IVC</td>
<td>Renal</td>
<td>Renal</td>
</tr>
<tr>
<td>Vas IVC</td>
<td>Vas Renal</td>
<td>Vas Renal</td>
</tr>
<tr>
<td>CO₂ / Gad</td>
<td>DSA</td>
<td>IVC</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>TIPS</td>
<td>Vas IVC</td>
</tr>
<tr>
<td>Vas Pulmonary</td>
<td>Fistulogram</td>
<td>CO₂ / Gadlo</td>
</tr>
<tr>
<td>Neuro</td>
<td>Vas Fistulogram</td>
<td>Perivision</td>
</tr>
<tr>
<td>Vertebroplasty</td>
<td>Tube Check</td>
<td>Vas Pelvis</td>
</tr>
<tr>
<td>Perc Neph Dyna</td>
<td>IVC</td>
<td>Perivision</td>
</tr>
<tr>
<td>Endoleaks Dyna</td>
<td>Vas IVC</td>
<td>Vas Perivision</td>
</tr>
<tr>
<td>DynaCT Body</td>
<td>PICC Line</td>
<td>Singel Lag</td>
</tr>
<tr>
<td>InfSpace 3D</td>
<td>Catheter Placement</td>
<td>Vas Single Lag</td>
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<tr>
<td>DynaCT Head</td>
<td>Tube Placement</td>
<td>General Dyna</td>
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<tr>
<td>Cardiac</td>
<td>Vertebroplasty</td>
<td>Vertebroplasty</td>
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<td>Cardiac OLD</td>
<td>Vertebroplasty</td>
<td>Vertebroplasty</td>
</tr>
<tr>
<td>2D/3D Cellb</td>
<td>BILATERAL PEPI</td>
<td>Pho’s Testing</td>
</tr>
</tbody>
</table>

Poor Protocol: High DSA and Fluoro Rate
**DMAIC: Physician Report – Shine a Light!**

**Take Aways!**

- Logs: Fluoro time, $K_{a,r}$ and $P_{KA}$
- Communicate procedures of ‘interest’
- Tedious calculations for PSD – new tools!
- Gain knowledge of procedures/equipment
- Analyze: Protocol/Patient Specific $K_{a,r}$/PSD
- Need multi-episode $K_{a,r}$
- Need Physician Specific $K_{a,r}$
- Need FGI ALARA Program!

**Team Members and I ‘Thank you’!**