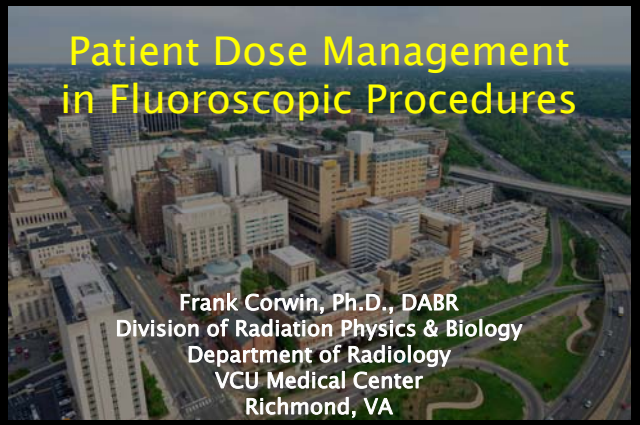
Patient Dose Management in Fluoroscopic Procedures



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Nothing specific to declare.
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AAPM Spring Clinical Meeting, Fluoroscopy Patient Peak Skin Dose Monitoring and Tracking
Diagnostic Symposium April 9 , 2018.

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Goals

- To highlight the inherent deficiency in the use of cumulative dose for Interventional Procedures
- To help Physicist become familiar with the Radiation Dose Structured Report for Peak Skin Dose reconstruction
- To lay a framework for moving from the Cumulative dose to a "true" Peak-Skin-Dose

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Managing Doses in Fluoroscopic Exams

- Fluoroscopic Time
  - 1994 FDA Advisory of Radiation Dose recommended recording cumulative fluoroscopy time for each procedure
- Kerma Area Product
- Cumulative Dose at a Reference Point

➢ *None of these metrics provide information regarding the spatial distribution of the entrance beam on the patients skin*

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Cumulative Dose at a Reference Point

Cumulative Dose received for each Procedure performed on the patient

Date (mm/dd/yyyy)	Lab	Study Type	RAD	Total DLP (mGy*cm)	DAP A (uGy-m^2)	Dose A (mGy)	FLT A (min)	DAP B (uGy-m^2)	Dose B (mGy)	FLT B (min)
9/18/2017 12:00:00 AM	OR_36	Peripheral^Neuro	267	0	30715	5716	26.3	8371	2882	18.6
2/26/2018 12:00:00 AM	OR_36	Peripheral^Neuro	24	0	2414	413	1.8	598	257	0.6

Date (mm/dd/yyyy)	Dose A (mGy)	Dose B (mGy)	Cumulative Dose for Procedure (mGy)	Cumulative Dose over 6 months (mGy)
9/18/2017 12:00:00 AM	5716	2882	8598	8598
2/26/2018 12:00:00 AM	413	257	670	9268

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Cumulative Dose at a Reference Point

Date (mm/dd/yyyy)	Dose A (mGy)	Dose B (mGy)
9/18/2017 12:00:00 AM	5716	2882
2/26/2018 12:00:00 AM	413	257

Can this Cumulative Dose result in some form of radiation determent to the Patient?

Questions that need to be asked:

- Was the patient always positioned at the Reference Point?
- Was the tube stationary during the entire exam?
- Where was the Plane B oriented?

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Radiation Dose Structured Report

- Non-image Information Object Definition (IOD) are parameters in the DICOM header that are decoupled from the image data
- Relevant exposure parameters are captured for each irradiation event during a patient procedure
  - Dose RP
  - Prime Angle, Secondary Angle
  - Source to Detector, Source to Isocenter
  - Table Long, Table Lat, Table Height, etc.
  - Event Type, Filter Material, etc

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Radiation Dose Structured Report

- Accessing and manipulating the RDSR data requires:
  - a working knowledge of a programming software (Matlab, Python, C++, etc.)
  - a Patient Radiation Dose Monitoring and Tracking System (PRDMT) software that receives and then allows exporting of the RDSR
    - Only a couple of PRDMT systems currently allow exporting of the RDSR data to a spreadsheet for further manipulations

A single procedure RDSR dataset can approach 500 rows

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Patient Dose Monitoring and Tracking

- So, what do we do with all of this data?
  - PRDMT systems can be configured to send a notification for all exams that meet a facilities chosen dose criteria
  - AT VCUHS we are following up on all patients who receive a cumulative exposure (adding both Planes A and B) over 6 month of greater than 5000 mGy

Cumulative Dose for Procedure (mGy)	Cumulative Dose over 6 months (mGy)
8598	8598
670	9268

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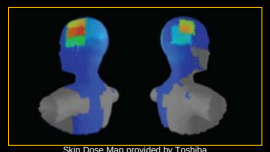
Patient Dose Monitoring and Tracking

But, Cumulative Doses are a very poor indicator of Peak Skin Dose

Peak Skin Dose: The maximum absorbed dose to the most heavily irradiated localized region of skin. (NCRP 168)



Skin Dose Map provided by Toshiba

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Peak Skin Dose Calculation
Methodology

Basic Steps for a Peak Skin Dose Calculation (PSD)

1. Establish the correction factors related to x-ray physics and the equipment
2. Export the RDSR data in a spreadsheet format
3. Manipulate the RDSR Positional data to define a field for the PSD calculations
4. Correct the Reference Point Dose to the Patient Entrance

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Peak Skin Dose Calculation
Beam Entrance on Skin Surface

Surface Area for a Peak Skin Dose Determination

- 10 x 10 cm on patients skin
- Roughly the actual size on the skin with a ~22 cm Image Receptor
- In the angular coordinate plane, 10 cm is approximately every 45^0 for head and 30^0 for body
- In the z-axis, 10 cm is approximately equal to the fully open beam width for the ~22 cm Image Receptor

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Peak Skin Dose Calculation
Beam Entrance on Skin Surface

In the RDSR spreadsheet this would look like:

Rounding the Tube Angulation

Column from RDSR Data

Prime Angle (deg)	Rounded Prime Angle (deg)
-28.1	-45
-28	-45
-28	-45
-28	-45
-2.5	0
-2.5	0
-2.5	0
-2.5	0
-2.5	0
-2.5	0
-2.5	0
-6.5	0
-89.9	-90

Inserted Column for Calculation

Rounding the Table z-axis Position

Column from RDSR Data

Table Lat (mm)	Rounded Table Lat (cm)
852.2	85
852.2	85
852.2	85
852.2	85
338.8	34
338.8	34
338.8	34
338.8	34
338.8	34
338.8	34
112.8	11
136.8	14
51.1	5

Inserted Column for Calculation

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Peak Skin Dose Calculation
Reference Point Dose Corrections

- Required corrections to the Reference Point Dose include:
  a. TG190 Corrections
  b. Tissue-to-PMMA Correction
  c. Backscatter Corrections
  d. Attenuation Corrections
  e. Distance Corrections

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Peak Skin Dose Calculation
Reference Point Dose Corrections

a. TG190 Correction – Must be determined by the Physicist at acceptance, annually and following any repairs that could effect the dose
b. Tissue to PMMA Correction – Reference Point Dose is calibrated by the manufacturers with the use of PMMA (~1.06)
c. Backscatter Correction – Energy and angle dependent (~1.30)
d. Attenuation Correction – Must be determined by the Physicist at acceptance and following any changes to the table or pad. Energy, spectral filter, and angle dependent

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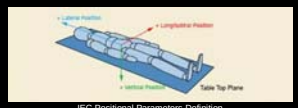
Peak Skin Dose Calculation
Distance Corrections

- The RP Dose is the dose at 15 cm toward the x-ray tube from the system Isocenter
  - Caution: Not all units have the same Isocenter
- Table Height values are measured from the Isocenter



IEC Positional Parameters Definition

An equation should look something like:

$$\frac{(Isocenter - 150mm)^2}{(Isocenter - TableHeight + TablePadThickness)^2}$$

For the simple case where the tube is under the table

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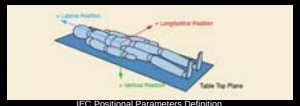
Peak Skin Dose Calculation
Distance Corrections

- Table Height values are only useful when the tube is primarily under or over the table
  - What about lateral projections
- The critical parameter now becomes the horizontal table shift
  - Table Long (Siemens, Philips)
  - Table Lat (GE)



IEC Positional Parameters Definition

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Peak Skin Dose Calculation
Distance Corrections

- For lateral projections (single or biplane), the system Isocenter remains the same as before
- An equation should look something like:

$$\frac{(Isocenter - 150mm)^2}{(Isocenter - TableLat - \frac{1}{2}PatientThickness)^2}$$

For the simple case where the tube is on the right side of the patient

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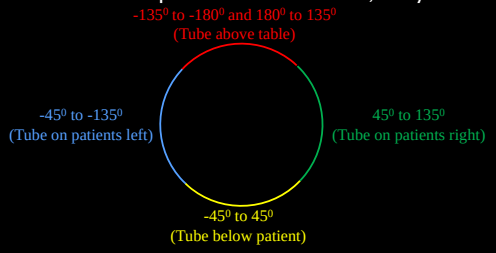
Peak Skin Dose Calculation
Tube Angulation

- What about tube angles not equal to 0^0, 180^0, 90^0 or 45^0
- For this simple PSD calculations, only four cases are considered:



Segment Dependent Parameters	
Tube Above Table	Table Height, Patient AP Thickness
Tube on Right	Table Long (or Lat), Patient Lat Thickness
Tube Below Table	Table Height, Table Attenuation, Table/Pad Thickness
Tube on Left	Table Long (or Lat), Patient Lat Thickness

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Peak Skin Dose Calculation
Corrected Dose RP (finally)

- Combining all of the corrections, an equation can be created in either a spreadsheet program or coded using a real programing language

```
=IF(I2="Rotational Acquisition",C2*1.06*1.3*0.333,IF(AND(G2<-45,G2>-135),C2*1.06*1.3*((R2-150)^2/(R2-S2-250)^2),IF(AND(G2>45,G2<135),C2*1.06*1.3*((R2-150)^2/(R2+S2-250)^2),IF(OR(G2<-135,G2>135),C2*1.06*1.3*((R2-150)^2/(R2+V2-200)^2),IF(Z2="No Filter",C2*1.06*1.3*0.5*((R2-150)^2/(R2-V2+50)^2),C2*1.06*1.3*0.7*((R2-150)^2/(R2-V2+50)^2))))))
```

Column from RDSR Data

Dose RP (mGy)	Corrected Dose RP (mGy)
5.95	4.3
25.51	13.1
0.09	0.1
33.58	24.2
1.76	1.4
4.21	3.4
0.65	0.5
9.48	7.8
2.01	1.6
0.21	0.2
0.71	0.6
3.09	2.5
0.02	0.0

Inserted Column for Calculation

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Peak Skin Dose Calculation
Special Case

- Some manufacturer employ a rotational CBCT type acquisition
  - The spinning c-arm will result in dose deposition around and possible along the axis of the patient
  - In RDSR, the Dose RP is the entire dose for the spin acquisition
  - In RDSR, the Primary Angle is the starting location of the spin
- *What does your manufacturer do!*
  - For Siemens, the c-arm spins over an arc of 270^0, then returns to the starting point, emitting radiation the entire time

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Peak Skin Dose Calculation
Putting it all Together

- To finalize our PSD calculation, the data needs to be binned into 10 x 10 cm blocks
  - Rounding of the Tube Angulation takes care of 1st dimension
  - Table motion in the z-axis will yield the 2nd dimension

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Peak Skin Dose Calculation
Putting it all Together

1. At a fixed Gantry Angle and at each z-axis Table Position, sum all of the exposures

Corrected Dose RP (mGy)	Rounded Tube Angle (°)	Rounded Table Lat (cm)
8.6	-90	15
212.8	-90	15
0.2	-90	18
80.5	-90	18
1.5	-90	18
183.2	-90	18
0.2	-90	18
1.8	-90	18
138.2	-90	18
1.4	-90	19
176.6	-90	19
0.8	-90	19
100.1	-90	19
1.4	-90	20
0.4	-90	20
1.3	-90	20

Rounded Tube Angle (°)	Rounded Table Lat (cm)	Cumulative Dose @ Table Lat Position (mGy)
-90	5	0.0
	6	0.0
	7	0.0
	8	0.0
	9	0.0
	10	0.0
	11	2.2
	12	0.0
	13	418.5
	14	4203.3
	15	221.3
	16	0.0
	17	0.0
	18	405.6
	19	278.9
	20	3.1

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Peak Skin Dose Calculation
Putting it all Together

2. Step-wise sum the z-axis table positions over 10 cm lengths

Tube Angle	Table Lat (cm)	Cumulative Dose @ Table Lat Position (mGy)
-90	5	0.0
	6	0.0
	7	0.0
	8	0.0
	9	0.0
	10	0.0
	11	2.2
	12	0.0
	13	418.5
	14	4203.3
	15	221.3
	16	0.0
	17	0.0
	18	405.6
	19	278.9
	20	3.1

Dose by 10 cm FOV (mGy)
4624.1
4845.4
4845.4
4845.4
5251.0
5529.8
5532.9
5781.5
5898.2
5479.7
1276.4
1055.1

Peak Skin Dose @ Tube Angle of -90^0

The same procedure can be repeated for other Tube Angles

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Peak Skin Dose vs. Cumulative Dose

- How does this compare to the Procedure Cumulative Dose
  - 5898 mGy PSD at -90^0 Tube Angle
  - From Earlier:

Date (mm/dd/yyyy)	Dose A (mGy)	Dose B (mGy)	Cumulative Dose for Procedure
9/18/2017 12:00:00 AM	5716	2882	8598

- The calculated PSD is ~60% of the Cumulative for this procedure!

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Peak Skin Dose w/ Multiple Studies

- Additional Procedures would require new PSD calculations
  - Peak Skin Doses from multiple procedures can cautiously be combined, if:
    - The same anatomical region is being imaged
    - The patient is repositioned similarly on the table

Date (mm/dd/yyyy)	Dose A (mGy)	Dose B (mGy)	Cumulative Dose for Procedure (mGy)	PSD @ Tube Angle of -90^0 (mGy)
9/18/2017 12:00:00 AM	5716	2882	8598	5898
2/26/2018 12:00:00 AM	413	257	9268	6160

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Observations and Conclusion

- Peak Skin Doses can be as low as 50% of the Procedure Cumulative Dose (but 100% or more of the Cumulative Dose is always a possibility)
- The greatest variable in these calculations can be the distance corrections
- Upcoming Modification to the RDSR data structure and machine designs will allow repeat procedures to be co-registered

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Observations and Conclusion

- Most manufacturers are moving toward providing real-time PSD calculations during a procedure

Skin Dose Map provided by Toshiba

  - Some manufacturers allow this PSD data to be saved with the patient data

Skin Dose Map created by Bayer

- Likewise, PRDMT are also moving toward creating dose maps for post-procedure PSD calculations

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Thank You

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