Joint ICTP-IAEA
Workshop on Establishment and Utilization of Diagnostic Reference Levels in Medical Imaging

ICTP

18 - 22 November 2019
Trieste, Italy

Further information:
http://indico.ictp.it/event/8729/
smr3333@ictp.it

Skin dose assessment
Trigger levels for patient follow-up

OBJECTIVES OF RADIATION PROTECTION

Two main objectives of radiation protection of the patient in interventional radiology are:

1. minimizing the risk of stochastic effects such as cancer induction or hereditary effects. As these risks are proportioned to the radiation dose to the radiosensitive organ, this may be achieved in practice by reducing patient doses.
2. avoiding, when possible, the risk of deterministic injuries occurring.

High Radiation Doses

- High radiation doses in the skin of patients may be produced during interventional procedures, especially:
  - In complex procedures.
  - In obese patients.
  - With repeated procedures on the same patient.
  - Non optimised X-ray equipment.
  - With operators not applying optimization criteria (and appropriate protocols) during procedures.

Not always such risk (and skin injury) is recognized by interventionists.

Deterministic Risk

- Shope T; Radiation-induced skin injuries from fluoroscopy; Radiographics 1996

Deterministic Risk

Fluoroscopically Guided Interventional Procedures: A Review of Radiation Effects on Patients' Skin and Hair[1]

Stephen Balter, PhD

Most advice currently available with regard to fluorosco

eactions from Single-Delivery Radiation Dose to Skin of the Neck, Torso, Pelvis, Buttocks, or Arms

Band	Single-Site Acute Skin-Dose Range (Gy)*	NCI Skin Reaction Grade†	Approximate Time of Onset of Effects: Prompt	Early	Midterm	Long Term
A1	0–2	NA	No observable effects expected	No observable effects expected	No observable effects expected	No observable effects expected
A2	2–5	1	Transient erythema	Epilation	Recovery from hair loss	No observable results expected
B	5–10	1–2	Transient erythema	Erythema, epilation	Recovery; at higher doses, prolonged erythema, permanent partial epilation	Recovery; at higher doses, dermal atrophy or induration
C	10–15	2–3	Transient erythema	Erythema, epilation; possible dry or moist desquamation; recovery from desquamation	Prolonged erythema; permanent epilation	Telangiectasia‡; dermal atrophy or induration; skin likely to be weak
D	>15	3–4	Transient erythema; after very high doses, edema and acute ulceration; long-term surgical intervention likely to be required	Erythema, epilation; moist desquamation	Dermal atrophy; secondary ulceration due to failure of moist desquamation to heal; surgical intervention likely to be required; at higher doses, dermal necrosis, surgical intervention likely to be required	Telangiectasia‡; dermal atrophy or induration; possible late skin breakdown;wound might be persistent and progress into a deeper lesion; surgical intervention likely to be required

- Balter S et al.; Fluoroscopically guided interventional procedures: a review of radiation effects on patients' skin and hair; Radiology 2010

Skin Dose

- Measured
- Estimated
- Calculated

Skin Dose

- **Measured**
- Estimated
- Calculated

Skin Dose – Measurements

- Termoluminescent dosimetry

Phys Med. 2015 Dec;31(8):1112-1117. doi: 10.1016/j.ejmp.2015.08.006. Epub 2015 Oct 4.

Characterisation of grids of point detectors in maximum skin dose measurement in fluoroscopically-guided interventional procedures.

Dabin J[1], Negri A[2], Farah J[3], Ciraj-Bjelac O[4], Clairand I[3], De Angelis C[5], Domienik J[6], Jarvinen H[7], Kopec R[8], Majer M[9], Malchair F[10], Novák L[11], Siiskonen T[7], Vanhavere F[12], Trianni A[13], Knežević Ž[9].

Author information

Skin Dose – Measurements

- Gafchromic film

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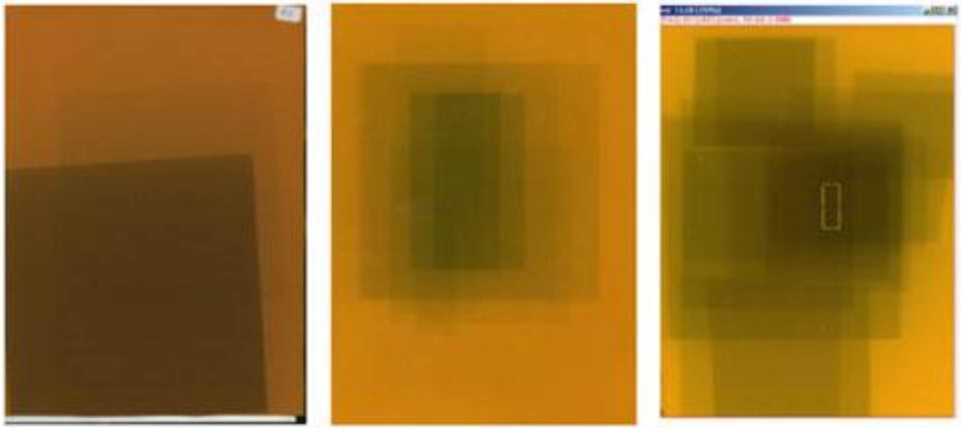
Author information



Uncertainties

Uncertainty parameter		Uncertainty value (2σ)
Calibration uncertainties	Air Kerma rate	5%
	Field uniformity and flatness	
	Repeatability	
Reading equipment uncertainties	Scan repeatability	0.5%
	Scan uniformity	2%
	Long term stability	
Film uncertainties	Batch uniformity	2%
	Polymerization	1%
	Energy dependence	30%*
	Dose rate dependence	0.5%
	Fitting uncertainty	1%**
TLD uncertainty	Energy response	20%
	Signal fading correction	1%

- Farah et al; Characterization of XR-RV3 GafChromic® films in standard laboratory and in clinical conditions and means to evaluate uncertainties and reduce errors; 2015

Skin Dose – Measurements

- Films = 2D spatial distribution, easy to use but high uncertainties
  - On average 20%
  - Can be reduce to within 5%
  - Can easily increase to over 40% if minimal care is not taken
- TLDs → More accurate and multiple usage possible but point measurements → risk of missing data

Skin Dose – Measurements

- «Easy» to perform
- Not for every patient
- Calibration, reading, fitting, and other film-related and scan-related processes need to be performed carefully in order to control the accuracy of the measurement

Skin Dose

- Measured
- **Estimated**
- Calculated

Skin Dose

- Measured
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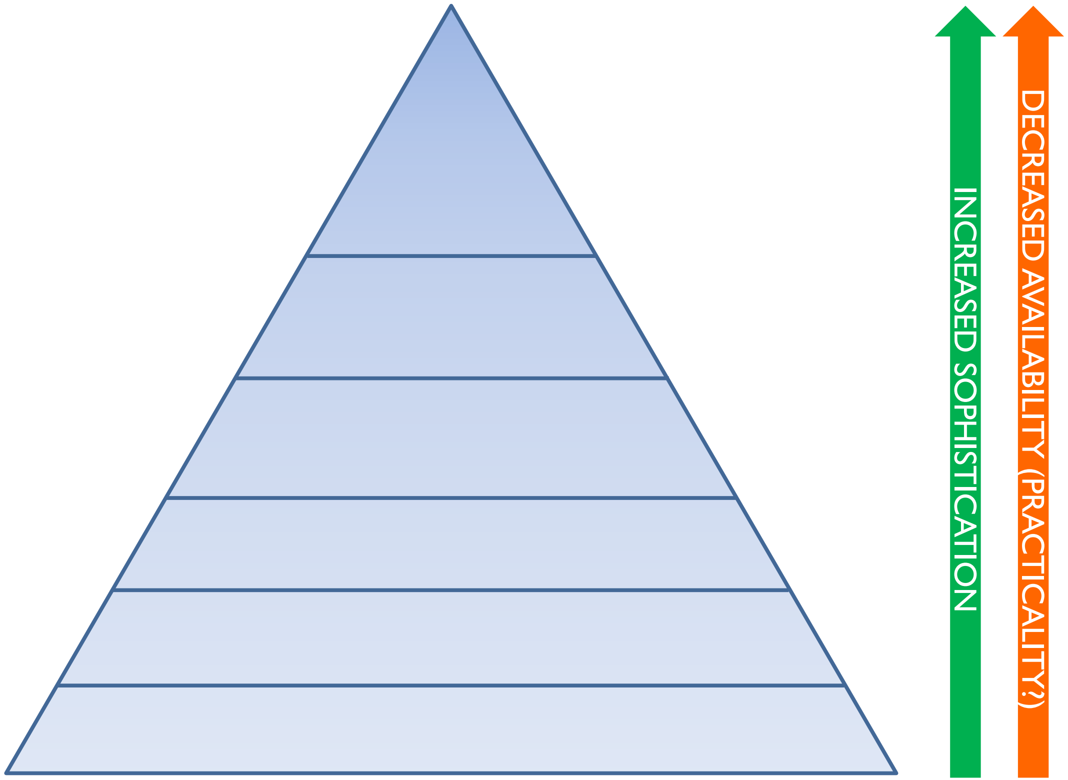

- Adapted from EFOMP-AAPM TG 246

Skin Dose

REFERENCE AIR KERMA AND AIR KERMA-AREA PRODUCT

Skin Dose

- Readily available since 2006
- Well defined IRP
- Includes Fluoro AND Acquisitions

REFERENCE AIR KERMA AND AIR KERMA-AREA PRODUCT

Adapted from EFOMP-AAPM TG 246

Trigger Levels

Trigger levels → dose alerts to help the operators identifying procedures potentially at risk for skin injuries

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The relevant risk quantity is absorbed dose in the skin at the site of maximum cumulative skin dose. A helpful approach is to select values for maximum cumulative absorbed dose in the skin at which various clinical actions regarding the patient's record or care (related to potential radiation-induced skin injuries) are taken (ICRP, 2000b).

Trigger Levels

Trigger levels → dose alerts to help the operators identifying procedures potentially at risk for skin injuries

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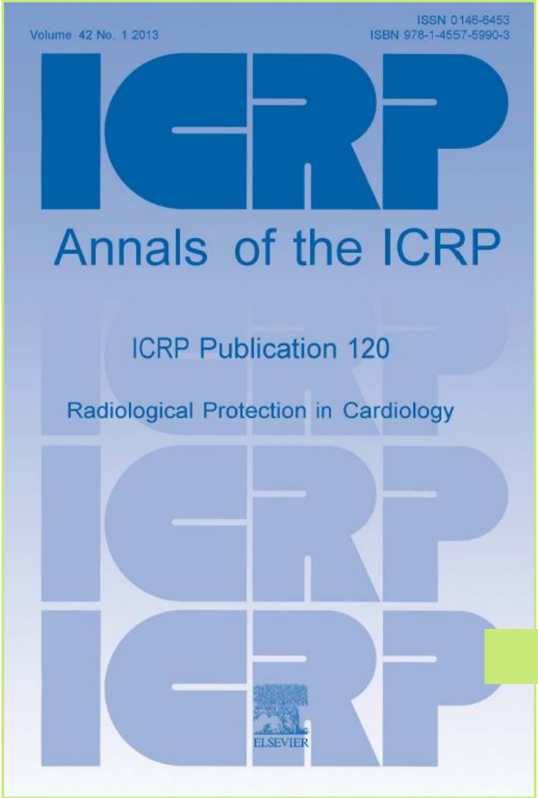
Skin dose cannot be assessed in real time. Therefore **procedures for estimating and monitoring skin dose in daily practice** need to be developed and on line dose indicators that could alert the physician about radiation risk should be individuate.

Trigger Levels

As stated in the ICRP 105:

"Diagnostic Reference Levels are not applicable to the management of deterministic effects …. In this case, the objective is to avoid tissue reactions in individual patients undergoing justified but long and complex procedures. The need here is to monitor, in real time, whether the ***threshold doses*** *for deterministic effects (tissue reactions) are being approached or exceeded for the actual procedure as conducted on a particular patient."*

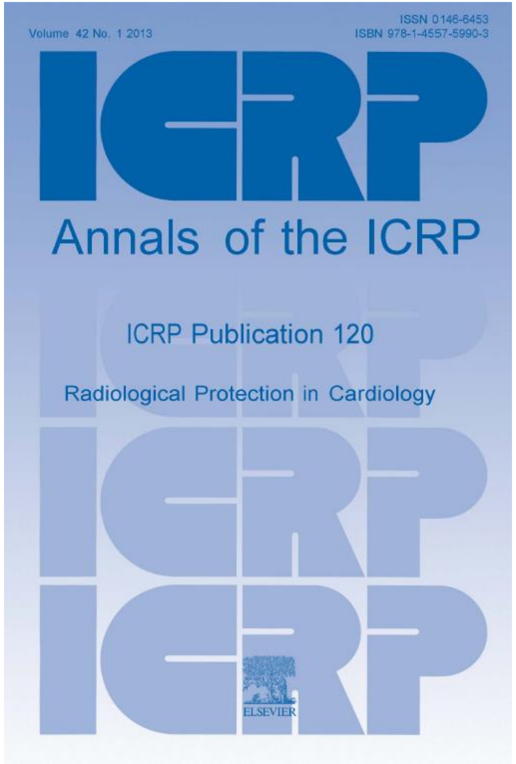
Trigger Levels and Follow up



Trigger Levels are used to trigger additional dose-management actions.

Guidelines

- The QA programme should establish a trigger level for individual clinical follow-up when there is a risk of radiation-induced skin injuries.
- Patient dose reports should be produced at the end of procedures, archived, and recorded in the patient's medical record.
- If dose reports are not available, dose values should be recorded in the patient's medical record together with the procedure and patient identification.



Different approaches in real practice

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- What is available in the operating room?
  - FT? KAP? CK? All?

Different approaches in real practice

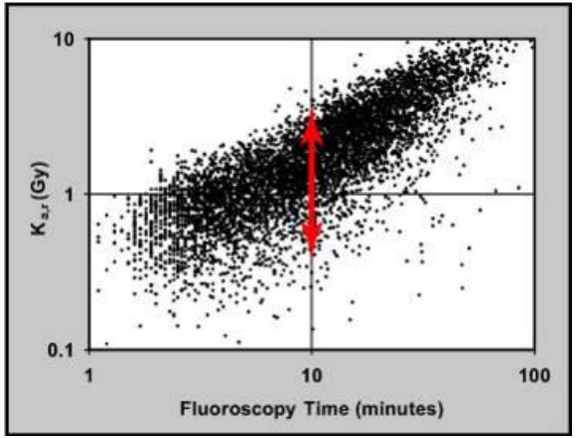
- What is available in the operating room?
  - FT? KAP? CK? All?
  - Real time skin dosimetry?

Different approaches in real practice

- What is available in the operating room?
  - FT

Fluoroscopy Time

For years, fluoroscopy time (FT) has been the parameter of choice to evaluate the dose received by the patient during an interventional procedure.



But FT does not correlate with patient dose → not the correct parameter for patient skin dose

Different approaches in real practice

- What is available in the operating room?
  - KAP and CK

Strategy

- Choice of "critical" procedures
- Select the dosimeter and measure skin dose
- Look for a correlation with online dose indicators to evaluate Trigger (or Alert) Levels

Which procedures?

PROCEDURE	No.	FT (min)	KAP (Gycm²)	CK (mGy)
Cerebral Angiography	197	6.1 ± 8.2	71.1 ± 49.2	770.9 ± 887.4
Aneurysm Embolization	76	26.6 ± 13.5	135.4 ± 60.8	2153.7 ± 1345.3
Chemo-embolization	144	14.1 ± 7.7	210.5 ± 138.6	1136.3 ± 767.9
Embolizations	57	26.2 ± 41.6	269.7 ± 320.8	1384.7 ± 1472.0
Peripheral Angiography	145	1.4 ± 1.9	43.4 ± 29.3	154.5 ± 106.1
Lower limb Angioplasty	44	15.6 ± 9.9	24.7 ± 37.6	149.0 ± 237.6
Carotid Angioplasty	73	9.4 ± 5.5	53.7 ± 26.0	247.3 ± 135.7
Iliac Angioplasty	45	11.4 ± 9.8	80.5 ± 89.5	401.9 ± 293.8
Below-knee Angioplasty	27	17.9 ± 10.4	8.9 ± 14.3	101.8 ± 326.0
Renal Angioplasty	12	7.7 ± 3.5	48.8 ± 54.8	308.6 ± 270.3
AAA/AAT	13	11.6 ± 5.1	87.6 ± 50.3	495.7 ± 248.6
Brachyteraphy	9	22.6 ± 19.8	16.4 ± 14.6	104.1 ± 94.5
Cavography	7	7.5 ± 6.5	66.1 ± 53.8	273.3 ± 216.4
Fibrinolysis	10	19.9 ± 11.0	28.1 ± 29.6	113.2 ± 102.9
Caval Filter	10	7.0 ± 7.3	64.1 ± 98.3	236.7 ± 282.7
Fistolography	10	4.6 ± 4.0	4.5 ± 14.6	28.4 ± 109.2
Flebography	26	6.5 ± 16.1	28.4 ± 58.9	300.2 ± 803.9
HVPG measurement	10	9.1 ± 7.1	29.2 ± 18.1	167.0 ± 100.1
TIPS	13	20.5 ± 13.3	117.3 ± 74.1	827.5 ± 609.5
Epiaortic trunk angiography	13	3.6 ± 3.3	40.9 ± 30.5	221.3 ± 150.4
Vertebroplasty	13	13.0 ± 16.1	51.4 ± 26.0	392.7 ± 157.3

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Metholodogy

- Calibration of films/TLDs in clinical X-ray beams
- Positioning of films/TLDs on patient
- Exposure data collection (equipment + patient)
- Films/TLDs readings + analyze to estimate the MSD
- Correlation with online parameters (FT, KAP, CK)
- Uncertanties estimation

Measurements in a sample

- Termoluminescent dosimetry

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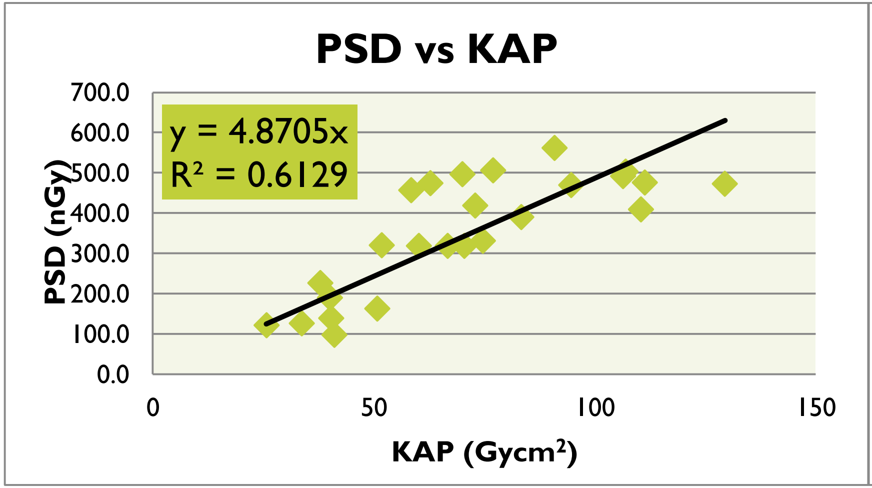
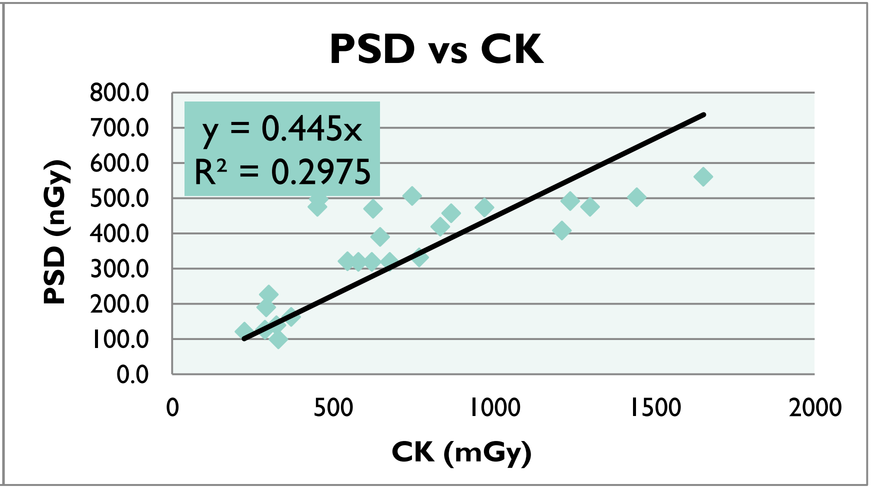
Author information

Cerebral angiography

No.	PSD (mGy)	Range (mGy)
25	352.4 ± 145.4	98.8 ÷ 561.9

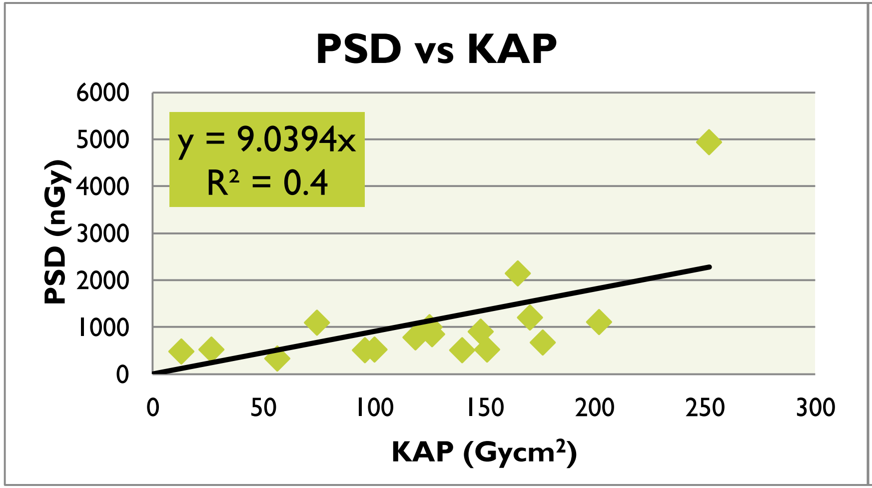


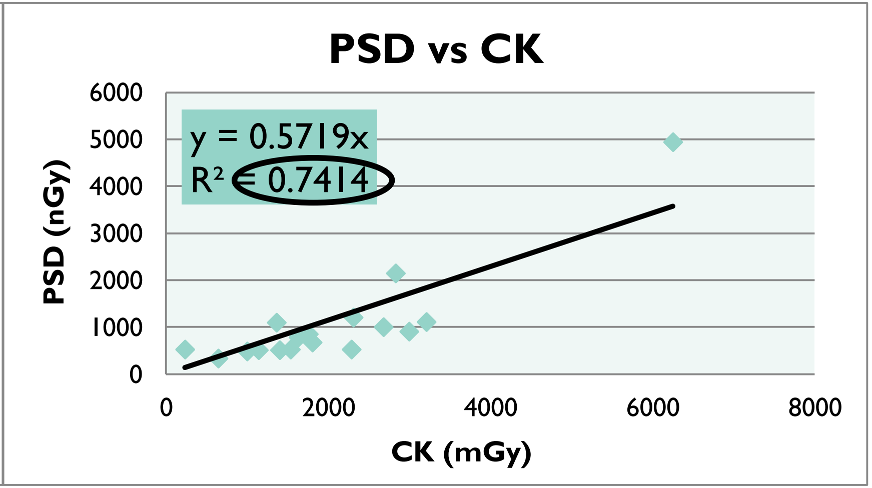


- Trianni et al; Assessment of trigger levels to prevent tissue reaction in interventional radiology procedures; 2010

Aneurysm embolisation

No.	PSD (mGy)	Range (mGy)
18	1072.5 ± 1085.2	332.2 ÷ 4941.9

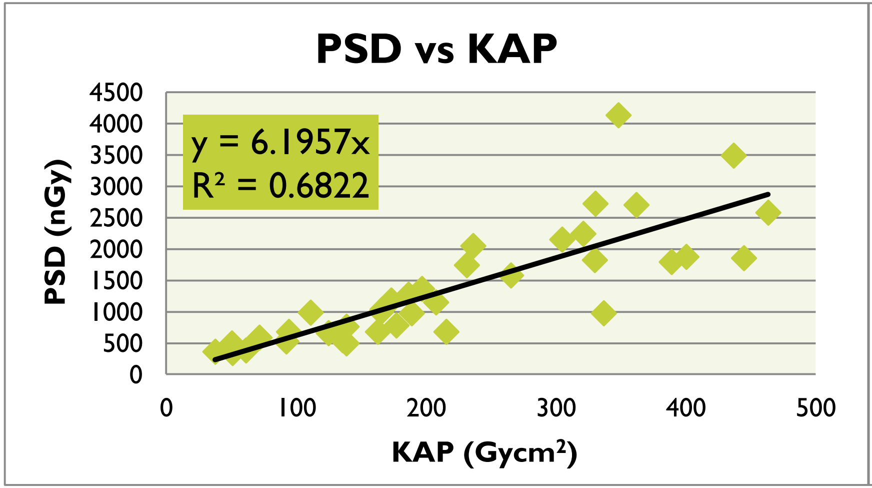


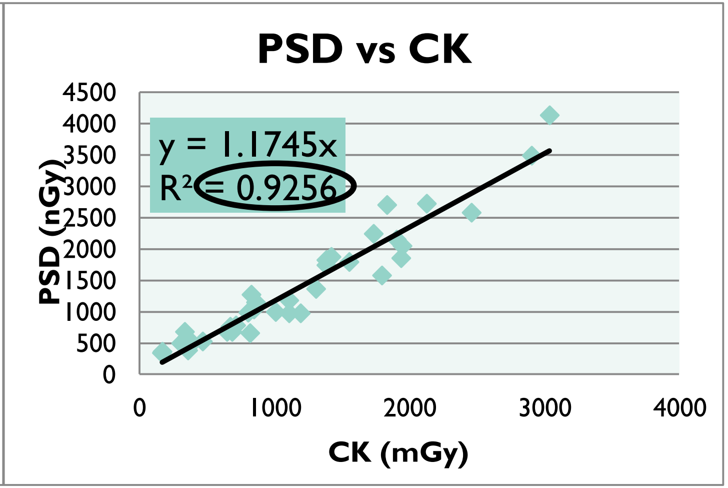


▶ Trianni et al; Assessment of trigger levels to prevent tissue reaction in interventional radiology procedures; 2010

Chemoembolisation

No.	PSD (mGy)	Range (mGy)
38	1343.8 ± 915.7	342.4 ÷ 4135.5





- Trianni et al; Assessment of trigger levels to prevent tissue reaction in interventional radiology procedures; 2010

Skin Dose – Reference Air Kerma

- ….not always

"Reality"

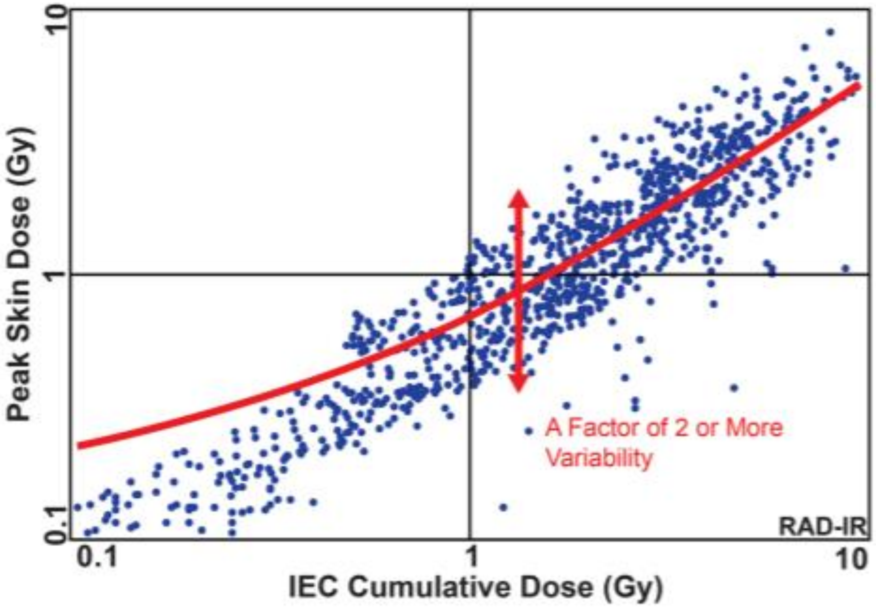
1a

0.0	0.0	0.2	0.2	0.0
0.0	0.2	0.3	0.3	0.2
0.1	0.3	0.5	0.4	0.3
0.1	0.3	0.4	0.4	0.2
0.0	0.2	0.3	0.2	0.1

"Cumulative AK"

1b

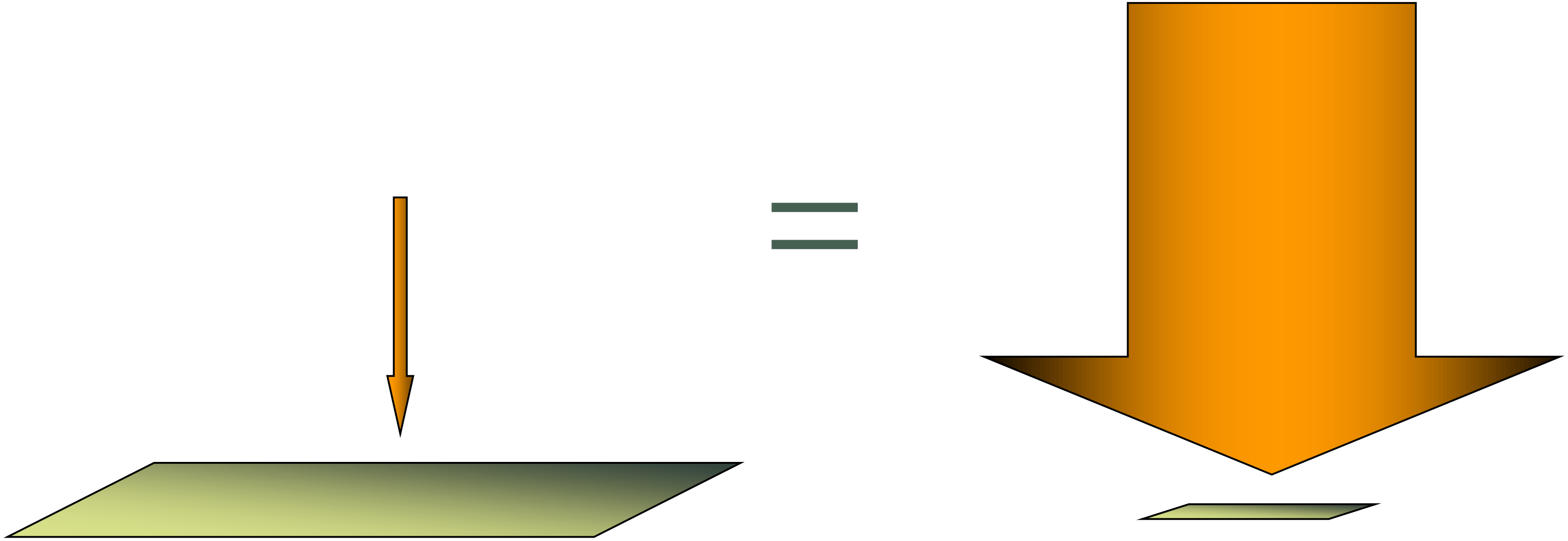
0	0	0	0	0
0	0	0	0	0
0	0	5.2	0	0
0	0	0	0	0
0	0	0	0	0



- Courtesy of S. Balter

Skin Dose – Air Kerma Area Product

- Not a very good indicator



Stecker and al. (2005)

Guidelines for Patient Radiation Dose Management

Michael S. Stecker, MD, Stephen Balter, PhD, Richard B. Towbin, MD, Donald L. Miller, MD, Eliseo Vañó, PhD, Gabriel Bartal, MD, J. Fritz Angle, MD, Christine P. Chao, MD, Alan M. Cohen, MD, Robert G. Dixon, MD, Kathleen Gross, MSN, RN-BC, CRN, George G. Hartnell, MD, Beth Schueler, PhD, John D. Statler, MD, Thierry de Baère, MD, and John F. Cardella, MD, for the SIR Safety and Health Committee and the CIRSE Standards of Practice Committee

J Vasc Interv Radiol 2009; 20:S263–S273

Abbreviations: ACR = American College of Radiology, FDA = Food and Drug Administration

Table 3
Summary of Radiation Monitoring Dose Notification Thresholds

Parameter	First Notification	Subsequent Notifications
Peak skin dose (PSD)	2,000 mGy	500 mGy
Reference point air kerma ($K_{a,r}$)	3,000 mGy	1,000 mGy
Kerma-area-product (P_{KA})	300 Gy · cm²*	100 Gy · cm²*
Fluoroscopy time (FT)	30 min	15 min

* Assuming a 100-cm² field at the patient's skin. The value should be adjusted to the actual procedural field size.

Table 4
Thresholds for Patient Follow-up

Parameter	Threshold
Peak skin dose (PSD)	3,000 mGy
Reference point air kerma ($K_{a,r}$)	5,000 mGy
Kerma-area-product (P_{KA})	500 Gy · cm²
Fluoroscopy time (FT)	60 min

NCRP 168 (2010)

TABLE 4.7–*Suggested values for first and subsequent notifications and the SRDL.*

Dose Metric	First Notification	Subsequent Notifications (increments)	SRDL
$D_{skin,max}$	2 Gy	0.5 Gy	3 Gy
$K_{a,r}$	3 Gy	1 Gy	5 Gy[a]
P_{KA}	300 Gy cm^2 [b]	100 Gy cm^2 [b]	500 Gy cm^2 [b]
Fluoroscopy time	30 min	15 min	60 min

[a]See additional discussion concerning the value 5 Gy in Section 4.3.4.2.

[b]Assuming a 100 cm^2 field at the patient's skin. For other field sizes, the P_{KA} values should be adjusted proportionally to the actual procedural field size (*e.g.*, for a field size of 50 cm^2, the SRDL value for P_{KA} would be 250 Gy cm^2).

Trianni et al. (2010)

Trigger Levels to prevent tissue reaction in interventional radiology procedures

Trianni Annalisa[1]; Gasparini Daniele[2]; Padovani Renato[1]
[1] Medical Physics Department, Udine University Hospital, ITALY
[2] Radiology Department, Udine University Hospital, ITALY

Local center Trigger Levels – 2010 Udine

ANEURYSM EMBOLISATION	CHEMIOEMBOLISATION
5200 mGy	2500 mGy

Vano et al. (2012)

Published August 2, 2012 as 10.3174/ajnr.A3211

Patient Radiation Dose Management in the Follow-Up of Potential Skin Injuries in Neuroradiology

Table 1: Dose values for cerebral embolizations

	DAP (Gy · cm^2)	Cumulative Dose (Gy)	DAP (Gy · cm^2)	Cumulative Dose (Gy)
Year	2009	2009	2010	2010
Sample	80	80	92	92
Median	242	2.4	270	2.5
3rd quartile	386	3.9	392	3.3
Mean	293	2.7	317	2.6
SD	188	1.7	234	1.5

Table 3: Dose reduction in entrance surface dose rate (with backscatter) measured with a PMMA phantom

	Low-Mode Fluoroscopy (mGy/min)	Normal-Mode Fluoroscopy (mGy/min)	DSA (mGy/image)
Normal dose (15 p/s in fluoro.) procedure	9.9	25.2	5.9
Low-dose (7.5 p/s in fluoro.) procedure	7.0	16.6	3.1
Dose reduction % (low dose/normal dose)	30	34	47

Note:—PMMA indicates polymethylmethacrylate. Focus-phantom distance: 67 cm; Focus image detector; 104 cm. 20-cm thickness of PMMA; FOV 31.1 cm. The dose per pulse in the new low-dose fluoroscopy mode has been increased in comparison with the "normal" one to reduce the noise.

- Trigger levels for a potential patient follow-up were adapted to the values recommended by the SIR-CIRSE guidelines (peak skin dose 3 Gy, CK 5 Gy, KAP 500 Gy.cm2, or FT 60 minutes).
- Cumulative skin dose of each of the planes (frontal and lateral) is considered independently as main trigger levels when one resulted in values 4 Gy,

Vano et al. (2013)

Cardiovasc Intervent Radiol (2013) 36:330–337
DOI 10.1007/s00270-012-0397-x

CLINICAL INVESTIGATION ARTERIAL INTERVENTIONS

Importance of a Patient Dosimetry and Clinical Follow-up Program in the Detection of Radiodermatitis After Long Percutaneous Coronary Interventions

Eliseo Vano · Javier Escaned · Sergio Vano-Galvan ·
Jose M. Fernandez · Carmen Galvan

«SIGNIFICANT RADIATION DOSE»:

- 3 Gy **PSD**
- 5 Gy **CAK**
- 500 Gy.cm^2 **KAP**
- 60 min $\mathbf{F_T}$

Jarvinen et al. (2018)

Original paper

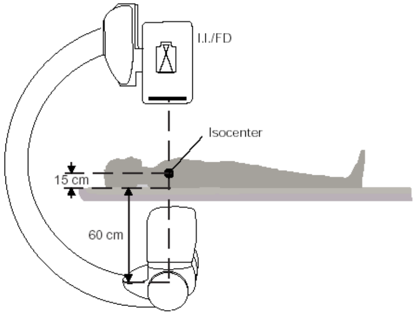
Feasibility of setting up generic alert levels for maximum skin dose in fluoroscopically guided procedures

Hannu Jarvinen[a,*], Jad Farah[b,1], Teemu Siiskonen[a], Olivera Ciraj-Bjelac[c], Jérémie Dabin[d], Eleftheria Carinou[e], Joanna Domienik-Andrzejewska[f], Dariusz Kluszczynski[g], Željka Knežević[h], Renata Kopec[i], Marija Majer[h], Francoise Malchair[j], Anna Negri[k], Piotr Pankowski[g], Sandra Sarmento[l], Annalisa Trianni[m]

The project

↗ Ten European Countries

- Measurement tools
  - XR-RV3 gafchromic films
  - TLDs chips (MTS - MCP)
- Interventional procedures
  - Neuro-embolizations (NE)
  - Chemo-embolizations (CE)
  - Coronary angioplasties (PTCA)
- Online dose indicators
  - Fluoroscopy time (FT)
  - Kerma-area product (KAP)
  - Cumulative air kerma (CK)



Data collection and analysis

Methodology

- Calibration of films/TLDs in clinical X-ray beams
- Positioning of films/TLDs on patient
- Exposure data collection (equipment + patient)
- Films/TLDs readings + analyze to estimate the MSD
- Correlation with online parameters (FT, KAP, CK)
- Uncertanties estimation

Positioning of films

Positioning of TLDs

85 TLDs for CE & PTCA (spacing 8 cm)
38 TLDs for NE (spacing 5.5 cm)

Uncertanties

- Uncertainties estimation:
  - Uncertainty on chamber readings
  - Film dose response with :
    - Energy
    - Dose rate
    - Postexposure growth
    - Uniformity
  - Scanner characteristic
    - Uniformity
    - Reproducibility
  - Calibration fit
  - KAP meter
  - Correlation

Results

Table 5
Suggested generic alert levels for MSD of 2 Gy and 5 Gy, based on mean alert levels of selected countries (countries which had roughly consistent alert levels).

Procedure	Suggested alert level, DAP (Gy cm^2)		Mean alert level DAP (Gy cm^2)		Number of countries included
	for MSD = 2 Gy	for MSD = 5 Gy	for MSD = 2 Gy	for MSD = 5 Gy	
TACE	300	750	323	746	5
PCI	150	250	138	240	6
NE	200	400	189	389	7

Table 6
Comparison of alert levels in terms of DAP for MSD = 2 Gy suggested in this work with similar levels published earlier.

Procedure	Publication	Alert level, DAP Gy cm^2	Number of procedures	MSD measurement device
TACE	*This work*	*300*	*91*	*RC film*
	SAFRAD [26]	500		
	Struelens et al. [27]	330	30	TLD
	D'Alessio et al. [28]	530	15	RC film and micro MOSFET
	Miller et al. [29], Stecker et al. [30]	350	709	
PCI	*This work*	*150*	*49*	*RC film*
	SAFRAD [26]	300		
	ICRP [24]	150–250		
	NCRP [31]	300		
	Bogaert et al. [32]	125–250	318	TLD
	Domienik et al. [33]	345–415	27–54	RC film
	Trianni et al. [34]	140	33	RC film
NE	*This work*	*200*	*104*	*RC film and TLD*
	Struelens et al. [27]	240	30	TLD
	Sandborg et al. [35]	300	50	TLD
	Sandborg et al. [36]	430	71	TLD
	Moritake et al. [37]	185	35	PLD
	Moritake et al. [38]	300	28	PLD
	D'Ercole et al. [39]	700	21	RC film

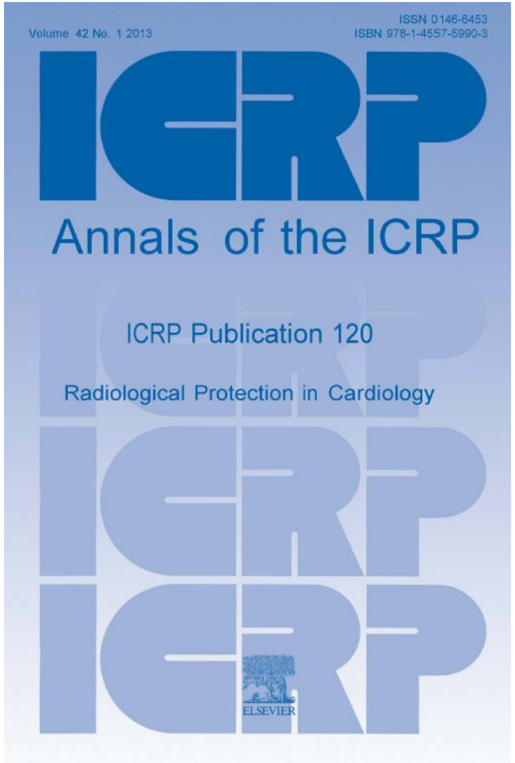
Skin Dose

REFERENCE AIR KERMA AND AIR KERMA-AREA PRODUCT

- Readily available since 2006
- Well defined IRP
- Includes Fluoro AND Acquisitions
- Not accurate
- Defined in air
- No spatial components

Adapted from EFOMP-AAPM TG 246

Guidelines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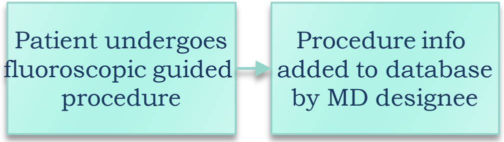
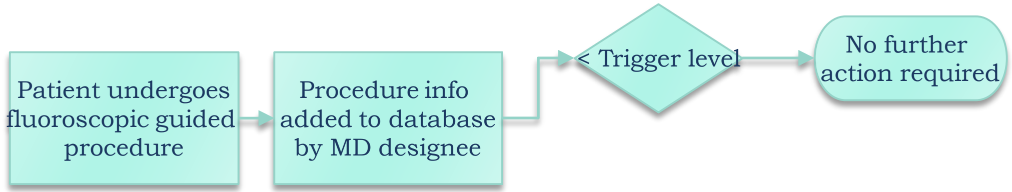
Annals of the ICRP
ICRP Publication 120
Radiological Protection in Cardiology
ELSEVIER

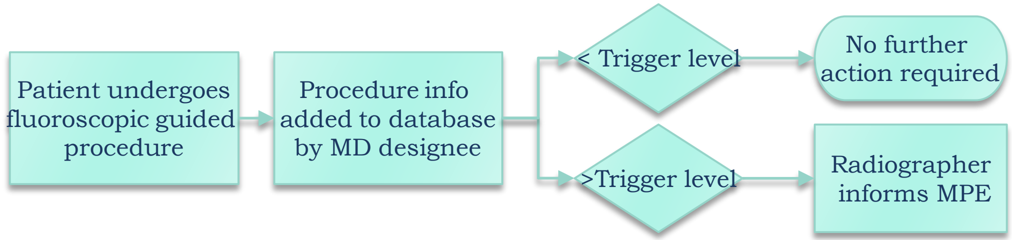
Follow Up scheme



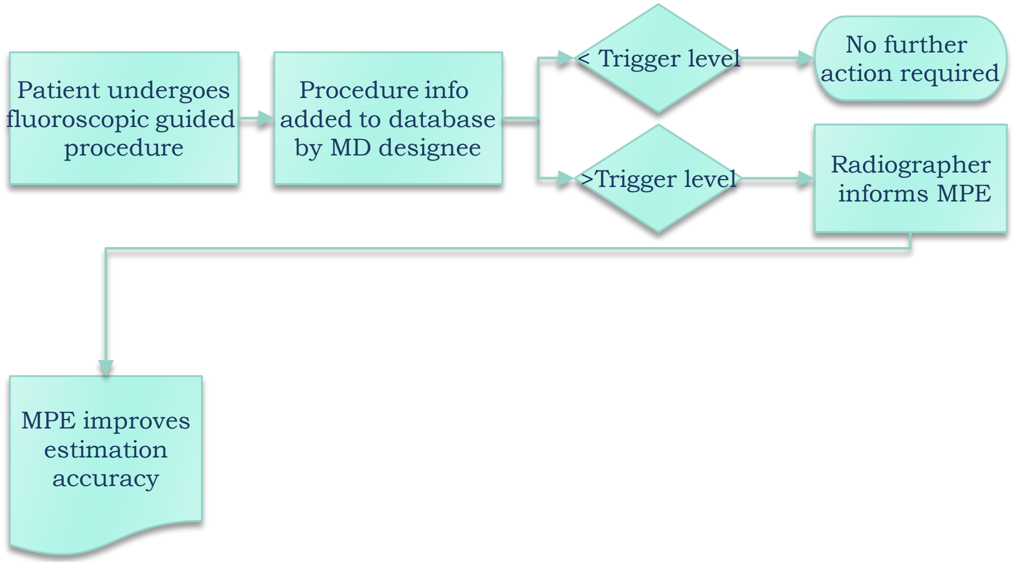
Follow Up scheme



Follow Up scheme



Follow Up scheme



From Reference Air Kerma to Skin Dose

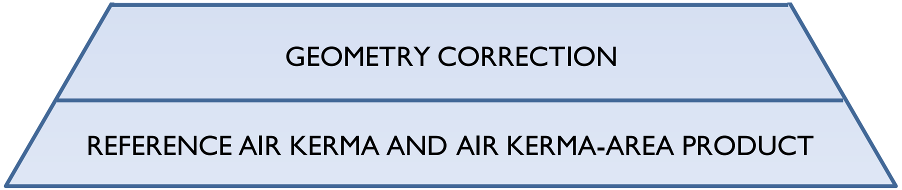
JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 12, NUMBER 4, FALL 2011

Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods

A. Kyle Jones,[1a] and Alexander S. Pasciak[2]

From Reference Air Kerma to Skin Dose

- Measured
- Estimated
- **Calculated**



- Adapted from EFOMP-AAPM TG 246

From CK_{RP} to CK_{pat} – ISL correction

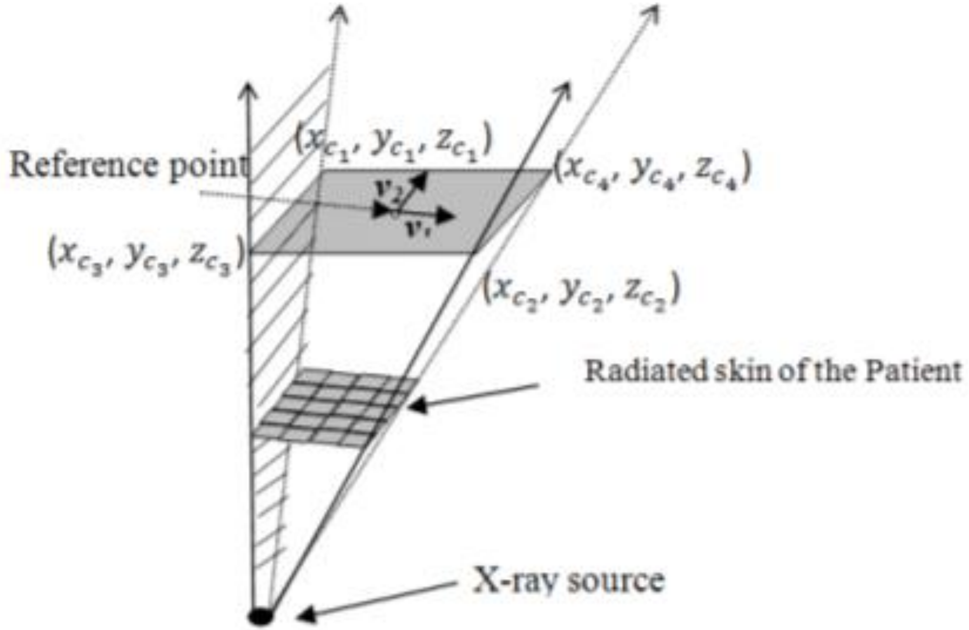
$$CK_{pat} = CK_{RP} \times \left(\frac{d_{source\ to\ RP}}{d_{source\ to\ patient}} \right)^2$$

ISL potential error

- The percent difference in dose calculation as a function of the mismatch in the distance along the beam direction can be up to 20%

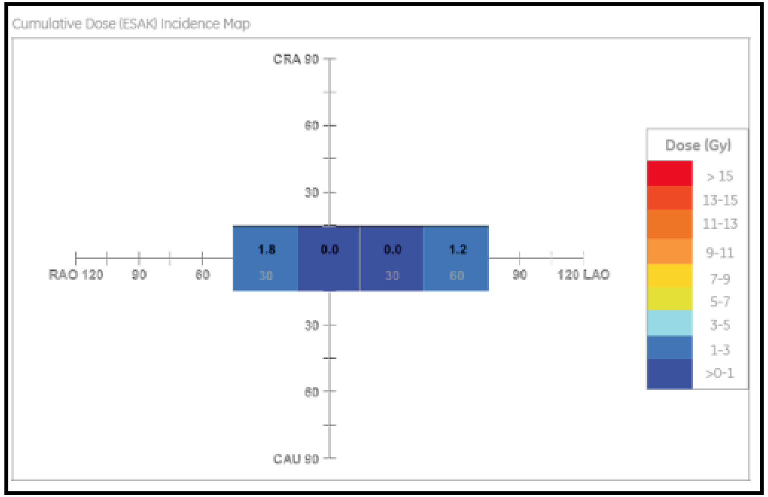
From CK_{RP} to CK_{pat} – Geometry

- Calculation has to be performed for each irradiation event, projecting the field on the table surface and taking into account the angles



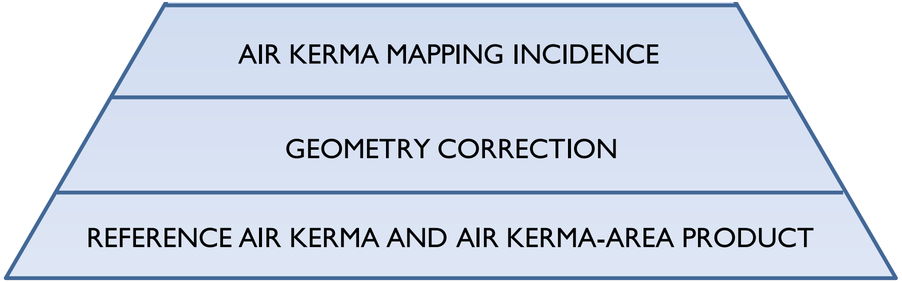
- Jones AK and Pasciak A; Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods; 2011

From Reference Air Kerma to Skin Dose



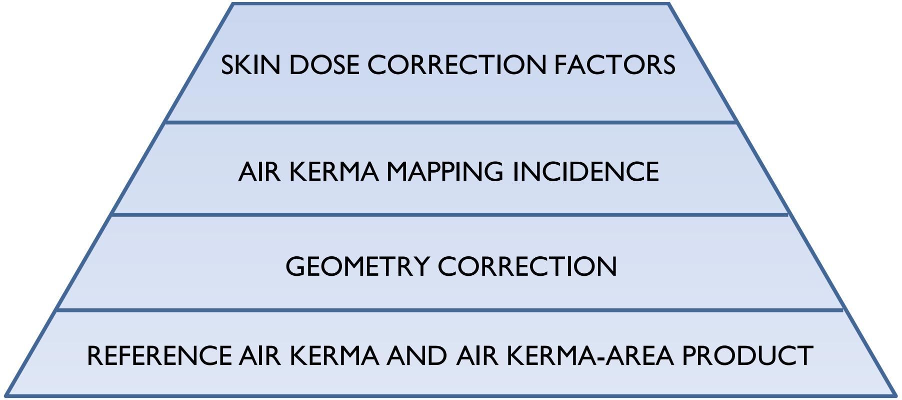
Sample for reference only, pulled from internal GE Innova Dose Report

- Baseline attempt at accounting for dose spread
- Not fully developed spatial consideration



▶ Adapted from EFOMP-AAPM TG 246

From Reference Air Kerma to Skin Dose



- Adapted from EFOMP-AAPM TG 246

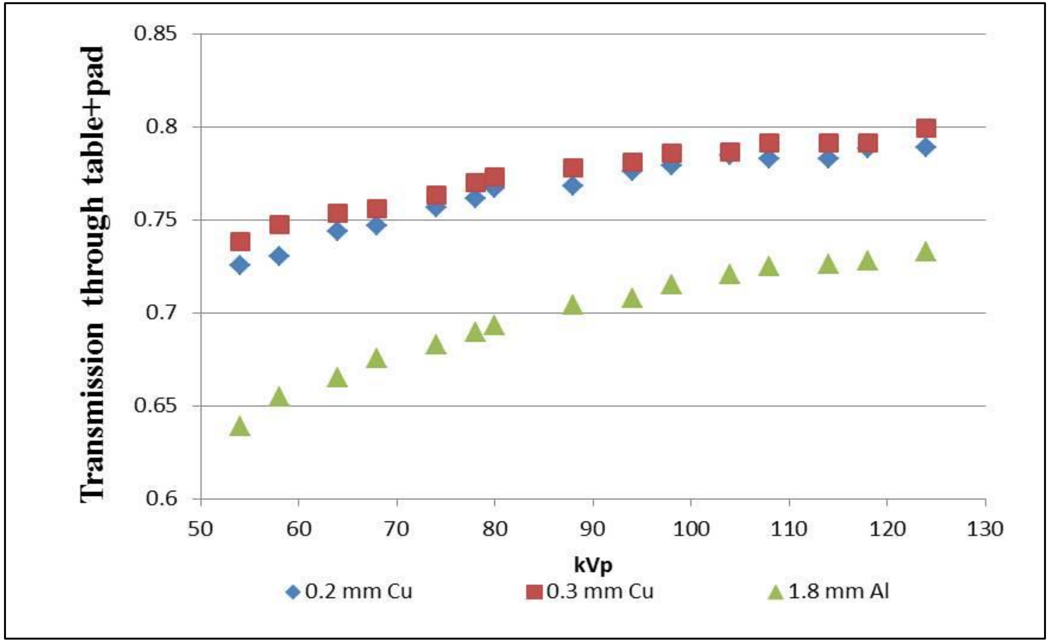
From CK_{RP} to CK_{pat} – Table and Pad

- Table normally attenuates primary beam by a small amount
- Thick table pad and some foam can reduce the iAK rate
- Need to know if CK is calibrated with or w/o table and pad

$$iAK = CK_{RP} \times \left(\frac{d_{source\ to\ RP}}{d_{source\ to\ patient}} \right)^2 \times t$$

From CK_{RP} to CK_{pat} – Table and Pad

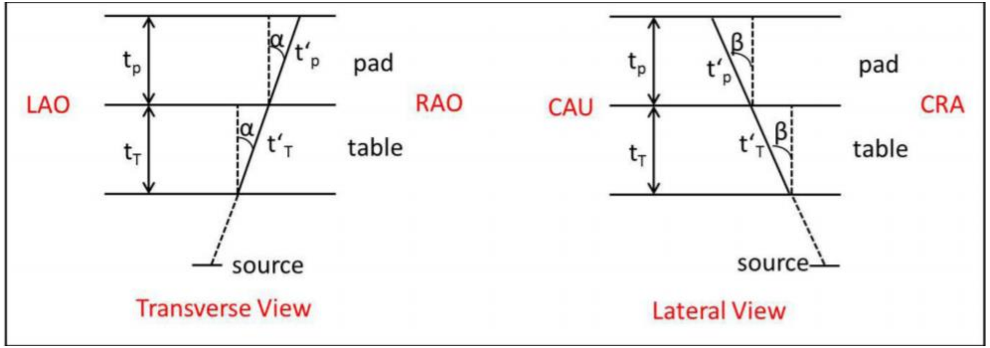
- Table and pad attenuation depends on beam quality

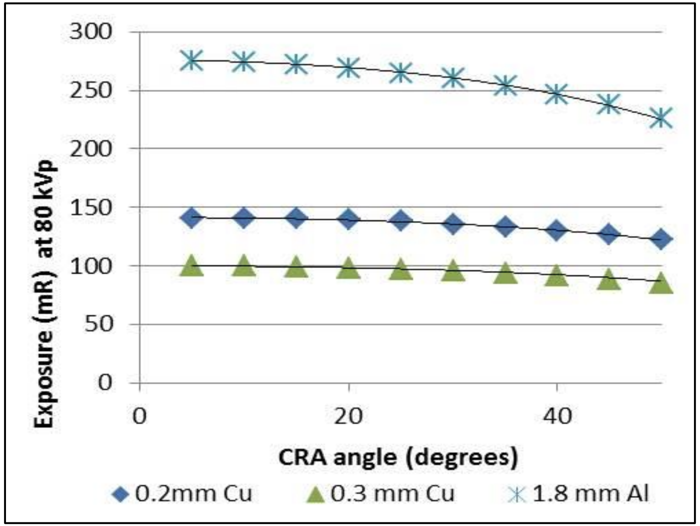


- Rana et al; Updates in the real-time Dose Tracking System (DTS) to improve the accuracy in calculating the radiation dose to the patients skin during fluoroscopic procedures; 2013

Table Attenuation Correction Potential Error

- Table and pad correction vary with angle





- Rana et al; Updates in the real-time Dose Tracking System (DTS) to improve the accuracy in calculating the radiation dose to the patients skin during fluoroscopic procedures; 2013

Table Attenuation Correction Potential Error

- Forward scatter:
  - The measured scatter fractions indicate that the patient table as well as the head holder contributes an additional 10-16% to the patient entrance dose depending on field size

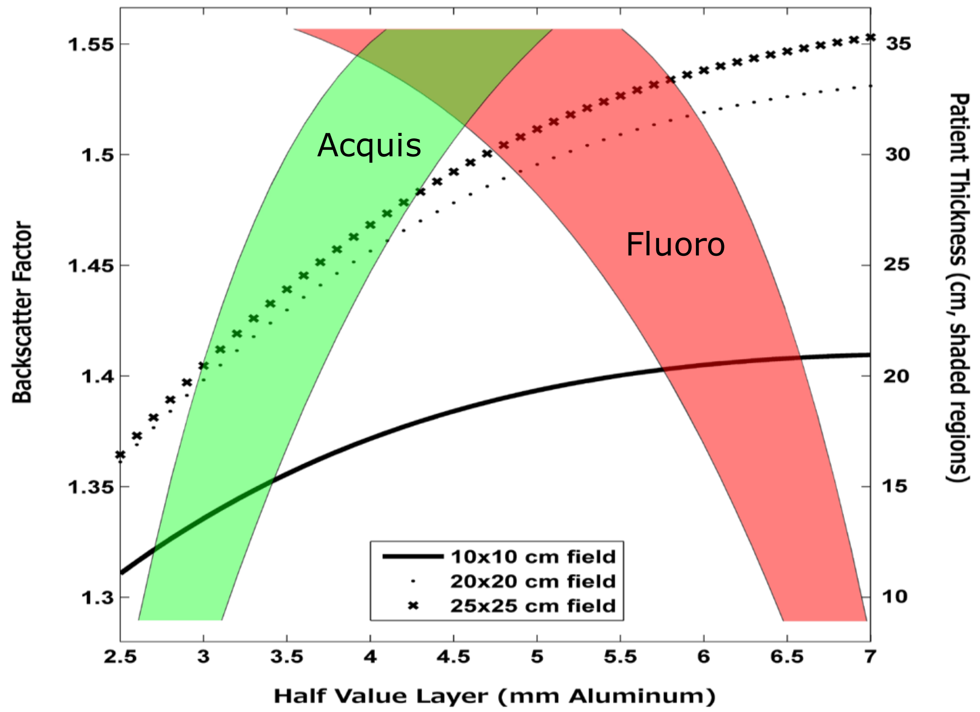
- Islam N et al; The Contribution to Skin Dose Due to Scatter From the Patient Table and the Head Holder During Fluoroscopy; 2015

From CK_{RP} to CK_{pat} – Backscatter factor

- The BSF can be determined both experimentally and through simulation as a function of:
  - Beam quality
  - Patient size
  - X-ray field size (obtained from KAP/Ka,r)

$$iAK = CK_{RP} \times \left(\frac{d_{source\ to\ RP}}{d_{source\ to\ patient}}\right)^2 \times t \times BSF$$

From CK_{RP} to CK_{pat} – Backscatter factor



- Jones AK and Pasciak A; Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods; 2011

From CK_{pat} to Skin Dose – f-factor

- Different tissues absorb ionizing radiation more or less efficiently depending on both the tissue type and X-ray beam quality.
- Therefore, a beam of ionizing radiation will deposit more of its energy in certain tissue types than others.

$$iAK = CK_{RP} \times \left(\frac{d_{source\ to\ RP}}{d_{source\ to\ patient}}\right)^2 \times t \times BSF \times \frac{\left(\frac{\mu_{en}}{\rho}\right)_{tissue}}{\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

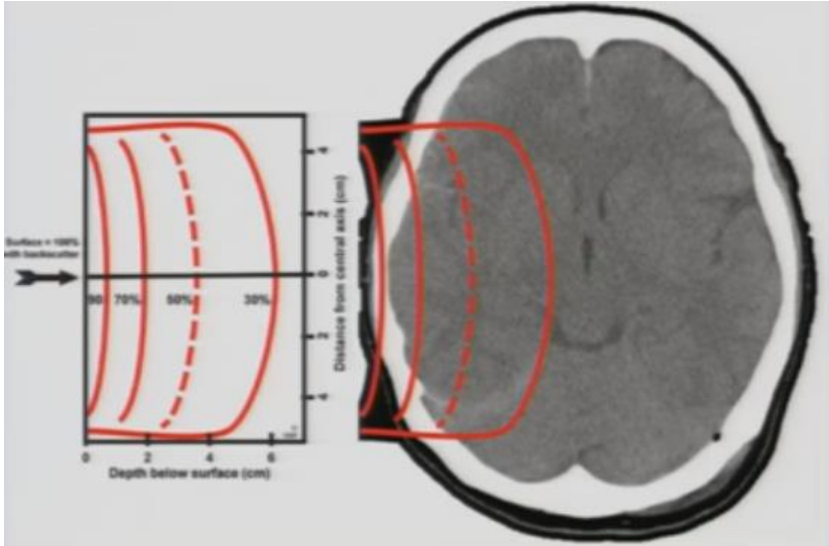
From CK_{pat} to Skin Dose – f-factor

- The f-factor has been tabulated for several tissue types

	f-factor	
kVp	*Fluoroscopic Mode*	*Digital Acquisition Mode*
60	1.061	1.056
65	1.063	1.058
70	1.065	1.059
75	1.066	1.061
85	1.068	1.063
95	1.069	1.066

- Jones AK and Pasciak A; Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods; 2011

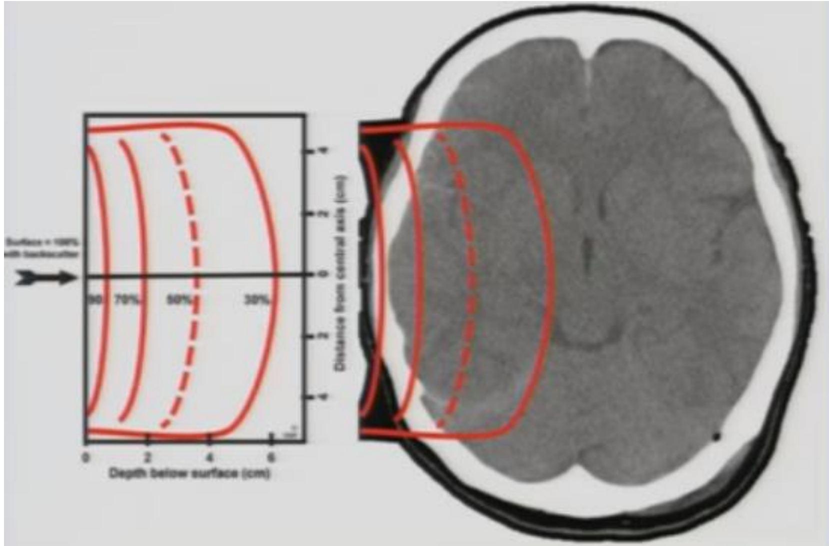
Concerning the f-factor…



f-factor ≈ 4.75 for bone

- Jones AK and Balter S; Medical imaging using ionizing radiation: Optimization of dose and image quality in fluoroscopy; 2014

Concerning the f-factor…



f-factor ≈ 4.75 for bone

- Jones AK and Balter S; Medical imaging using ionizing radiation: Optimization of dose and image quality in fluoroscopy; 2014

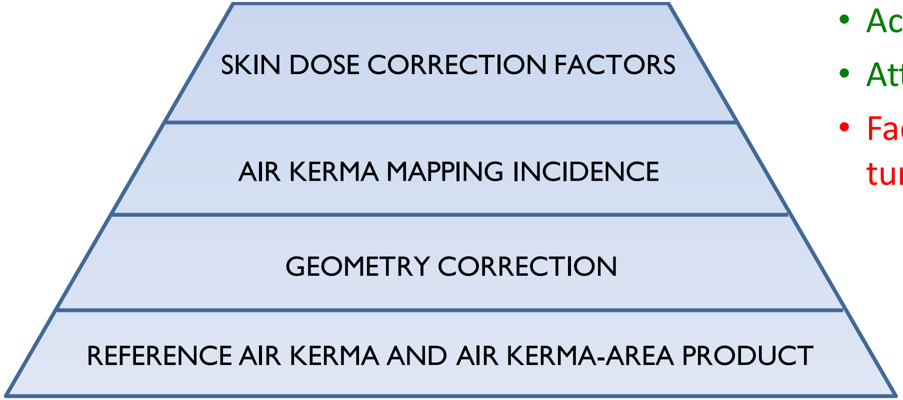
From Reference Air Kerma to Skin Dose

Table Attenuation

Forward Scatter from the Table

Backscatter Factor (BSF)

Mean Energy Absorption Coefficient Ratio



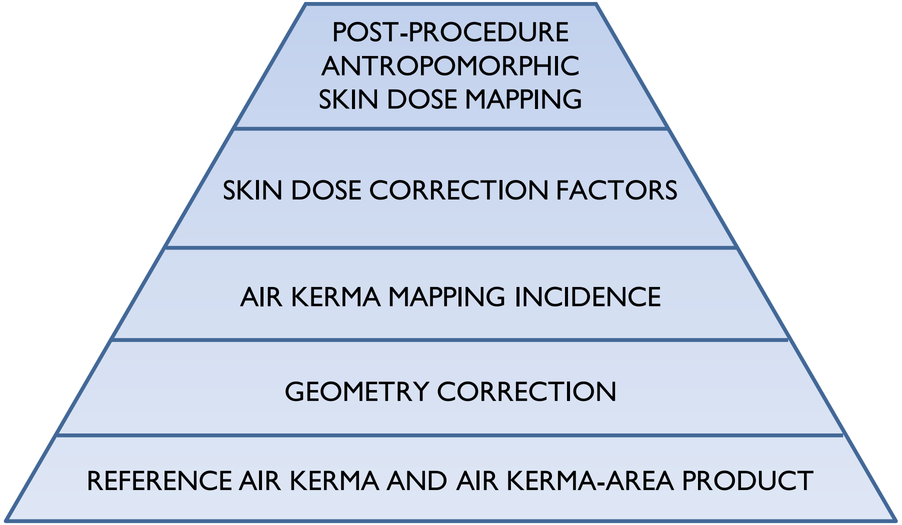
- Achievable amount of physics measurement
- Attempts to convert Exposure to Skin Dose
- Factors based on 'average' setup, some ability to fine tune

Adapted from EFOMP-AAPM TG 246

Sources of Uncertainty

SOURCE	UNCERTAINTY
Reference Air Kerma	MPE Dosimeter: up to 5% 35% tolerance
Table and Pad	25 - 45%
Forward scattered from table and pad	8 – 12% of the primary beam
Backscattered X-rays (soft tissue)	5- 50% depending on field size and image quality
Backscattered X-rays (phantom)	0 – 10% depending on the phantom used
Actual distance of the skin	0 – 20%
F-factor	0 – 4% depending on the energy

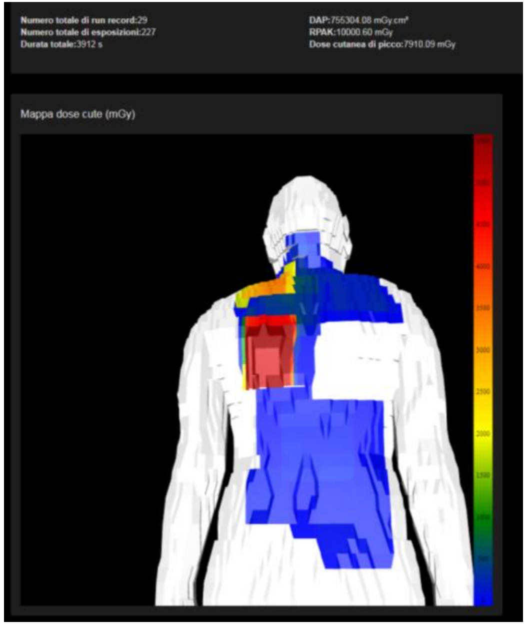
From Reference Air Kerma to Skin Dose

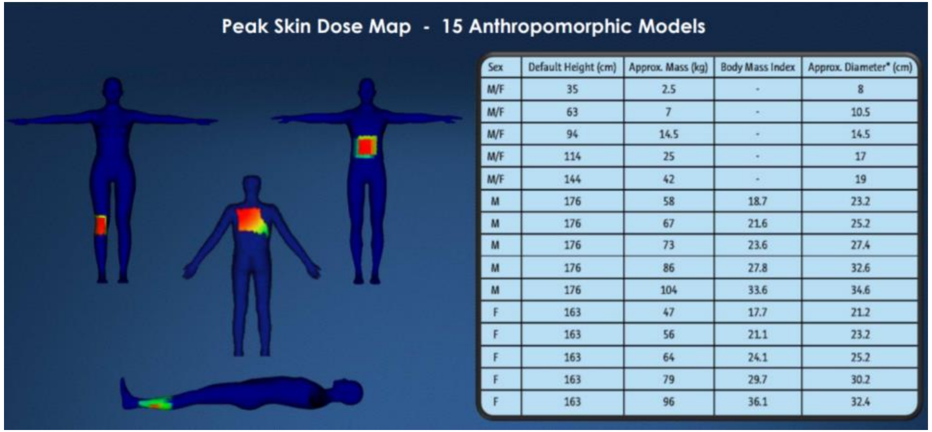


- Adapted from EFOMP-AAPM TG 246

Skin Dose Mapping

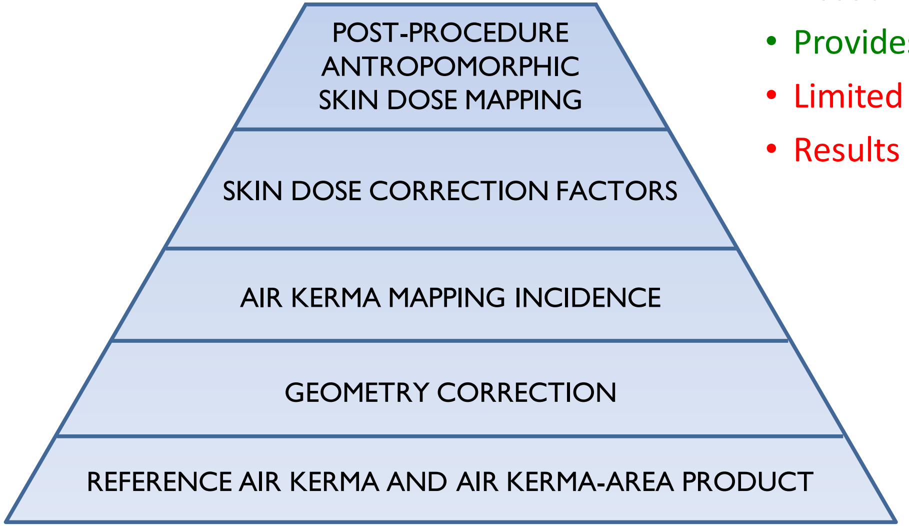
- Commercially available (e.g: Radimetrics, Bayer; DoseWatch, GE healthcare)
- Different types of phantoms





Sex	Default Height (cm)	Approx. Mass (kg)	Body Mass Index	Approx. Diameter* (cm)
M/F	35	2.5	-	8
M/F	63	7	-	10.5
M/F	94	14.5	-	14.5
M/F	114	25	-	17
M/F	144	42	-	19
M	176	58	18.7	23.2
M	176	67	21.6	25.2
M	176	73	23.6	27.4
M	176	86	27.8	32.6
M	176	104	33.6	34.6
F	163	47	17.7	21.2
F	163	56	21.1	23.2
F	163	64	24.1	25.2
F	163	79	29.7	30.2
F	163	96	36.1	32.4

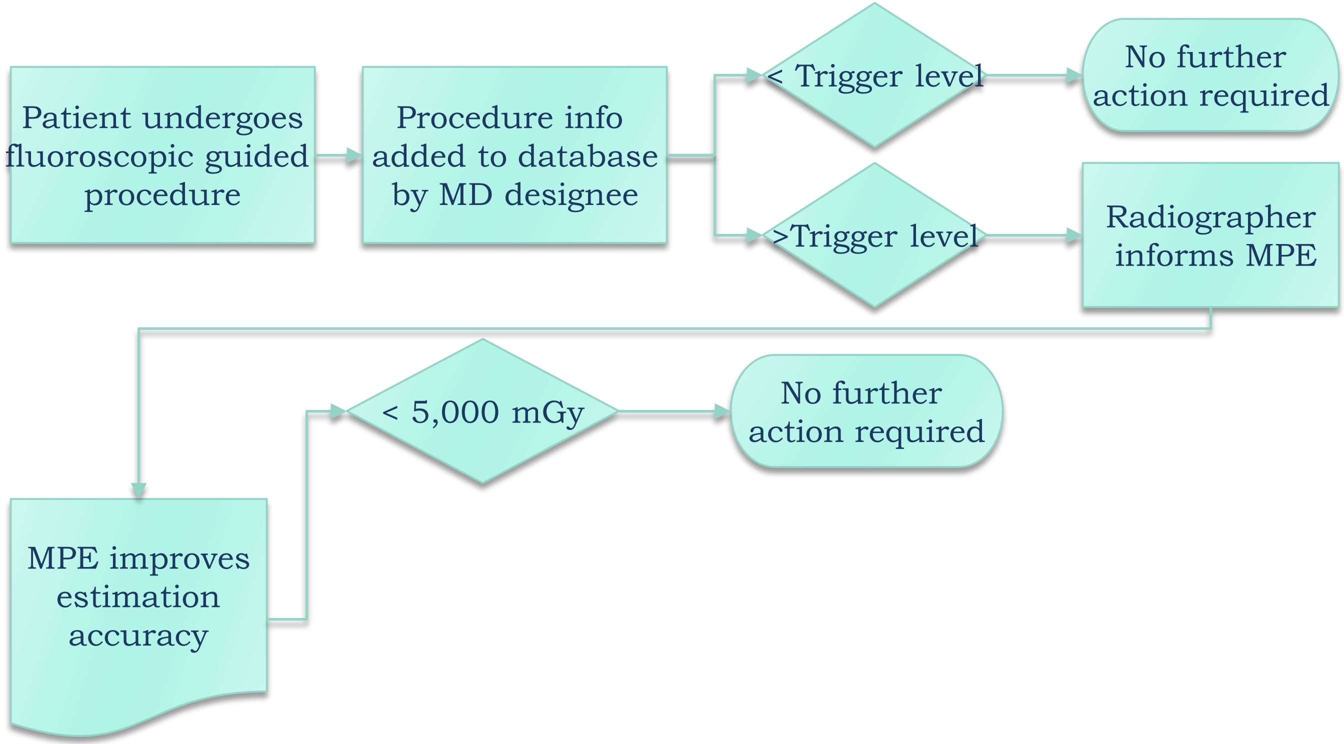
From Reference Air Kerma to Skin Dose



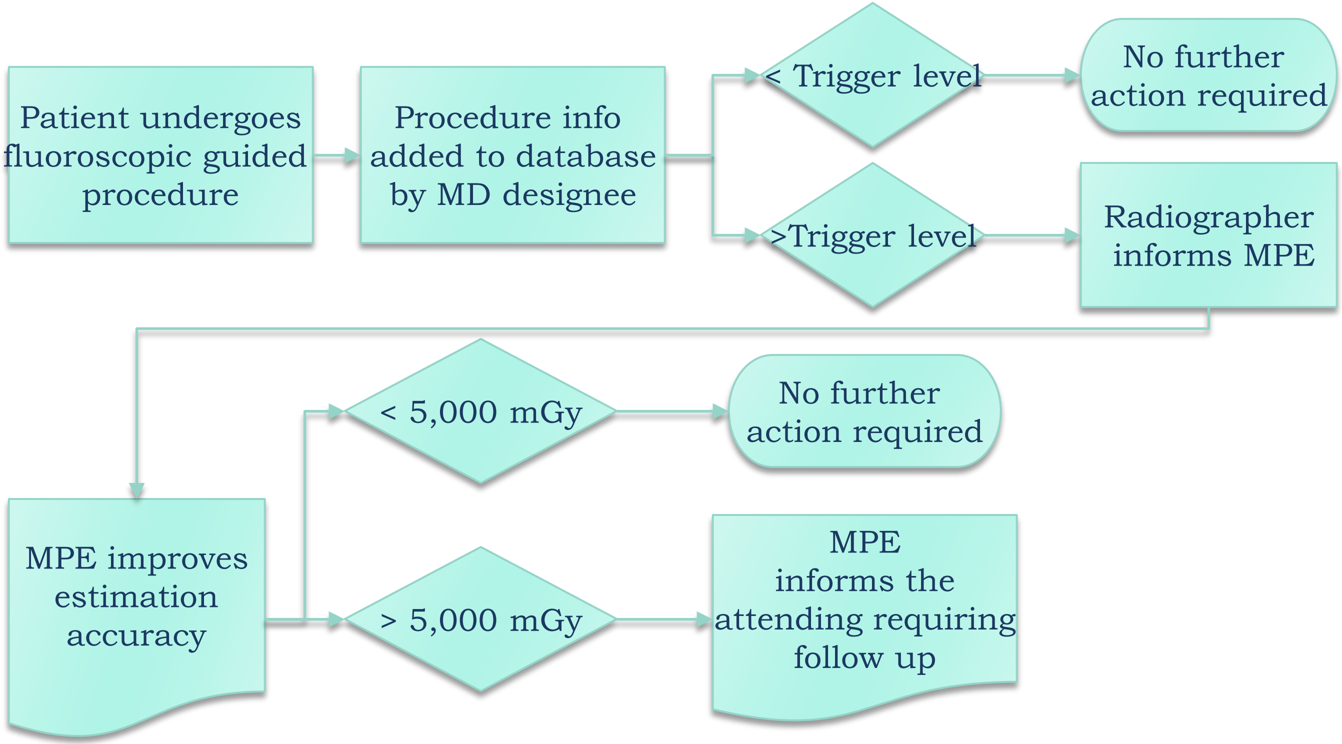
- Accounts for dose spread
- Provides actionable QA Metrics
- Limited by available information
- Results limited to post procedure

Adapted from EFOMP-AAPM TG 246

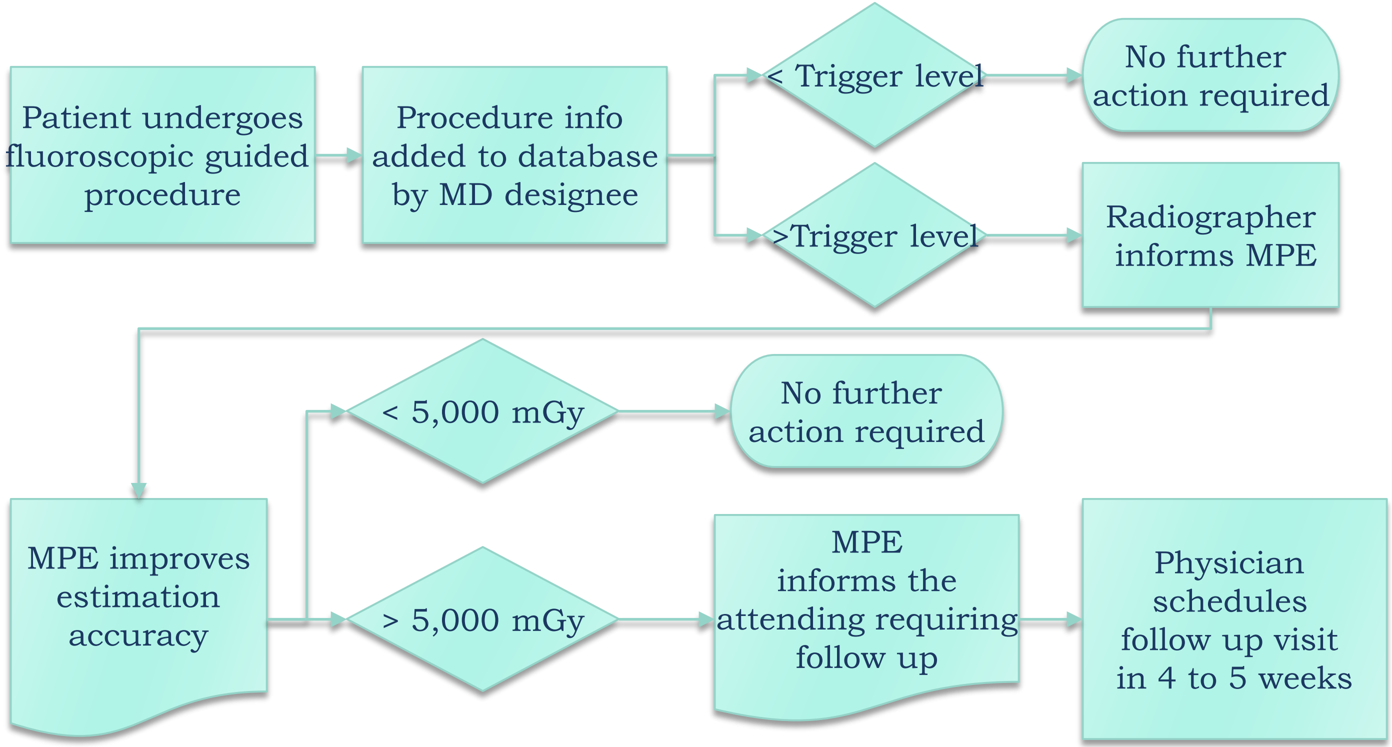
Follow Up scheme



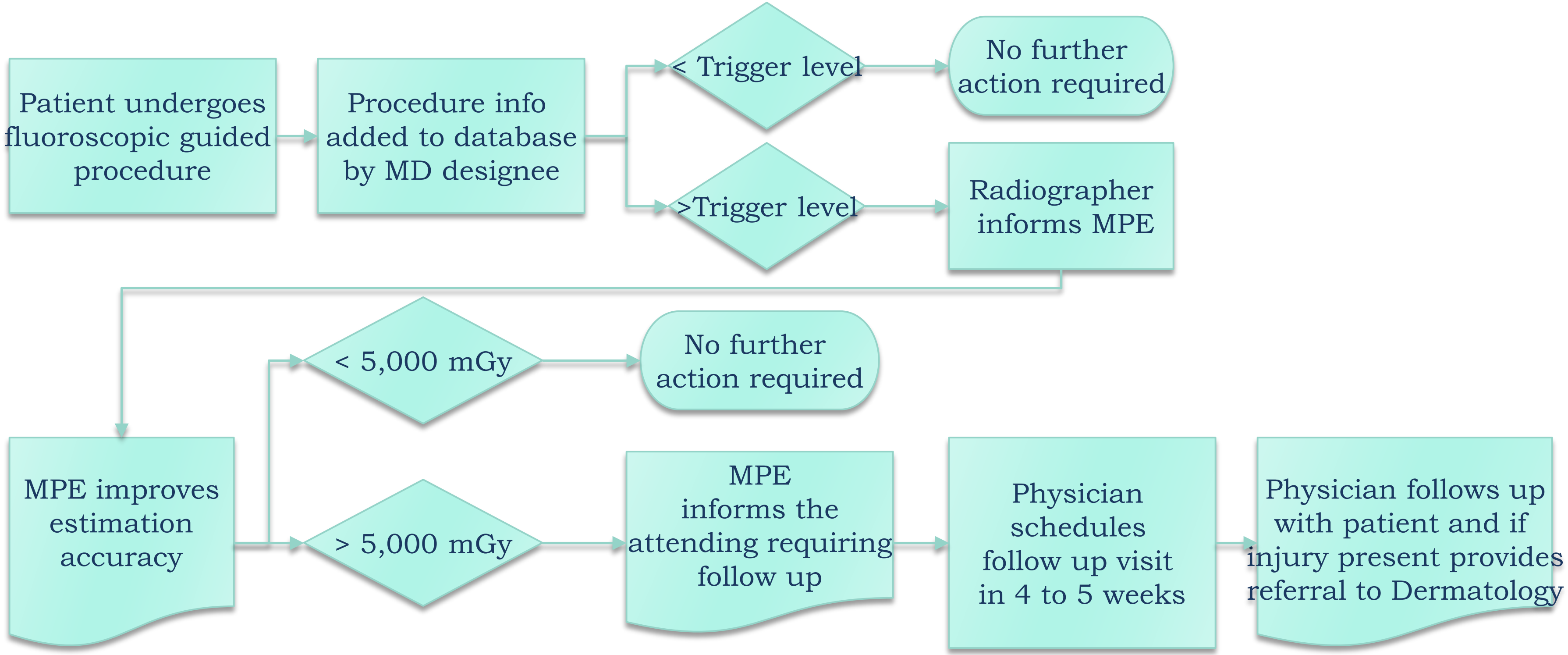
Follow Up scheme



Follow Up scheme



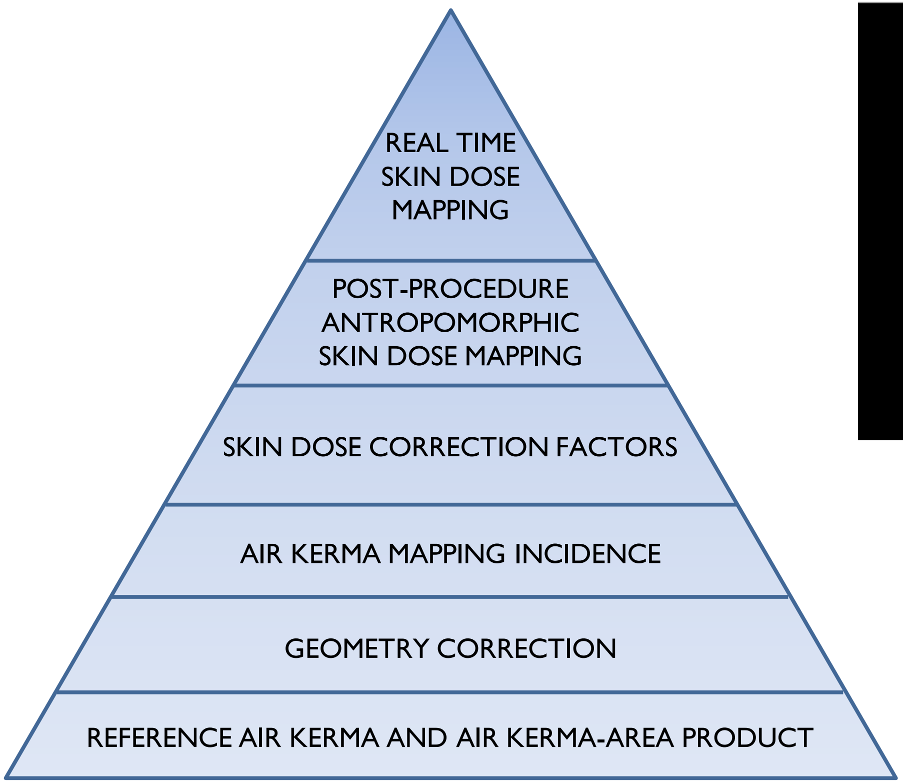
Follow Up scheme

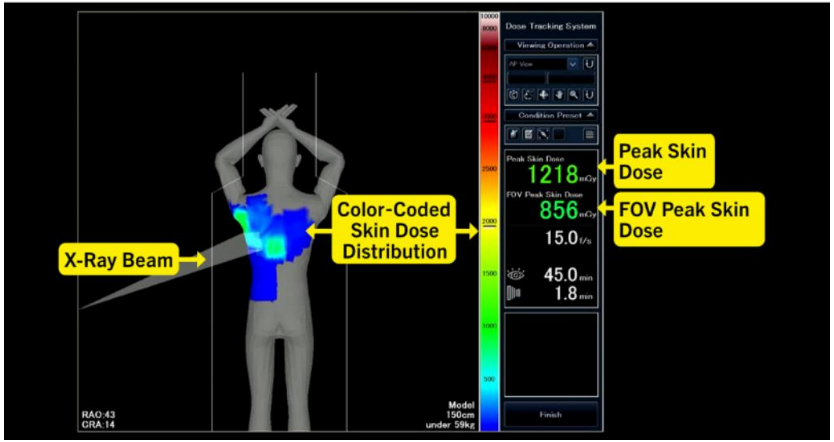


Different approaches in real practice

- What is available in the operating room?
  - Real time skin dosimetry

From Reference Air Kerma to Skin Dose

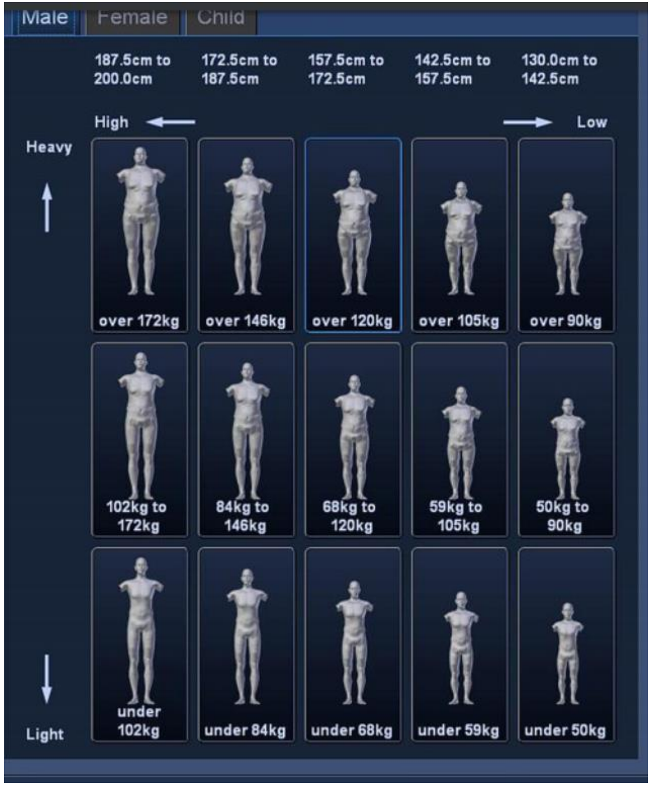




- Adapted from EFOMP-AAPM TG 246

Available systems – Canon Medical Systems

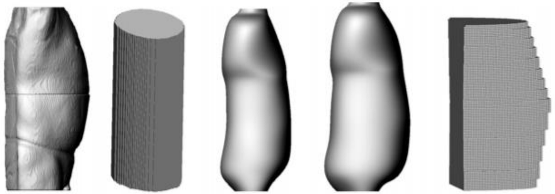
- Morphometric phantoms
- Validated with Gafchromic films
- Accuracy: 20% (proper selection of the phantom)



Available systems – Canon Medical Systems

Skin dose mapping for fluoroscopically guided interventions

Perry B. Johnson and David Borrego
Biomedical Engineering, University of Florida,



Patient-specific – Unique to patient
Ref stylized – One to represent all patients
Ref hybrid – One to represent all patients
PD hybrid – Selected from 25 member library
Sculped-contour – Unique to patient

TABLE III. Mean absolute percent difference in PSD between patient-specific models and four different phantom types. Results are grouped according to patient size, tube projection, and orientation.

		Cardiac					Abdominal			
		Reference stylized	Reference hybrid	Patient-dependent	Patient-sculpted		Reference stylized	Reference hybrid	Patient-dependent	Patient-sculpted
Male						PA				
	Heavy	0.9	1.1	4.6	0.9		1.0	2.1	4.9	1.0
	Light	2.7	1.5	2.1	2.7		1.9	1.7	2.1	1.9
	All	2.0	1.4	3.0	2.0		1.6	1.8	3.1	1.6
						Lt Lat				
	Heavy	5.5	5.8	2.5	1.6		3.1	10.7	6.7	1.9
	Light	10.9	9.1	8.0	2.5		16.0	5.2	3.4	3.3
	All	9.0	7.9	6.0	2.2		11.4	7.1	4.5	2.8
						AP				
	Heavy	34.4	18.4	5.8	7.3		40.5	21.1	9.8	2.3
	Light	20.9	8.6	8.3	7.1		25.2	6.9	7.7	3.2
	All	25.7	12.0	7.4	7.2		30.6	12.0	8.4	2.9
Female						PA				
	Heavy	3.6	8.0	10.7	3.6		2.4	10.3	10.0	2.4
	Light	4.6	7.1	7.4	4.6		4.3	8.6	9.1	4.3
	All	4.2	7.5	8.7	4.2		3.5	9.3	9.5	3.5
						LT Lat				
	Heavy	9.2	13.3	12.1	5.5		12.4	19.1	14.5	5.5
	Light	11.6	5.5	3.0	3.9		19.7	4.5	6.3	3.8
	All	10.6	8.8	6.8	4.5		16.7	10.6	9.7	4.5
						AP				
	Heavy	39.1	8.6	9.8	5.2		46.7	22.4	9.1	9.0
	Light	16.8	29.1	17.1	9.8		16.2	20.3	11.3	6.3
	All	26.1	20.6	14.1	7.9		28.9	21.2	10.4	7.4

Available systems – GE Healthcare

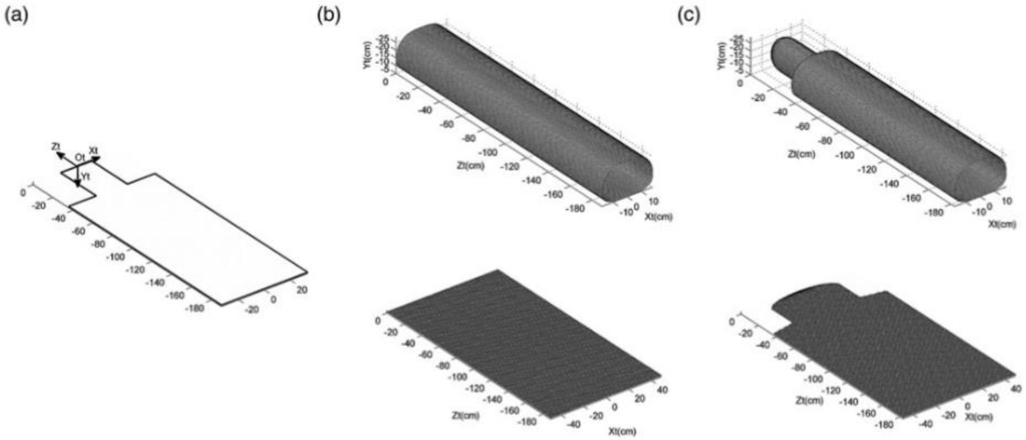
- Superellipses
- Validated with Gafchromic films
- Accuracy: 25%

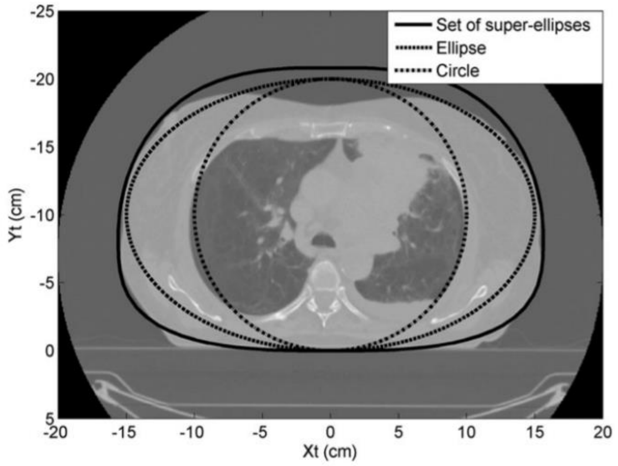
Available systems – GE Healthcare

Radiation Protection Dosimetry (2014), pp. 1–13 doi:10.1093/rpd/ncu181

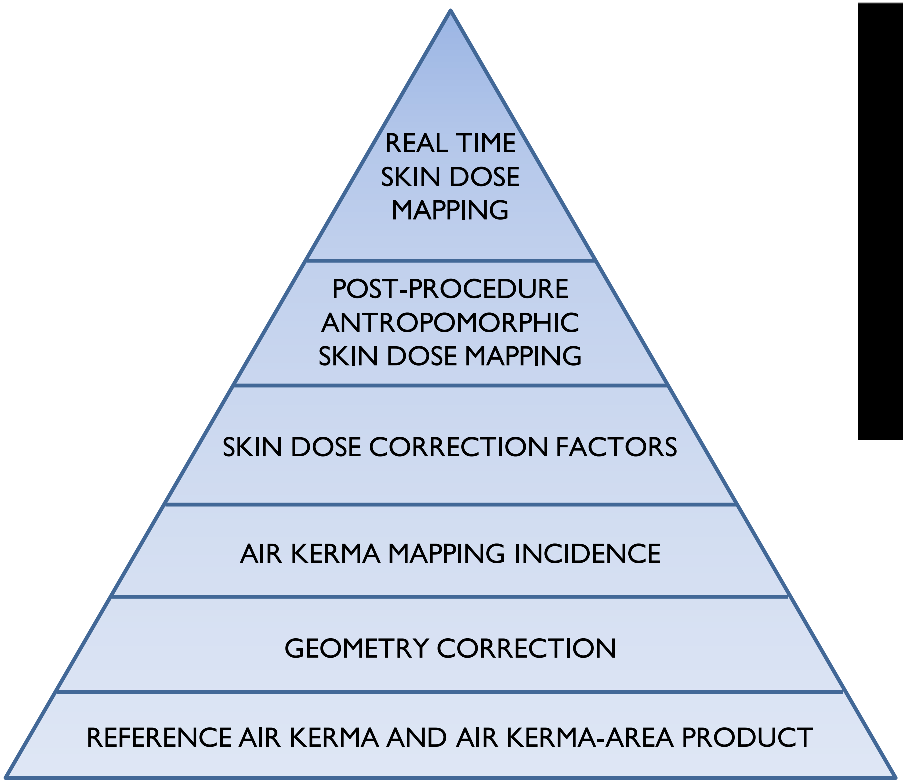
PATIENT DOSE MAP INDICATIONS ON INTERVENTIONAL X-RAY SYSTEMS AND VALIDATION WITH GAFCHROMIC XR-RV3 FILM

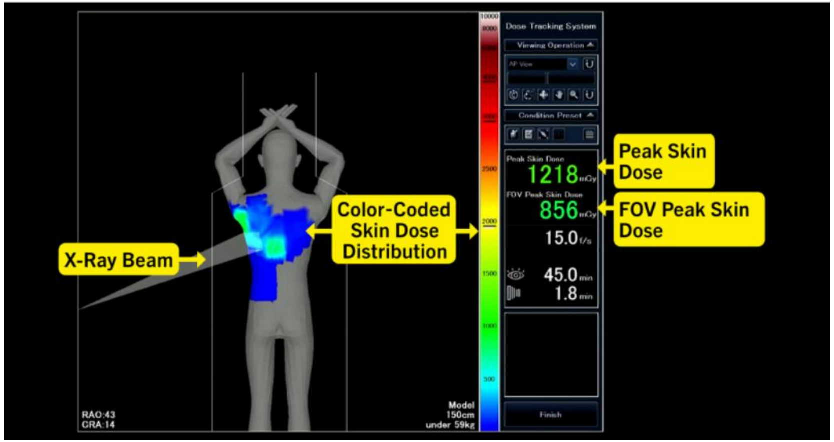
C. Bordier*, R. Klausz and L. Desponds
Detection and Guidance Solutions, Image Quality and Dose Center of Excellence, GE Healthcare,
283 rue de la Minière, Buc 78530, France





From Reference Air Kerma to Skin Dose





- Provides PSD values Real Time!
- Use of Actionable QA Metrics
- Real time use of device messaging

Adapted from EFOMP-AAPM TG 246

Follow Up scheme