Learning Objectives

- Review of available dosimetric indications
- Real-time skin dose maps
- Managing radiation dose during a procedure
- Managing radiation dose after a procedure

**The Past | FLUOROSCOPY TIME**

<table>
<thead>
<tr>
<th>Inadequate Estimation of Radiation Exposure</th>
<th>30 Minutes</th>
<th>15 Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Weight: 70 kg</td>
<td>2x</td>
<td>Patient Weight: 100 kg</td>
</tr>
<tr>
<td>Frame Rate: 7.5 fps</td>
<td>10x</td>
<td>Frame Rate: 15 fps</td>
</tr>
<tr>
<td>Cine Frames: 50</td>
<td>2x</td>
<td>Cine Frames: 200</td>
</tr>
<tr>
<td>Cumulative Air Kerma (mGy): 250</td>
<td>4x</td>
<td>Cumulative Air Kerma (mGy): 3750</td>
</tr>
<tr>
<td></td>
<td>15x</td>
<td></td>
</tr>
</tbody>
</table>
A Look at the Data | NCRP REPORT 168*

(A) 2,100 Non-Cardiac
AK = 0.41 + 0.037 x FT; R² = 0.50

(B) 1,700 Coronary-Artery Procedures
AK = 0.53 + 0.12 x FT; R² = 0.68


Because fluoroscopy time is such a poor indicator of radiation dose, its use is generally discouraged... in favor of alternative dose measures.

An order of magnitude variability observed across most fluoroscopy times!

The Present | AIR KERMA (...AND DAP)

Better Estimation of Radiation Exposure

<table>
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<th>15 Minutes</th>
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<td>Patient Weight: 70 kg</td>
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Dose Metrics | AIR KERMA AND DAP

- Detector Exposure – R (Drives AERC)
- Organ Dose / Effective Dose – mSv (Patient Dose)
- Peak Skin Dose (PSD) – mGy (Patient Dose)
- Air Kerma at Reference Point* - mGy (Machine Output)
- Dose Area Product (DAP) – Gy cm² (Machine Output)

Patient Entrance Reference Point* = 15 cm from isocenter towards focus (IEC Standard)
Inverse Square Law: 60 cm vs 65 cm = 20%

Detector
X-ray Tube
Detector Exposure Reference Point* = 15 cm from isocenter towards focus (IEC Standard)
Inverse Square Law: 60 cm vs 65 cm = 20%
What's Missing?

- No Source-to-Skin Distance Corrections
- No Spatial Information (Dose Summed as if it occurred at a Single Point in Space, No Examiner Adjustment Included)
- Dose to Air, Not Dose to Tissue (No Patient Support Attenuation/Scatter, Tissue Absorption Factor, Backscatter)
- Individual Variability Reduced to a Factor of ~2x
- No Source Information

Dose Metrics | MORE RECENT ADVANCEMENTS

- IEC:2010 recommends a visual warning when RAK exceeds a (configurable) threshold expected to produce a skin injury
- Multiple Implementations of Air Kerma(+) "Maps"

- IEC:2018 recommends a dose map

Transition Towards Meaningful Dose Information

- Reference Air Kerma (Dose To Air at Reference Location)
- Real-Time Patient Dose Tracking System (DTS) (Estimated Skin Dose on Patient Graphic)
DTS | VALIDATION

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DTS | VALIDATION – EXAMPLE RESULTS*

*VK Rana et al, “A tracking system to calculate patient skin dose in real-time during neurointerventional procedures using a biplane x-ray imaging system,” Med Phys 43(9), 5131-5144 (2016)

*Bednarek et al, “Verification of the performance accuracy of a real-time skin-dose tracking system for interventional fluoroscopy procedures” SPIE 796127-1 (2011)

DTS | ON SITE CALIBRATION

➢ 5 Beam Filters
➢ 50 to 120 kV
➢ Fluoroscopy and Radiographic Modes
➢ LUTs Used for Rest (FOV, Head v Body, etc.)

*Typical Accuracy ± 20% With Careful Matching of Patient Graphic with Actual Patient (Geometry ± 5%)

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DTS | PATIENT MODELS AND POSITIONING

*Skin dose to arms is of secondary value due to smaller body part thickness and variability in position on patient support.

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DTS | BIPLANE CONFIGURATIONS
DTS | BODY VERSUS HEAD

Body Backscatter Factor

Head Backscatter Factor (0.80 – 0.85)

DTS | REAL-TIME

Exam Room Display
**DTS | REPORTING**

- Local Storage of 2D and 3D Maps
- Export to: USB; Windows Networked Drive; External Server via FTP

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**DTS | MULTIPLE PROCEDURES**

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**Real-Time Dose Monitoring | STAFF**

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Clinical Dose Optimization

[Diagram showing dose rate and clinical dose optimization]

Clinical Dose Optimization

[Another diagram showing dose rate and different settings]

Canon

Debraite
A CASE REPORT

➢ 46 Year Old Male
➢ FGI: Cerebral angio with transvenous coil and glue embolization
➢ Procedure Time: 150 minutes
➢ Exposure Time: 67 minutes
➢ Peak Skin Dose: 2.9 Gy
➢ Two weeks: nonscarring alopecia
➢ Four months: complete hair regrowth

Dose Management | DURING A PROCEDURE

➢ 6 months pre / post DTS display in exam room
➢ 16 operators free to choose all imaging parameters
➢ 1,077 consecutive procedures

Next Generation Dose Reduction Technologies
**Dose Management | DURING A PROCEDURE**

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Procedure Descriptions</th>
<th>Total Cases</th>
<th>&gt; 1 Gy</th>
<th>&gt; 2 Gy</th>
<th>&gt; 3 Gy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoro</td>
<td>New obliteration closure</td>
<td>146</td>
<td>16</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Fluoro</td>
<td>New obliteration repair</td>
<td>65</td>
<td>10</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Sclerotherapy</td>
<td>Stent</td>
<td>6</td>
<td>9</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sclerotherapy</td>
<td>Compression</td>
<td>47</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

All Sclerotherapy Procedures: 140 cases, 106 > 1 Gy, 58 > 2 Gy, 24 > 3 Gy

Table 1: Comparison of PTVs with Fluoro

Area of overlap avoided

State of Practice: 1 in 5 exceed threshold dose
Study Population: <1 in 100 exceed threshold dose

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**Dose Management | POST PROCEDURE**

- Compare to state-of-practice data
- DICOM RDSR is most effective for monitoring and managing clinical radiation dose levels post procedure.
- Monitor to understand actual results with clinical use.

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**Dose Management | POST PROCEDURE**

- MONTH 1
- MONTH 2
- MONTH 3
- MONTH 6

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**Dose Management | POST PROCEDURE**

- MONTH 6

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**Dose Management | POST PROCEDURE**

- MONTH 6
Dose Management | POST PROCEDURE

Summary | KEY LEARNING POINTS

➢ Fluoro Time < Air Kerma < Peak Skin Dose
➢ Skin dose estimates need to include backscatter, patient support attenuation/scatter, field size, beam angulation, etc.
➢ Real-time skin dose maps empower the operator to better manage patient dose
➢ DICOM RDSR is an effective tool for monitoring and managing clinical radiation dose levels

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