MAYO CLINIC

# medical informatics and patient dose management with FGI

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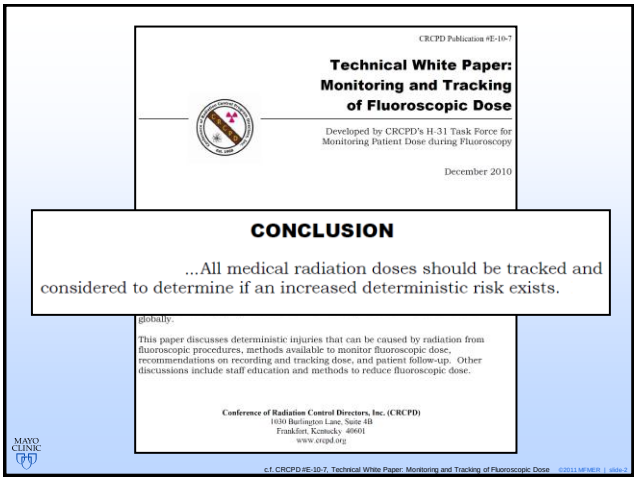
AAPM/COMP Vancouver, BC 2011






c.f. CRCPD #E-10-7, Technical White Paper: Monitoring and Tracking of Fluoroscopic Dose



## 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

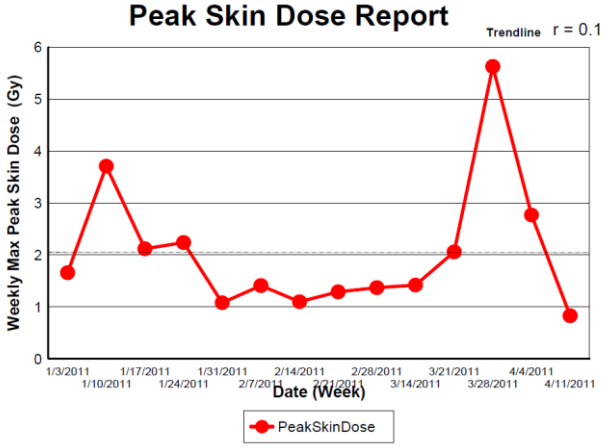


## Educational Objectives

- 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

## 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)




## 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!**

## **Define** ‘Peak’ Skin Dose

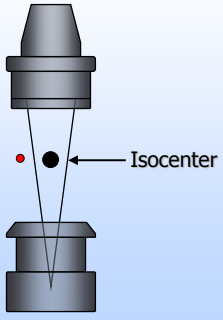
- $\boldsymbol{D_{skin,max}}$ –the most highly-irradiated skin region

*Compute* $D_{skin}$ from $K_{a,i}$:
- Validated Vendor $K_{a,r}$
- Backscatter
- Mass-energy absorption coefficient ratio *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



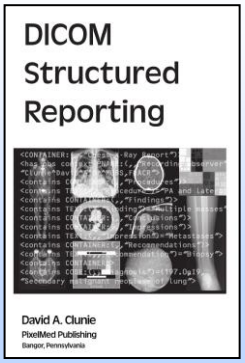



## Getting Information! – $K_{a,r}$ Is KEY!

- 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



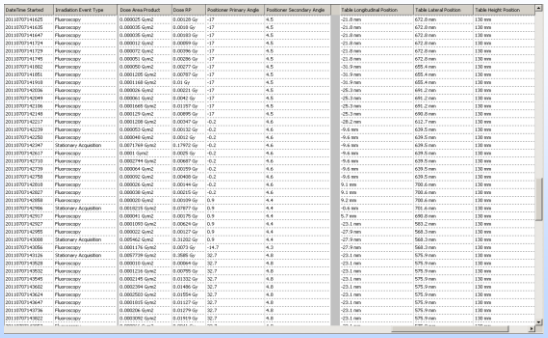

Clunie D. DICOM Structured Reporting. Bangore, Pennsylvania: PixelMed; 200.



## DICOM RDSR

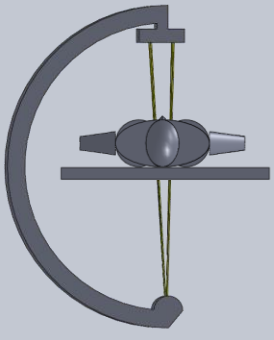
| Tag(Group,Element) | NAME | Value |
|---|---|---|
| 0040,A730-0040,A300-0040,A30A | Dose Area Product Total (Gym2) | 0.0124 |
| 0040,A730-0040,A300-0040,A30A | Dose (RP) Total (Gy) | 0.48313 |
| 0040,A730-0040,A300-0040,A30A | Fluoro Dose Area Product Total (Gym2) | 0.00614 |
| 0040,A730-0040,A300-0040,A30A | Fluoro Dose (RP) Total | 0.2267 |
| 0040,A730-0040,A300-0040,A30A | Total Fluoro Time(s) | 2504 |
| 0040,A730-0040,A300-0040,A30A | Acquisition Dose Area Product Total (Gym2) | 0.00624 |
| 0040,A730-0040,A300-0040,A30A | Acquisition Dose (RP) Total | 0.2564 |
| 0040,A730-0040,A730-0040,A124 | Irradiation Event UID | 1.2.556.8268.402.1200… |
| 0008,1030 | Performing Physician's Name | Physician |

## DICOM RD SR
## Patient having 287 separate 'events'



| | DICOM & Info | Primary angle | Secondary angle | Table Longitudinal Position | Table Lateral Position | Table Height | PERP (mGy) | Local dose mGy @ skin |
|---|---|---|---|---|---|---|---|---|
| FLUORO USE | Fluoroscopy Event 1 | -17 | 4.5 | -21.8 | 672 | 130 | 1.3 | |
| | Fluoroscopy Event 2 | -0.2 | 4.6 | -28.2 | 612 | 130 | 3.4 | |
| | Fluoroscopy Event 3 | 0.9 | 4.4 | -23.1 | 583 | 130 | 6.3 | |
| | Fluoroscopy Event 4 | 32.7 | 4.8 | -23.1 | 576 | 130 | 13.3 | |
| DSA USE | Acquisition Event 1 | -0.2 | 4.6 | -9.6 | 640 | 130 | 179.7 | |
| | Acquisition Event 2 | 0.9 | 4.4 | -0.6 | 702 | 130 | 78.7 | |
| | Acquisition Event 3 | 0.9 | 4.4 | -27.9 | 568 | 130 | 312.0 | |
| | Acquisition Event 4 | 32.7 | 4.8 | -23.1 | 576 | 130 | 358.5 | |

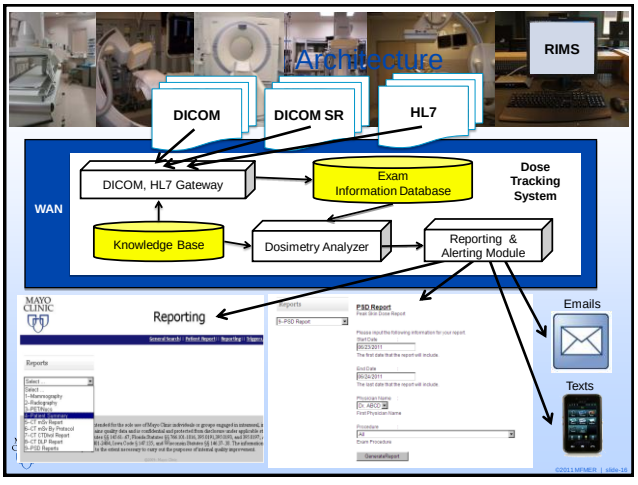
## Simple Geometry or assume $K_{a,r}$ is > PSD



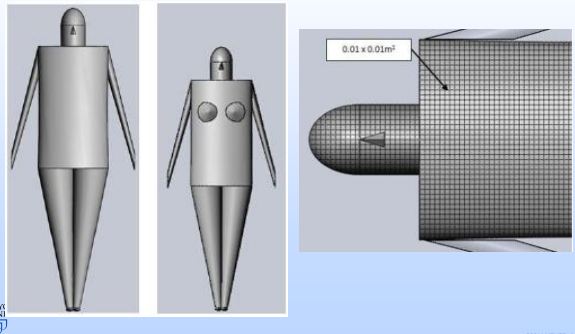
$K_{a,r}$ = 5 Gy
Machine correction = 0.85
BSF = 1.4
Tissue/Air = 1.06
Ref Pt/Skin = '0'
Table/Pad = 0.7

**PSD = 4.4 Gy**

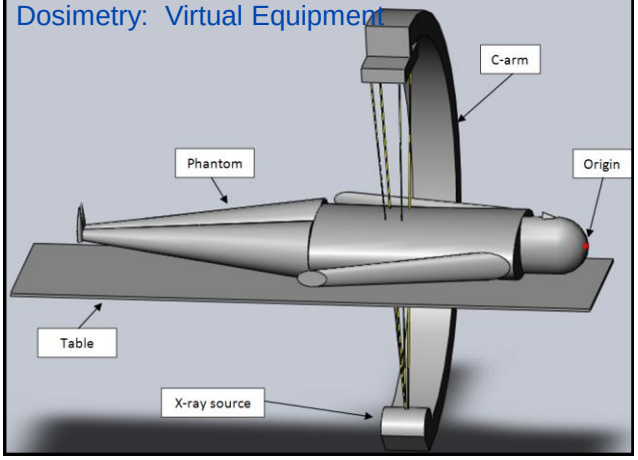
**Both Fluoro AND Acquistions needed!**



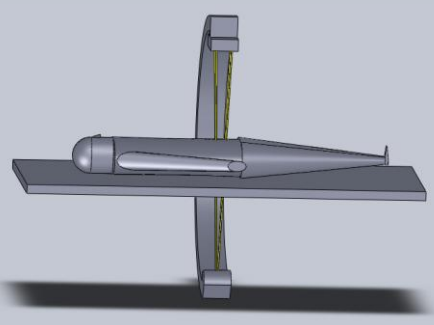
## Dosimetry: Virtual (reference) Patients



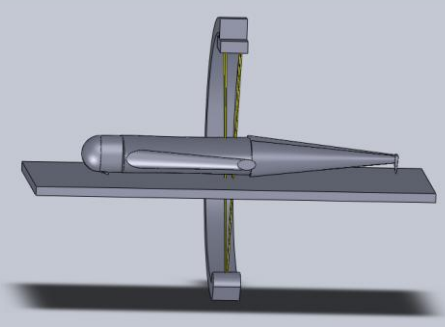

## Dosimetry: Virtual Equipment



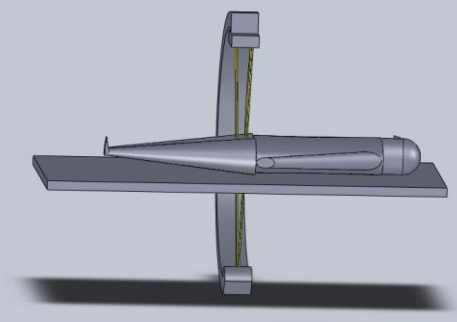

## Patient: Supine, Head First



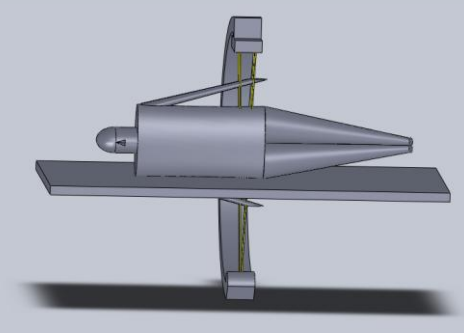
## Patient: Prone



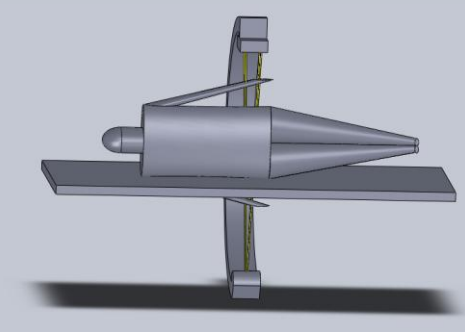
Patient: Supine, Feet First



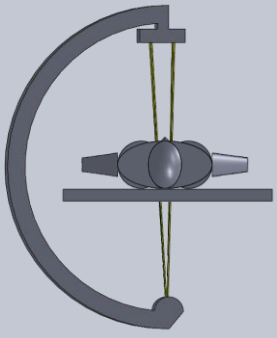
Patient: Right Side



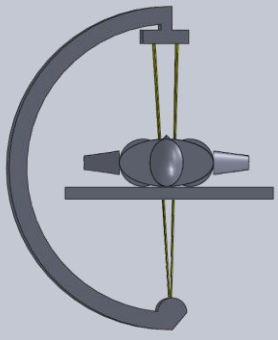
Patient: Left Side



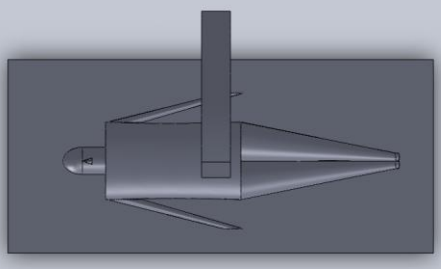
C-Arm Primary Angle (+)



C-Arm Primary Angle (–)



C-Arm Secondary Angle (+)



C-Arm Secondary Angle (–)

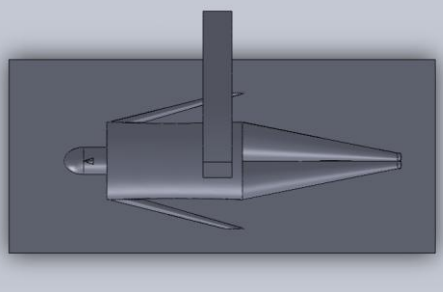
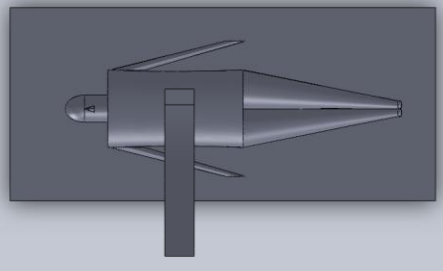
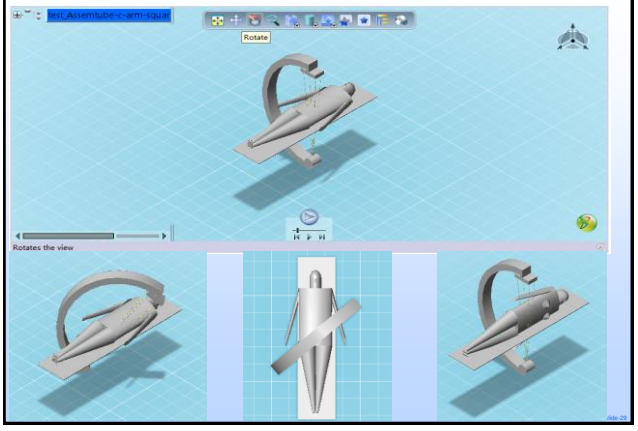


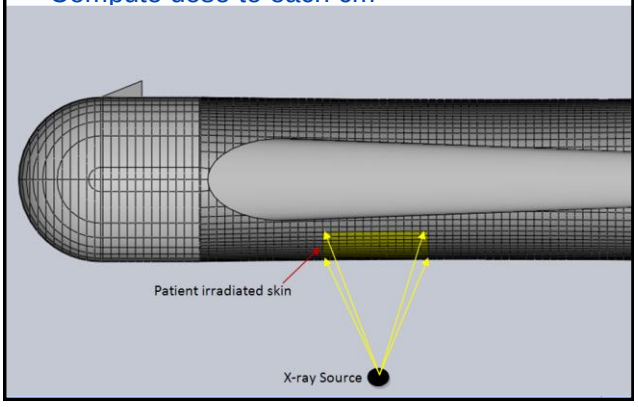
Table Lateral – “Image Context”



## New Physics Tool: Patient/Operator Ref Frame Converter

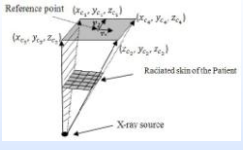



## Locate the area irradiated
## Compute dose to each cm²




## A point calculation of air kerma to a 0.01×0.01m² radiated region

Square shape field of view




$$v_1 = (Cos(\alpha_2),\ Sin(\alpha_2) \times Sin(\alpha_2),\ Cos(\alpha_2) \times Sin(\alpha_2)) \quad (10)$$

$$v_2 = (0,\ (\alpha_1),\ -Sin(\alpha_1)) \quad (11)$$

$$l = \sqrt{KAP_{air} / K_{air}} \quad \text{length of the side of the radiated area at IRP with } l \quad (12)$$

$$(x_{c1}, y_{c1}, z_{c1}) = (x_{RP}, y_{RP}, z_{RP}) - l/2 \times v_1 + l/2 \times v_2 \quad (13)$$

$$(x_{c2}, y_{c2}, z_{c2}) = (x_{RP}, y_{RP}, z_{RP}) + l/2 \times v_1 - l/2 \times v_2 \quad (14)$$

$$(x_{c3}, y_{c3}, z_{c3}) = (x_{RP}, y_{RP}, z_{RP}) - l/2 \times v_1 - l/2 \times v_2 \quad (15)$$

$$(x_{c4}, y_{c4}, z_{c4}) = (x_{RP}, y_{RP}, z_{RP}) + l/2 \times v_1 + l/2 \times v_2 \quad (16)$$

With three points on each triangle face, we can construct the four faces of the pyramid such as $Ax + By + Cz + D = 0$, where A, B, C, D are coefficients. As an example, for the plane consisting of source, $(x_{c1}, y_{c1}, z_{c1})$ and $(x_{c4}, y_{c4}, z_{c4})$ coefficients of plane are as follows,

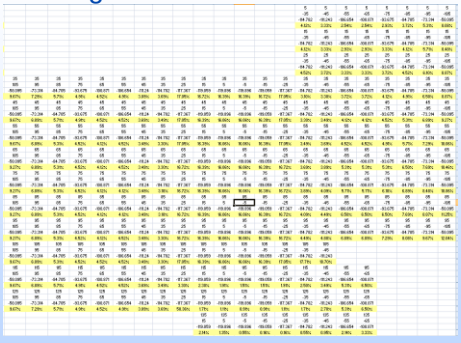
$$A = y_{Spot} \times (z_{c1} - z_{c4}) + y_{c1} \times (z_{c4} - z_{Spot}) + y_{c4} \times (z_{Spot} - z_{c1}) \quad (17)$$

$$B = z_{Spot} \times (x_{c1} - x_{c4}) + z_{c1} \times (x_{c4} - x_{Spot}) + z_{c4} \times (x_{Spot} - x_{c1}) \quad (18)$$

$$C = x_{Spot} \times (y_{c1} - y_{c4}) + x_{c1} \times (y_{c4} - y_{Spot}) + x_{c4} \times (y_{Spot} - y_{c1}) \quad (19)$$

$$D = -x_{Spot} \times (y_{c1} \times z_{c4} - y_{c4} \times z_{c1}) - x_{c1} \times (y_{c4} \times z_{Spot} - y_{Spot} \times z_{c4}) - x_{c4} \times (y_{Spot} \times z_{c1} - y_{c1} \times z_{Spot}) \quad (20)$$

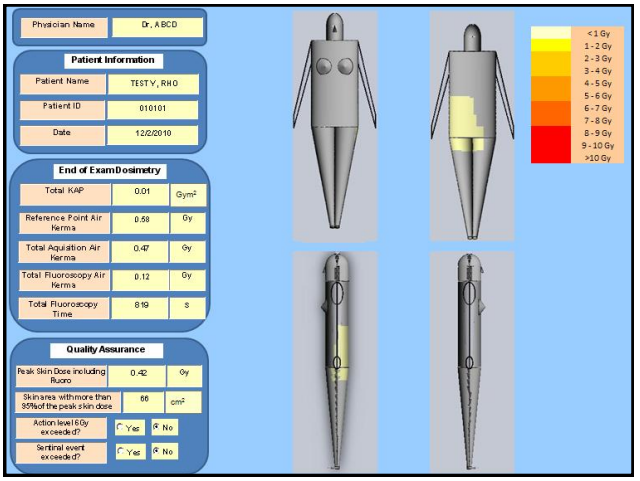
## Compute: Dose to each 1 cm² point in defined region



## Sort $D_{skin}$ - 'define' Peak Skin Dose

| DOSE_INFO_UID | X_COOR | Y_COOR | Z_COOR | DOSE |
|---|---|---|---|---|
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237451 | 635 | -55 | 96.14442 | -0.353137923330936 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237452 | 645 | -55 | 96.14442 | -0.353270026648389 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237453 | 655 | -55 | 96.14442 | -0.353270026648389 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237454 | 665 | -55 | 96.14442 | -0.353137923330936 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237455 | 675 | -55 | 96.14442 | -0.352874013552598 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237456 | 685 | -55 | 96.14442 | -0.352478889356718 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237457 | 695 | -55 | 96.14442 | -0.351953434651383 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237458 | 705 | -55 | 96.14442 | -0.351298820269946 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237459 | 715 | -55 | 96.14442 | -0.350516497465581 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237460 | 725 | -55 | 96.14442 | -0.349608189907128 |
| 1.3.12.2.1107.5.3.2.113.5456.12345689.1789.1234564449.1237461 | 735 | -55 | 96.14442 | -0.348575884258219 |






| ID | Gender | Procedure | KAP/air kerma (cm2) | Number of the scans | Number of Fluoro | Peak skin dose | Total area radiated (cm²) |
|---|---|---|---|---|---|---|---|
| Test | f | IR Emobilization (non-Neuro) | 245.7 | 180 | 162 | **4.3 Gy** | 1068 |

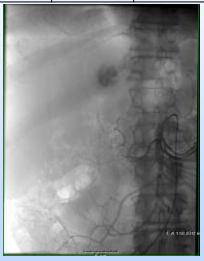
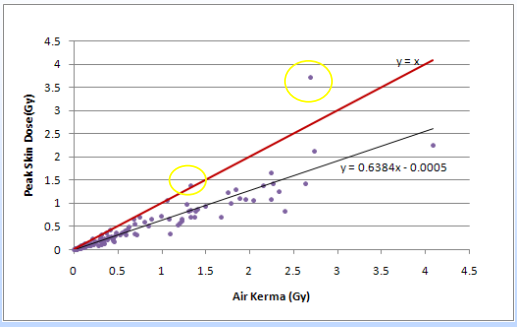


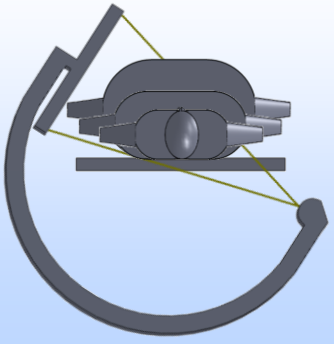
Table: 0.8; Machine : 0.8; BSF: 1.4 TAR:1.06



## Analysis: Why would PSD be> $K_{a,r}$?



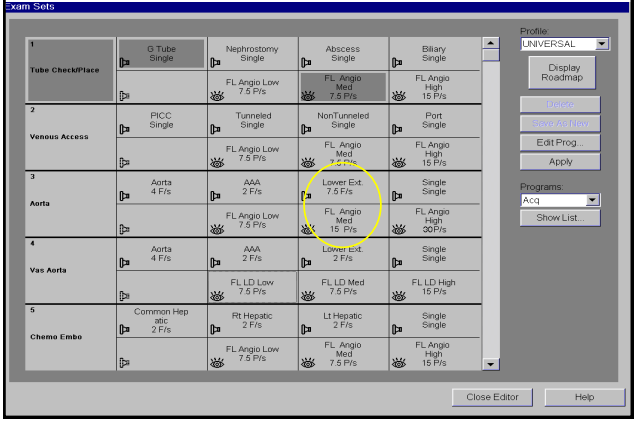
## Skin Dose 'angled views and patient size'

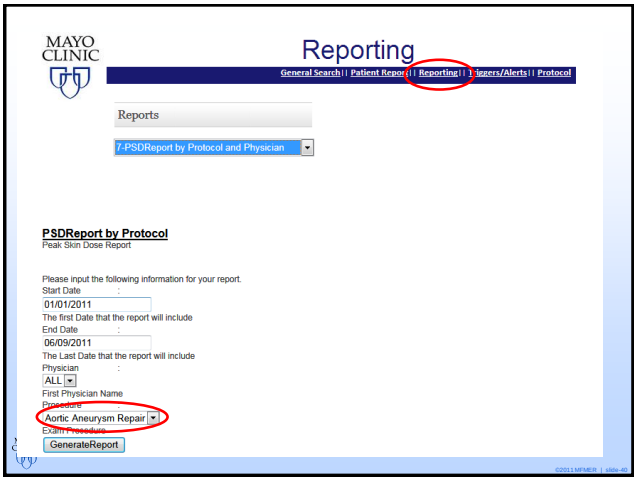


**Analysis:** FGI Protocols (need standardization)

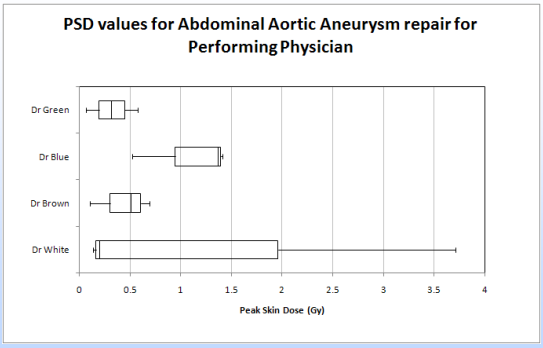
| IR Unit 1 | IR Unit 2 | IR Unit 3 |
|---|---|---|
| Vas Upper Extremities | Vas Mesenteric | Aorta |
| Pelvis / Peri | Upper Extremity | Vas Aorta |
| Vas Pelvis | Vas Upper Extremity | Mesenteric |
| Renal | Lower Extremity | Vas Mesenteric |
| Vas Renal | Vas Lower Extremity | Chemo Embo |
| IVC | Renal | Renal |
| Vas IVC | Vas Renal | Vas Renal |
| $CO_2$ / Gad | DSA | IVC |
| Pulmonary | TIPS | Vas IVC |
| Vas Pulmonary | Fistulogram | $CO_2$ / Gado |
| Neuro | Vas Fistulogram | Pelvis |
| Vertebroplasty | Tube Check | Vas Pelvis |
| Perc Neph Dyna | IVC | Perivision |
| Endoleaks Dyna | Vas IVC | Vas Perivision |
| DynaCT Body | PICC Line | Singel Leg |
| InSpace 3D | Catheter Placement | Vas Single Leg |
| DynaCT Head | Tube Placement | General Dyna |
| Cardiac | Vertebroplasty | Vertebroplasty |
| Cardiac OLD | GenDYNA | DSA 0 |
| 2D/3D Calib | BILATERAL PERI | Physic's Testing |

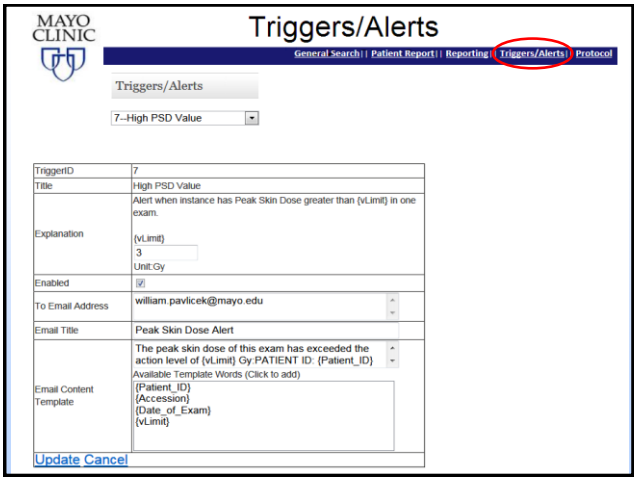
## Poor Protocol: High DSA and Fluoro Rate



## DMAIC: Physician Report – Shine a Light!

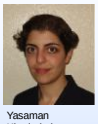



## Take Aways!

- 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'!

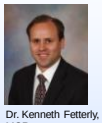

Yasaman Khodadadegan


Dr. Brian Chong, MCA

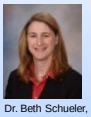

Dr. Eric Huettl, MCA


Gene Paden, MS., MCA


Stephen Sabyan, R.T. (R), MCA


Dr. Kenneth Fetterly, MCR


Dr. Steve Langer, MCR


Dr. Beth Schueler, MCR


Dr. Richard Morin, MCJ


Dr. Kevin Nelson, MCJ


Dr. Teresa Wu, ASU


Dr. Muhong Zhang, ASU