



medical informatics and patient dose management with FGI

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Mayo Clinic Arizona

AAPM/COMP Vancouver, BC 2011

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CRCPD Publication AE-10-7 **Technical White Paper: Monitoring and Tracking of Fluoroscopic Dose**

Developed by CRCPD's H-31 Task Force for
Monitoring Patient Dose during Fluoroscopy

December 2010

CONCLUSION

...All medical radiation doses should be tracked and considered to determine if an increased deterministic risk exists.

globally.

This paper discusses deterministic injuries that can be caused by radiation from fluoroscopic procedures, methods available to monitor fluoroscopic dose, recommendations on recording and tracking dose, and patient follow-up. Other discussions include staff education and methods to reduce fluoroscopic dose.

Conference of Radiation Control Directors, Inc. (CRCPD)
1630 Burlington Lane, Suite 4B
Frankfort, Kentucky 40601
www.crcpd.org



c11 CRCPD-H-31-7, Technical White Paper: Monitoring and Tracking of Fluoroscopic Dose | ©2011 MAYO CLINIC | 4554-2

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



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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



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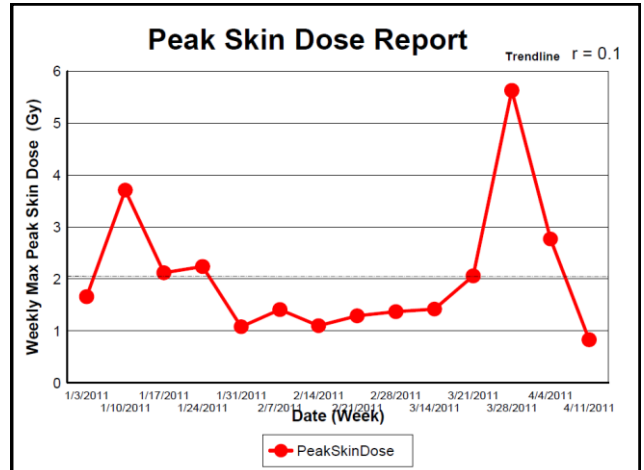
DMAIC 'Basis of Six Sigma'

"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_{skin} from $K_{a,i}$:

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

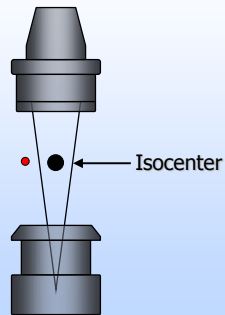
- Table and pad attenuation
- Equipment/patient specific information
- Account for locations of the x-ray beam/patient
- Actual source-skin entrance distances



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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



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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'!



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DICOM Radiation Dose SR

DICOM Structured Reporting



David A. Clunie
PixelMed Publishing
Bangor, Pennsylvania



Clunie D. DICOM Structured Reporting. Bangor, Pennsylvania: PixelMed; 200. ©2011 MPMSP | 4659-11

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



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Device	Model	Resolution (x, y)	Time Step	Time Step	Positional History Size	Positional Security Index	Table Length (number of rows)	Table Label (number of classes)	Table Length (number of classes)
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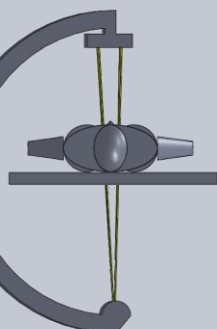
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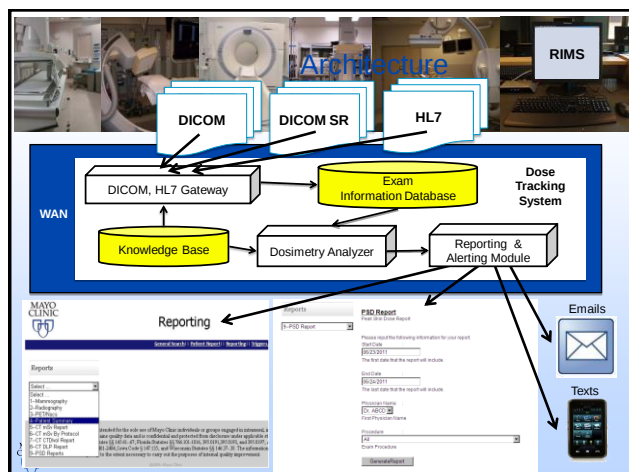
	DICOM & Info	Primary angle	Secondary angle	Table Longitudinal Position	Table Lateral Position	Table Height	PERP (mGy)	Local dose mGy @ skin
FLUORO USE	Fluoroscopy Event 1	-17	4.5	-21.8	672	130	1.3	
	Fluoroscopy Event 2	-0.2	4.6	-28.2	612	130	3.4	
	Fluoroscopy Event 3	0.9	4.4	-23.1	583	130	6.3	
	Fluoroscopy 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	

C0011 MEMPHIS 1 556-2

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

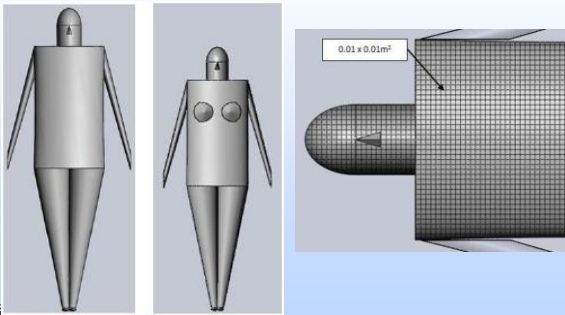


Both Fluoro AND Acquisitions needed!

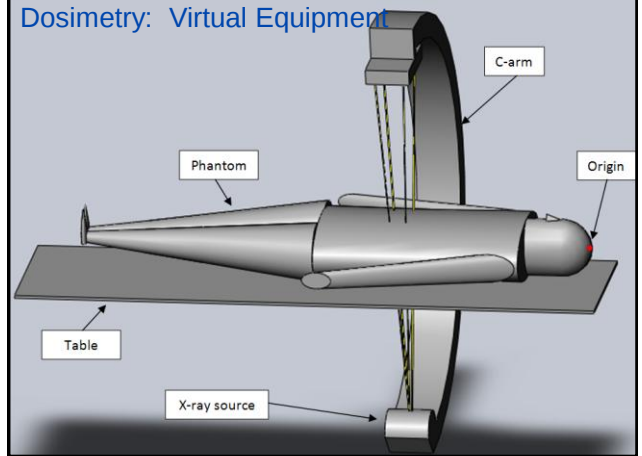


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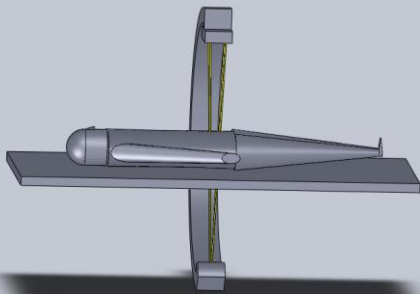
Dosimetry: Virtual (reference) Patients



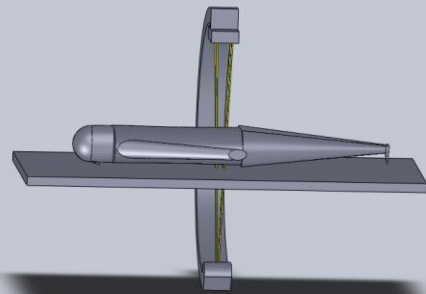
Dosimetry: Virtual Equipment



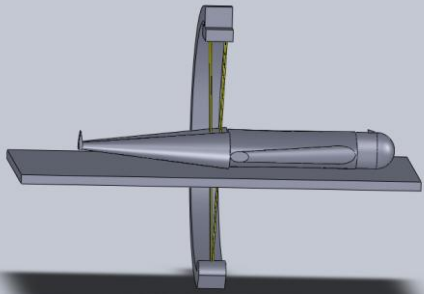
Patient: Supine, Head First



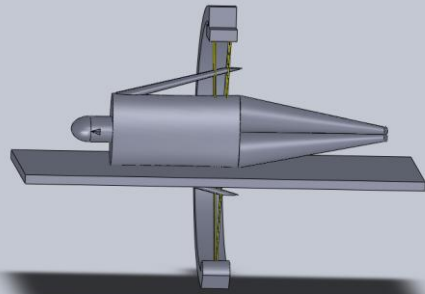
Patient: Prone



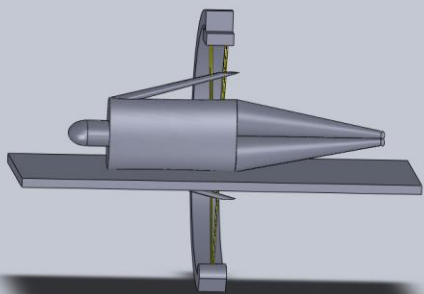
Patient: Supine, Feet First



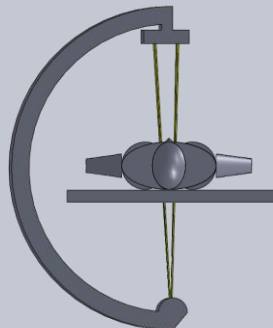
Patient: Right Side



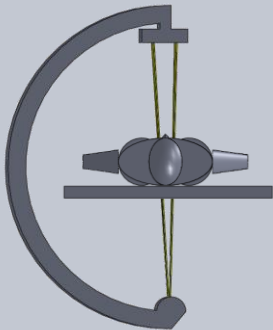
Patient: Left Side



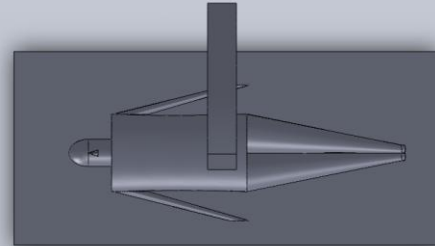
C-Arm Primary Angle (+)



C-Arm Primary Angle (-)



C-Arm Secondary Angle (+)



C-Arm Secondary Angle (-)

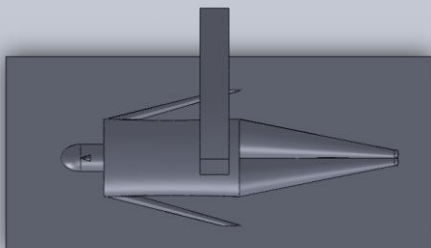
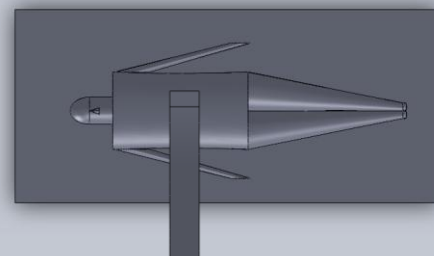
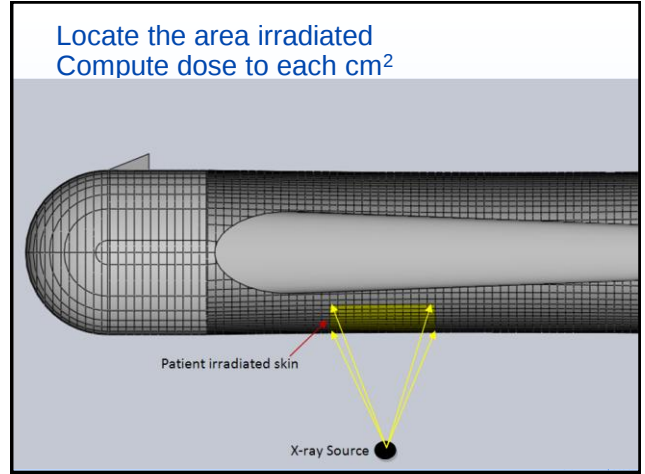
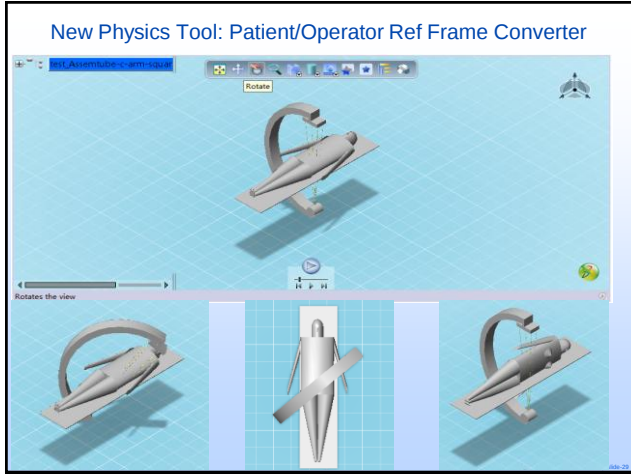


Table Lateral – “Image Context”





A point calculation of air kerma to a $0.01 \times 0.01 \text{m}^2$ radiated region

Square shape field of view

Reference point (x_{rp}, y_{rp}, z_{rp})

Radiated skin of the Patient

X-ray source

$v_1 = (\cos(\alpha_1), \sin(\alpha_1)) \times \sin(\alpha_2), \cos(\alpha_1) \times \sin(\alpha_2)$ (10)
 $v_2 = (0, \sin(\alpha_1), \cos(\alpha_1))$ (11)

$l = \sqrt{KAP_{50} / K_{50}}$ length of the side of the radiated area at IRP with l
 $(x_{c1}, y_{c1}, z_{c1}) = (x_{rp}, y_{rp}, z_{rp}) - l/2 \times v_1 + l/2 \times v_2$ (12)
 $(x_{c2}, y_{c2}, z_{c2}) = (x_{rp}, y_{rp}, z_{rp}) + l/2 \times v_1 - l/2 \times v_2$ (13)
 $(x_{c3}, y_{c3}, z_{c3}) = (x_{rp}, y_{rp}, z_{rp}) - l/2 \times v_1 - l/2 \times v_2$ (14)
 $(x_{c4}, y_{c4}, z_{c4}) = (x_{rp}, y_{rp}, z_{rp}) + l/2 \times v_1 + l/2 \times v_2$ (15)

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,

$A = y_{\text{spur}} \times (x_{c1} - x_{c4}) + y_{c1} \times (x_{c4} - x_{\text{spur}}) + y_{c4} \times (x_{\text{spur}} - x_{c1})$ (17)
 $B = z_{\text{spur}} \times (x_{c1} - x_{c4}) + z_{c1} \times (x_{c4} - x_{\text{spur}}) + z_{c4} \times (x_{\text{spur}} - x_{c1})$ (18)
 $C = x_{\text{spur}} \times (y_{c1} - y_{c4}) + x_{c1} \times (y_{c4} - y_{\text{spur}}) + x_{c4} \times (y_{\text{spur}} - y_{c1})$ (19)
 $D = -x_{\text{spur}} \times (y_{c1} \times z_{c4} - y_{c4} \times z_{c1}) - x_{c1} \times (y_{c4} \times z_{\text{spur}} - y_{\text{spur}} \times z_{c4}) - x_{c4} \times (y_{\text{spur}} \times z_{c1} - y_{c1} \times z_{\text{spur}})$ (20)

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31

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Compute: Dose to each 1 cm^2 point in defined region

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

DOSE INFO UID	x	coord1	coord2	coord3	coord4	coord5	coord6	coord7	coord8	coord9	coord10	coord11	coord12	coord13	coord14	coord15	coord16	coord17	coord18	coord19	coord20	coord21	coord22	coord23	coord24	coord25	coord26	coord27	coord28	coord29	coord30	coord31	coord32	coord33	coord34	coord35	coord36	coord37	coord38	coord39	coord40	coord41	coord42	coord43	coord44	coord45	coord46	coord47	coord48	coord49	coord50	coord51	coord52	coord53	coord54	coord55	coord56	coord57	coord58	coord59	coord60	coord61	coord62	coord63	coord64	coord65	coord66	coord67	coord68	coord69	coord70	coord71	coord72	coord73	coord74	coord75	coord76	coord77	coord78	coord79	coord80	coord81	coord82	coord83	coord84	coord85	coord86	coord87	coord88	coord89	coord90	coord91	coord92	coord93	coord94	coord95	coord96	coord97	coord98	coord99	coord100	coord101	coord102	coord103	coord104	coord105	coord106	coord107	coord108	coord109	coord110	coord111	coord112	coord113	coord114	coord115	coord116	coord117	coord118	coord119	coord120	coord121	coord122	coord123	coord124	coord125	coord126	coord127	coord128	coord129	coord130	coord131	coord132	coord133	coord134	coord135	coord136	coord137	coord138	coord139	coord140	coord141	coord142	coord143	coord144	coord145	coord146	coord147	coord148	coord149	coord150	coord151	coord152	coord153	coord154	coord155	coord156	coord157	coord158	coord159	coord160	coord161	coord162	coord163	coord164	coord165	coord166	coord167	coord168	coord169	coord170	coord171	coord172	coord173	coord174	coord175	coord176	coord177	coord178	coord179	coord180	coord181	coord182	coord183	coord184	coord185	coord186	coord187	coord188	coord189	coord190	coord191	coord192	coord193	coord194	coord195	coord196	coord197	coord198	coord199	coord200	coord201	coord202	coord203	coord204	coord205	coord206	coord207	coord208	coord209	coord210	coord211	coord212	coord213	coord214	coord215	coord216	coord217	coord218	coord219	coord220	coord221	coord222	coord223	coord224	coord225	coord226	coord227	coord228	coord229	coord230	coord231	coord232	coord233	coord234	coord235	coord236	coord237	coord238	coord239	coord240	coord241	coord242	coord243	coord244	coord245	coord246	coord247	coord248	coord249	coord250	coord251	coord252	coord253	coord254	coord255	coord256	coord257	coord258	coord259	coord260	coord261	coord262	coord263	coord264	coord265	coord266	coord267	coord268	coord269	coord270	coord271	coord272	coord273	coord274	coord275	coord276	coord277	coord278	coord279	coord280	coord281	coord282	coord283	coord284	coord285	coord286	coord287	coord288	coord289	coord290	coord291	coord292	coord293	coord294	coord295	coord296	coord297	coord298	coord299	coord300	coord301	coord302	coord303	coord304	coord305	coord306	coord307	coord308	coord309	coord310	coord311	coord312	coord313	coord314	coord315	coord316	coord317	coord318	coord319	coord320	coord321	coord322	coord323	coord324	coord325	coord326	coord327	coord328	coord329	coord330	coord331	coord332	coord333	coord334	coord335	coord336	coord337	coord338	coord339	coord340	coord341	coord342	coord343	coord344	coord345	coord346	coord347	coord348	coord349	coord350	coord351	coord352	coord353	coord354	coord355	coord356	coord357	coord358	coord359	coord360	coord361	coord362	coord363	coord364	coord365	coord366	coord367	coord368	coord369	coord370	coord371	coord372	coord373	coord374	coord375	coord376	coord377	coord378	coord379	coord380	coord381	coord382	coord383	coord384	coord385	coord386	coord387	coord388	coord389	coord390	coord391	coord392	coord393	coord394	coord395	coord396	coord397	coord398	coord399	coord400	coord401	coord402	coord403	coord404	coord405	coord406	coord407	coord408	coord409	coord410	coord411	coord412	coord413	coord414	coord415	coord416	coord417	coord418	coord419	coord420	coord421	coord422	coord423	coord424	coord425	coord426	coord427	coord428	coord429	coord430	coord431	coord432	coord433	coord434	coord435	coord436	coord437	coord438	coord439	coord440	coord441	coord442	coord443	coord444	coord445	coord446	coord447	coord448	coord449	coord450	coord451	coord452	coord453	coord454	coord455	coord456	coord457	coord458	coord459	coord460	coord461	coord462	coord463	coord464	coord465	coord466	coord467	coord468	coord469	coord470	coord471	coord472	coord473	coord474	coord475	coord476	coord477	coord478	coord479	coord480	coord481	coord482	coord483	coord484	coord485	coord486	coord487	coord488	coord489	coord490	coord491	coord492	coord493	coord494	coord495	coord496	coord497	coord498	coord499	coord500	coord501	coord502	coord503	coord504	coord505	coord506	coord507	coord508	coord509	coord510	coord511	coord512	coord513	coord514	coord515	coord516	coord517	coord518	coord519	coord520	coord521	coord522	coord523	coord524	coord525	coord526	coord527	coord528	coord529	coord530	coord531	coord532	coord533	coord534	coord535	coord536	coord537	coord538	coord539	coord540	coord541	coord542	coord543	coord544	coord545	coord546	coord547	coord548	coord549	coord550	coord551	coord552	coord553	coord554	coord555	coord556	coord557	coord558	coord559	coord560	coord561	coord562	coord563	coord564	coord565	coord566	coord567	coord568	coord569	coord570	coord571	coord572	coord573	coord574	coord575	coord576	coord577	coord578	coord579	coord580	coord581	coord582	coord583	coord584	coord585	coord586	coord587	coord588	coord589	coord590	coord591	coord592	coord593	coord594	coord595	coord596	coord597	coord598	coord599	coord600	coord601	coord602	coord603	coord604	coord605	coord606	coord607	coord608	coord609	coord610	coord611	coord612	coord613	coord614	coord615	coord616	coord617	coord618	coord619	coord620	coord621	coord622	coord623	coord624	coord625	coord626	coord627	coord628	coord629	coord630	coord631	coord632	coord633	coord634	coord635	coord636	coord637	coord638	coord639	coord640	coord641	coord642	coord643	coord644	coord645	coord646	coord647	coord648	coord649	coord650	coord651	coord652	coord653	coord654	coord655	coord656	coord657	coord658	coord659	coord660	coord661	coord662	coord663	coord664	coord665	coord666	coord667	coord668	coord669	coord670	coord671	coord672	coord673	coord674	coord675	coord676	coord677	coord678	coord679	coord680	coord681	coord682	coord683	coord684	coord685	coord686	coord687	coord688	coord689	coord690	coord691	coord692	coord693	coord694	coord695	coord696	coord697	coord698	coord699	coord700	coord701	coord702	coord703	coord704	coord705	coord706	coord707	coord708	coord709	coord710	coord711	coord712	coord713	coord714	coord715	coord716	coord717	coord718	coord719	coord720	coord721	coord722	coord723	coord724	coord725	coord726	coord727	coord728	coord729	coord730	coord731	coord732	coord733	coord734	coord735	coord736	coord737	coord738	coord739	coord740	coord741	coord742	coord743	coord744	coord745	coord746	coord747	coord748	coord749	coord750	coord751	coord752	coord753	coord754	coord755	coord756	coord757	coord758	coord759	coord760	coord761	coord762	coord763	coord764	coord765	coord766	coord767	coord768	coord769	coord770	coord771	coord772	coord773	coord774	coord775	coord776	coord777	coord778	coord779	coord780	coord781	coord782	coord783	coord784	coord785	coord786	coord787	coord788	coord789	coord790	coord791	coord792	coord793	coord794	coord795	coord796	coord797	coord798	coord799	coord800	coord801	coord802	coord803	coord804	coord805	coord806	coord807	coord808	coord809	coord810	coord811	coord812	coord813	coord814	coord815	coord816	coord817	coord818	coord819	coord820	coord821	coord822	coord823	coord824	coord825	coord826	coord827	coord828	coord829	coord830	coord831	coord832	coord833	coord834	coord835	coord836	coord837	coord838	coord839	coord840	coord841	coord842	coord843	coord844	coord845	coord846	coord847	coord848	coord849	coord850	coord851	coord852	coord853	coord854	coord855	coord856	coord857	coord858	coord859	coord860	coord861	coord862	coord863	coord864	coord865	coord866	coord867	coord868	coord869	coord870	coord871	coord872	coord873	coord874	coord875	coord876	coord877	coord878	coord879	coord880	coord881	coord882	coord883	coord884	coord885	coord886	coord887	coord888	coord889	coord890	coord891	coord892	coord893	coord894	coord895	coord896	coord897	coord898	coord899	coord900	coord901	coord902	coord903	coord904	coord905	coord906	coord907	coord908	coord909	coord910	coord911	coord912	coord913	coord914	coord915	coord916	coord917	coord918	coord919	coord920	coord921	coord922	coord923	coord924	coord925	coord926	coord927	coord928	coord929	coord930	coord931	coord932	coord933	coord934	coord935	coord936	coord937	coord938	coord939	coord940	coord941	coord942	coord943	coord944	coord945	coord946	coord947	coord948	coord949	coord950	coord951	coord952	coord953	coord954	coord955	coord956	coord957	coord958	coord959	coord960	coord961	coord962	coord963	coord964	coord965	coord966	coord967	coord968	coord969	coord970	coord971	coord972	coord973	coord974	coord975	coord976	coord977	coord978	coord979	coord980	coord981	coord982	coord983	coord984	coord985	coord986	coord987	coord988	coord989	coord990	coord991	coord992	coord993	coord994	coord995	coord996	coord997	coord998	coord999	coord1000
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33

Physician Name

Dr. ABCD

Patient Information

Patient Name

TEST V_RWO

Patient ID

010101

Date

12/20/10

End of Exam Dosimetry

Total KAP

0.01

Gy^{m2}

Reference Point Air Kerma

0.58

Gy

Total Acquisition Air Kerma

0.47

Gy

Total Fluoroscopy Air Kerma

0.12

Gy

Total Fluoroscopy Time

8.10

s

Quality Assurance

Peak Skin Dose including Ruoro

0.42

Gy

Skin area with more than 50% of the peak skin dose

66

cm²

Action level 6 Gy exceeded?

☒ Yes ☐ No

Serious event exceeded?

☐ Yes ☒ No

ID	Gender	Procedure	KAP/air kerma (cm2)	Number of the scans	Number of Fluoro	Peak skin dose	Total area radiated (cm ²)
Test	f	IR Embolization (non-Neuro)	245.7	180	162	4.3 Gy	1068

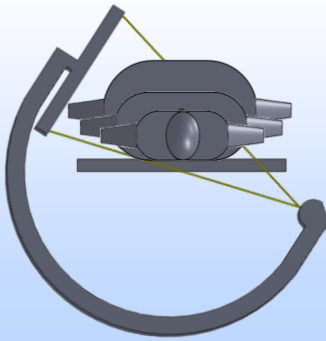
Table: 0.8; Machine : 0.8; BSF: 1.4 TAR:1.06

35

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

36

Skin Dose 'angled views and patient size'



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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 Testino



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Poor Protocol: High DSA and Fluoro Rate

Exam Sets

1	Tube Check/Place	O Tube Single	Nephrostomy Single	FL Angio Low 7.5 F/s	FL Angio Med 7.5 F/s	FL Angio High 15 F/s
2	Venous Access	PICC Single	Tunneled Single	FL Angio Low 7.5 F/s	FL Angio Med 7.5 F/s	FL Angio High 15 F/s
3	Aorta	Aorta 4 F/s	AAA 2 F/s	FL Angio Low 7.5 F/s	FL Angio Med 15 F/s	FL Angio High 30 F/s
4	Vas Aorta	Aorta 4 F/s	AAA 2 F/s	FL LD Low 7.5 F/s	FL LD Med 7.5 F/s	FL LD High 15 F/s
5	Chemo Embo	Common Hepatic 2 F/s	Rt Hepatic 2 F/s	FL Angio Low 7.5 F/s	FL Angio Med 7.5 F/s	FL Angio High 15 F/s

Profile: UNIVERSAL

Display Roadmap

Buttons: Delete, Save As New, Edit Prog, Apply

Programs: Acq

Show List

Close Editor Help

Reporting

General Search | Patient Report | **Reporting** | Issues/Alerts | Protocol

Reports

7-PSDReport by Protocol and Physician

PSDReport by Protocol

Peak Skin Dose Report

Please input the following information for your report.

Start Date: 01/01/2011

The first Date that the report will include

End Date: 06/09/2011

The Last Date that the report will include

Physician: ALL

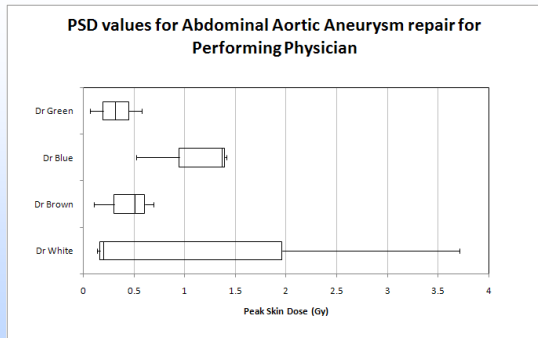
First Physician Name

Procedure: **Aortic Aneurysm Repair**

Exam Procedures

Generate Report

DMAIC: Physician Report – Shine a Light!



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Triggers/Alerts

General Search | Patient Report | Reporting | **Triggers/Alerts** | Protocol

Triggers/Alerts

7-High PSD Value

TriggerID	7
Title	High PSD Value
Explanation	Alert when instance has Peak Skin Dose greater than (vLimit) in one exam. (vLimit) 3 Unit: Gy
Enabled	☒
To Email Address	william.pavlicek@mayo.edu
Email Title	Peak Skin Dose Alert
Email Content Template	The peak skin dose of this exam has exceeded the action level of (vLimit) Gy. PATIENT ID: (Patient_ID) Available Template Words (Click to add) (Patient_ID) (Accession) (Date_of_Exam) (vLimit)

Update Cancel

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!



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Team Members and I 'Thank you'!



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