Fluoroscopy Dose Management: Trials, Tribulations, & Successes

Experiences with Homegrown, Non-commercial Solutions

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The MetroHealth System, Cleveland Ohio
Homebrewed Solutions

Fluoroscopy Dose Tracking

• Implementing a dose tracking system can be very expensive
  • Time – DIY
  • Money – Commercial Product
• Costs can depend on the size and complexity of the healthcare system
• Skillset can be beyond that of a typical physicist
• Ultimately can build the best solution for your individual needs
Homebrewed Solutions

Fluoroscopy Dose Tracking

I’ve spent the last 10+ years of my career working on fluoroscopy dose tracking systems and polices, but never with a commercial product.

These systems have ranged from very basic
I’ve spent the last 10+ years of my career working on fluoroscopy dose tracking systems and polices, but never with a commercial product. These systems have ranged from very basic to much more advanced.
Chapter 1: In the beginning...
Initially started at Shands Hospital at the University of Florida as a graduate student then resident from 2009 through the end of 2012

- Joint Commission Sentinel Event added ~ 2005
  - “Peak Skin Dose” summed over 6 – 12 months
  - PSD not reported by equipment
  - Onboard dose meters & RDSRs not widespread
- NCRP Report No. 168 published in 2010
Fluoroscopy Dose Tracking

- Relatively small operation all at one physical location
  - Interventional Radiology only, initially 4 suites, expanded to 6
  - Several suites initially had no onboard dose monitors

- Simple Excel based system relied on technologists manually recording $K_{a,r}$, fluoro time, # of runs, and table height & physicists tracking over time

- Policy set patient levels based on cumulative air kerma:
  - Level 1: > 3 Gy
  - Level 2: > 6 Gy
  - Level 3: > 9 Gy

- Physicists would estimate PSD for every case/patient above Level 2
  - Manually calculated cumulative dose
  - Labor intensive, but had grad students and later residents to handle day to day
# Dose Meter Calculations

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<th>Meter Based Calculation</th>
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<tr>
<td><strong>Room</strong></td>
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<tr>
<td>* Input '1' for AR1, '2' for AR2</td>
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<table>
<thead>
<tr>
<th>Meter input</th>
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<tr>
<td><strong>Total Air Kerma</strong></td>
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<tr>
<td><strong>frontal</strong></td>
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<tr>
<td><strong>lateral</strong></td>
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<table>
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<tr>
<th>Adjusted Doses</th>
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<td><strong>Frontal Dose (Gy)</strong></td>
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<td><strong>Lateral Dose (Gy)</strong></td>
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<tr>
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<th>AR1</th>
<th>AR2</th>
<th>Room 11</th>
<th>Room 12</th>
<th>Room 13</th>
<th>Room 16</th>
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<th>(cm)</th>
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<td>Distance to skin surface</td>
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<th>Name</th>
<th>Exams</th>
<th>Estimated Peak Dose (Gy)</th>
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<td>up to date</td>
<td>123456</td>
<td>Ringo</td>
<td>8/21/2012, 8/23, 11/15, 12/13</td>
<td>11.3 Gy</td>
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<tr>
<td>up to date</td>
<td>123456</td>
<td>George</td>
<td>11/15</td>
<td>4 Gy</td>
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<td>up to date</td>
<td>132456</td>
<td>John</td>
<td>11/17</td>
<td>5.5 Gy</td>
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<td>123456</td>
<td>Paul</td>
<td>11/19</td>
<td>2 Gy</td>
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<tr>
<td>up to date</td>
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<td>Ringo</td>
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<td>3.8 Gy</td>
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<td>125256</td>
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<td>Ringo</td>
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<td>11/30/2012, 12/3, 12/4, 12/5</td>
<td>6.6 Gy</td>
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<td>11/8</td>
<td>3.2 Gy</td>
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### Daily IR Scheduling Program

**Vascular and Interventional**

#### Interventional Radiology Daily Schedule - Visceral, Neuro, and Spine

**Schedule Date:** [ ]/2011  
**Submit Date:** [ ]

**Thursday, March [ ], 2011**

<table>
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<tr>
<th>Time</th>
<th>Case</th>
<th>Status</th>
<th>Type</th>
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<th>Neuro</th>
<th>Spine</th>
<th>Active</th>
<th>Cervical, Neuro, and Spine Cases</th>
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<tbody>
<tr>
<td>09:00</td>
<td>15</td>
<td>New Case</td>
<td>Visceral, Neuro, and Spine</td>
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<td>16</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Active</td>
<td></td>
</tr>
</tbody>
</table>

**Case Information**

- **Case 15:**  
  - Visceral: Yes  
  - Neuro: Yes  
  - Spine: No  
  - Active: Active  
  - **Visceral, Neuro, and Spine Cases:**
    - **Level 1 (6:10 AM - 6:07 PM):**
      - **Case 15:** New Case

- **Case 16:**  
  - Visceral: Yes  
  - Neuro: Yes  
  - Spine: No  
  - Active: Active  
  - **Visceral, Neuro, and Spine Cases:**
    - **Level 1 (6:10 AM - 6:07 PM):**
      - **Case 16:** New Case

- **Case 17:**  
  - Visceral: Yes  
  - Neuro: Yes  
  - Spine: No  
  - Active: Active  
  - **Visceral, Neuro, and Spine Cases:**
    - **Level 1 (6:10 AM - 6:07 PM):**
      - **Case 17:** New Case
Fluoroscopy Dose Tracking – Summary

Pros
- Relatively lo fi, but functional and manageable
- Room specific corrections along with table height = ability to calculate PSD
- Notifications on daily schedule

Cons
- Labor intensive, manual processes
- Not easily scalable
- IR only

Shands Hospital at University of Florida
Chapter 2: The pond gets much larger…
Cleveland Clinic Scope

Much larger healthcare system
- ~ 90 IR/Cath Labs
- ~ 200 R/F, Mobile C-arms, etc.
Spread across ~ 35 locations in multiple states
Cleveland Clinic Scope

Much larger healthcare system
• ~ 90 IR/Cath Labs
• ~ 200 R/F, Mobile C-arms, etc.
Spread across ~ 35 locations in multiple states

LOTS OF DATA
Previously handled via paper logs
• Meets regulatory requirement
• Cumulative doses challenging
• Commercial tracking system not an option
Transition to Electronic Logs

Radiology

Started in Radiology and worked with IT group to build data form within RIS using tech notes

- Patient info already within RIS so no entry required
- Utilized free text and dropdowns
- Eventually transitioned to RDSR entry for capable equipment
- Data sent to database accessible from the web
Trials and Tribulations

Radiology

- Training staff
Trials and Tribulations

Radiology

- Training staff
- Variations in unit reporting
  - Air kerma
Trials and Tribulations

Radiology

- Training staff
- Variations in unit reporting
  - Air kerma
  - AKAP

Ten orders of magnitude difference between Gy*m² and uGy*cm²!
Trials and Tribulations

Radiology

- Training staff
- Variations in unit reporting
  - Air kerma
  - AKAP
  - Time

1:48 case could be displayed as:

- 1:48
- 1.8 min
- 108 sec
- 108.5 sec
### Trials and Tribulations

**Radiology**

- Training staff
- Variations in unit reporting
  - Air kerma
  - AKAP
  - Time
- **Manual entry**
  - Clinical Engineering #
  - Operator Names
  - Dose & Time

---

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<thead>
<tr>
<th><strong>FLUOROSCOPIC SUMMARY INFORMATION:</strong></th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Total Air Kerma primary (A) plane (ME):</td>
<td>[Input]</td>
</tr>
<tr>
<td>Total Air Kerma A-plane units (ME):</td>
<td>[Input]</td>
</tr>
<tr>
<td>Total Air Kerma lat (B) plane (Biplane systems only)</td>
<td>[Input]</td>
</tr>
<tr>
<td>Fluoro Mode of Operation:</td>
<td>[Input]</td>
</tr>
<tr>
<td>Total Fluoroscopy Time Minutes (ME):</td>
<td>[Input]</td>
</tr>
<tr>
<td>Total Fluoroscopy Time Seconds (ME):</td>
<td>[Input]</td>
</tr>
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<td>Dose Area Product:</td>
<td>[Input]</td>
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<td>Dose Area Product units:</td>
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<td>Total Number of Acquisitions and Radiographs (ME):</td>
<td>[Input]</td>
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<td>Clinical Engineering ID# (ME):</td>
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<td>Primary Fluoroscope Operator Last Name (ME):</td>
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<td>Secondary Fluoroscope Operator First Name:</td>
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## CMS Payment Reduction

### Web-accessed Database

#### Fluoro Exam Log - QC By Facility

- **Facility:** Main - Imaging
- **Dept:** IR
- **Report Type:** Site QC: All Entries with Errors
- **Date Range:** 03/22/2017 - 03/22/2018

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<th>Dept</th>
<th>Facility</th>
<th>Exam Date</th>
<th>Accession</th>
<th>CE#</th>
<th>Equipment</th>
<th>Oper1 Last</th>
<th>Oper1 First</th>
<th>Oper2 Last</th>
<th>Oper2 First</th>
<th>Fluoro (sec)</th>
<th>AK APlane (mGy)</th>
<th>AK BPlane (mGy)</th>
<th>AKAP (mGy-cm)</th>
<th>APAloneClose</th>
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<tbody>
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<td>NAEEM SANA</td>
<td>FRUNER FRANK</td>
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<td>MC</td>
<td>MCA</td>
<td>Main - Imaging</td>
<td>202537</td>
<td>Siemens Artis Q</td>
<td>RAVIUN ALBERTS</td>
<td>RAVIUN ALBERTS</td>
<td>TRITTE BEN</td>
<td>30</td>
<td>2.2</td>
<td>0</td>
<td>2670.0</td>
<td>REPORTED</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Here are a bunch of entries with similar, but incorrect CE#s. Click the check box next to each entry, and the “Fix CE#” box will appear at the top of the column.
Efficient end user data cleanup

Equipment

Similar, but incorrect CE#s. entry, and the “Fix CE#” box.
The ability to batch corrections made a HUGE improvement in the efficiency of data clean up.
Longitudinal High Dose Patient Tracking

- System can sum $K_{a,r}$ over 6 month period based on patient MR #
  - Included all fluoroscopy across entire system
  - Built a high dose report view of data
  - Plans to include Rad Onc notification
  - Email notifications for patients over thresholds
  - Not able to split out by body region yet
Longitudinal High Dose Patient Tracking

Patient Total Dose Above 10Gy Detected: 1
Date Range: 12/12/2019 - 6/12/2020
With last exam within past 3 days.

<table>
<thead>
<tr>
<th>MPI</th>
<th>Patient Name</th>
<th>AirKerma Total</th>
<th>Exam Count</th>
<th>Last Exam</th>
<th>Status</th>
<th>Ph. Of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>13270.5</td>
<td>Ringo</td>
<td>5</td>
<td></td>
<td>6/11/2020 11:34:00 AM</td>
<td>Pending Review</td>
<td></td>
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</tbody>
</table>

High-Dose Exam Detected: 1

<table>
<thead>
<tr>
<th>Date</th>
<th>Hosp</th>
<th>Accession</th>
<th>Procedure</th>
<th>MPI</th>
<th>Patient Name</th>
<th>DOB</th>
<th>Fluoro Seconds</th>
<th>AirKerma</th>
<th>KAP</th>
<th>Data Src</th>
<th>Status</th>
<th>Ph. Of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/11/2020 3:51:00 PM/AG</td>
<td>AG</td>
<td>NIL CAROTID CEREBRAL BILATERAL</td>
<td>3630 Ringo</td>
<td>8417.0 0.0</td>
<td>TechNote/Pending Review</td>
<td>Yoko</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Longitudinal High Dose Patient Tracking

• System can sum $K_{a,r}$ over 6 month period based on patient MR #
  • Included all fluoroscopy across entire system
  • Plans to include Rad Onc notification
  • Email notifications for patients over thresholds
  • Built a high dose report view of data
  • Not able to split out by body region yet

• Initially had issues as an individual could be issued multiple MR #'s depending on how/where they entered our healthcare system
  • MR #'s would eventually be merged but process had a time lag which could delay notifications
  • Eventually was able to work out

• Later built out patient case review infrastructure
Patient Case Review Framework

- Notifications & documentation of follow-up contact or visits
- Can assign cases to staff for review
- Determine whether follow-up required
- Can track follow up
  - Post procedure documentation in EMR
  - Auto generated alerts for follow up
  - Call/visit at 4 & 26 weeks
  - Referrals to other services
- Tying fluoro dose information back into patient care

Image from Kevin Wunderle
Areas for Future Growth

- No real analytics, despite huge amount of data
- Have location, operator, procedure & equipment information in addition to fluoro data
  - Create and compare Facility Datasets per, NCRP Report No. 168
  - Equipment & procedure specific thresholds for review
  - Compare sites/equipment/operators for outliers
    - Median and percentile $K_{a,r}$ and time comparisons
    - Derived metrics
      - Divide $K_{a,r}$ by fluoro time to get average rate per user – can gauge use of acquisitions
Air Kerma Rate per Case: Operator – Q3

Air Kerma Rate (mGy/min)

Entire System
John
Paul
George
Ringo
Areas for Future Growth

• No real analytics, despite huge amount of data
• Have location, operator, procedure & equipment information in addition to fluoro data
  • Create and compare Facility Datasets per, NCRP Report No. 168
  • Equipment & procedure specific thresholds for review
  • Compare sites/equipment/operators for outliers
    • Median and percentile $K_{a,r}$ and time comparisons
    • Derived metrics
      • Divide $K_{a,r}$ by fluoro time to get average rate per user – can gauge use of acquisitions
      • Divide AKAP by $K_{a,r}$ to get average field size to show differences in collimation use
• Also had database system for occupational dose, could compare operator’s total $K_{a,r}$ over period to dosimetry
Cleveland Clinic

Fluoroscopy Dose Tracking – Summary

Pros
- Highly customized to handle clinical situation
- Multiple streams of data into enterprise-wide database
  - Scalable
- Integration with training databases to improve regulatory compliance
- High dose case review framework

Cons
- Took a lot of work & Vadim
- No analytics
MetroHealth
The Next Episode
Current situation looks a lot like my first:

- Much smaller operation:
  - 3 IR suites & 3 Cath labs, 1 OR hybrid room, all in one building
- No commercial dose tracking system
- No Vadim 😞
- Back to Manual / Excel based process
Fluoroscopy Dose Tracking – Ongoing Issues

- Last mile problem
  - Even with robust system, data is mostly in front of physicists, not physicians
- Lower end fluoroscopy still an issue
  - Joint Commission & some states require
  - Generally no RDSR
  - Often need multiple data entry pathways
  - Overall dose and risk is low
  - Is tracking even useful?

<table>
<thead>
<tr>
<th>Low End Fluoro Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>3261</td>
</tr>
</tbody>
</table>
Fluoroscopy Dose Tracking

- Size of the system and resources available will dictate the approach
- There are freeware systems available (OpenREM)
  - Requires some programming chops
- If you have the right resources, a homegrown system can offer substantial advantages as far as customization and clinical integration

**Homebrewed Solutions – Conclusions**

**Fluoroscopy Dose Tracking**

- Size of the system and resources available will dictate the approach
- There are freeware systems available (OpenREM)
  - Requires some programming chops
- If you have the right resources, a homegrown system can offer substantial advantages as far as customization and clinical integration

**OpenREM**

Free and Open Source Radiation Exposure Monitoring for the physicist
Fluoroscopy Dose Tracking

- Size of the system and resources available will dictate the approach.
- There are freeware systems available (e.g., OpenREM).
- Requires some programming chops.
- If you have the right resources, a homegrown system can offer substantial advantages as far as customization and clinical integration.

Homebrewed Solutions

- Conclusions