Imaging Education Symposium: Patient Dose Calculations in Fluoroscopy

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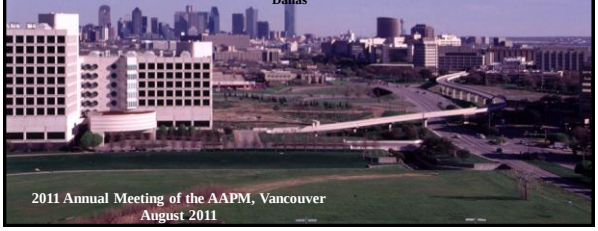
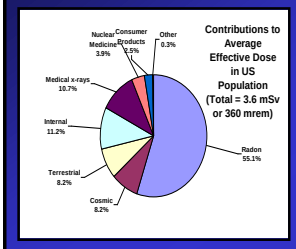


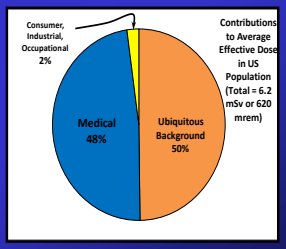
2011 Annual Meeting of the AAPM, Vancouver
August 2011

Radiation Exposure in US

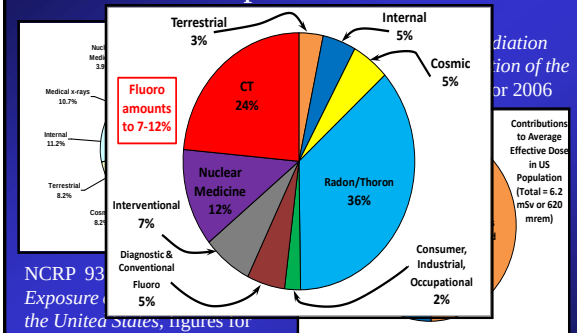


NCRP 93, *Ionizing Radiation Exposure of the Population of the United States*, figures for 1980-82

NCRP 160, *Ionizing Radiation Exposure of the Population of the United States*, figures for 2006



Radiation Exposure in US

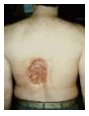


NCRP 93 *Exposure ... the United States*, figures for 1980-82

Patient Dose Calculations in Fluoroscopy: What is of Concern?

- **"How much radiation did I get? Will it hurt me? Will I get cancer"**
- **Deterministic Injury**
  - **Erythema**
  - **Epilation**
  - **Desquamation**
- **Stochastic Injury**
  - **Cancer induction**

Recording Information In The Patient's Medical Record That Identifies The Potential For Serious X-Ray-Induced Skin Injuries (FDA, 1995)



Shope*, Radiation-induced Skin Injuries from Fluoroscopy *1995

Patient Dose Calculations in Fluoroscopy: Which Dose Is of Interest?

- Deterministic Injury
  - Erythema
  - Epilation
  - Desquamation

→ **Organ Doses** (typically skin dose [easiest!]; maybe uterus/fetus)

- Stochastic Injury
  - Cancer induction

→ **Effective Dose*** (more complicated, more uncertainties)

*caveats latter

Threshold Ranges for Deterministic Radiation Injury of the Skin

Summary Radiation Injury Effects for Single Exposure Events

Threshold Dose Range [Gy]	Onset Time Range: Prompt (< 2wks)	Early (2-8 wks)	Midterm (6-52 wks)	Long Term (>40 wks)
0-2	Not expected	Not expected	Not expected	Not expected
2-5	Transient erythema	Epilation	Recovery from epilation	Not expected
5-10	Transient erythema	Erythema, epiliation	Recovery, but at higher doses may see prolonged erythema or permanent epilation	Recovery, but at higher doses dermal atropy or induration

following the classification of Balter et al. [Radiology 254:326-41(2010)]

Onset time and skin dose threshold ranges for radiation injuries to most (neck, torso, pelvis, buttocks, arms) skin surfaces on the body for single exposure incidents. The scalp may be more sensitive to epilation and less susceptible to erythema.

Threshold Ranges for Deterministic Radiation Injury of the Skin – **higher doses**

Summary Radiation Injury Effects for Single Exposure Events

Threshold Dose Range [Gy]	Onset Time Range: Prompt (< 2wks)	Early (2-8 wks)	Midterm (6-52 wks)	Long Term (>40 wks)
10-15	Transient erythema	Erythema, epiliation, possible dry or wet desquamation	Prolonged erythema, permanent epilation	Telangiectasia, dermal atrophy or induration; weakening of the skin
>15	transient erythema and at higher doses edema and acute ulceration	Erythema, epilation, wet desquamation	Dermal atropy and at higher doses secondary ulceration and dermal necrosis	Telangiectasia, dermal atrophy or induration, possible breakdown of the skin

following the classification of Balter et al. [Radiology 254:326-41(2010)]

Threshold Ranges for Deterministic Radiation Injury of the Skin

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>15	transient erythema and at higher doses edema and acute ulceration	Erythema, epilation, wet desquamation	Dermal atropy and at higher doses secondary ulceration and dermal necrosis	Telangiectasia, dermal atrophy or induration, possible breakdown of the skin

Note that both DOSE LEVELS and ONSET TIMES are expressed as broad ranges to reflect the wide variation of effects in different subjects! Some sources make it sound much more cut-and-dried than this!

following the classification of Balter et al. [Radiology 254:326-41(2010)]

A Specific Need for Organ Dose Estimates: Investigating the Joint Commission Radiologic Sentinel Event

The Joint Commission defined the radiological sentinel event in November 2005 as

- Prolonged fluoroscopy with cumulative dose >1500 rads to a single field or any delivery of radiotherapy to the wrong body region or >25% above the planned radiotherapy dose

The JC Fleshes Out the Fluoroscopic Sentinel Event with an FAQ Page

- "Cumulative dose > 1500 rads" is the peak skin dose, taking overlap of different fields (all runs, all fluoro) into consideration
- Cumulative dose, for the JC, refers neither to a single procedure nor to a lifetime; the JC indicates "...monitoring cumulative dose over a period of six months to a year would be reasonable."

  http://www.jointcommission.org/assets/1/6/2011_CAMH_SE.pdf
- http://www.jointcommission.org/about/JointCommissionFaqs.aspx?CategoryId=8

Problems Relating to Sentinel Events

- Terminology
  - Cumulative Dose (CD) , to the medical physicist (ICRP, IEC), is the air kerma at the interventional reference point (IRP) (15 cm toward x-ray tube from isocenter or vendor specified) at end of procedure
  - Cumulative dose, in the JC definition, is essentially a cumulative Peak Skin Dose (PSD or $D_{skin,max}$), summed for a "reasonable" time (6-12 mo)
- Multiple procedures in hospital (difficult)
- Multiple institutions (can be much harder !!!)

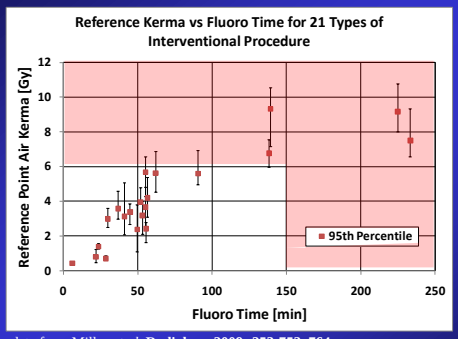
Strategies: Skin Dose Investigation

- Monitor and record surrogates for skin dose
  - Fluoro time (possible on all machines)
  - Air Kerma (AK_{ref} or $K_{a,r}$) or KERMA-Area-Product (KAP or $P_{K,A}$) readings on machines so equipped (such monitors required by FDA on new machines post-2006)
  - Skin dose software (e.g. Siemens CareGraph, PEMNET, etc.) if present
  - Number of DA or DSA runs or total # DA/DSA images

Strategies: Skin Dose Investigation

- Establish "threshold" values of the surrogates and a hospital notification process to trigger an investigation
- Threshold should be
  - Low enough to catch all real events
  - High enough to keep workload on physics department within realistic limits
- At our institution currently,
  - 6000 mGy AK_{ref} or 150 min fluoro time

Some Justification from the RAD-IR Data



data from Miller *et al.* **Radiology 2009; 253:753–764**

Only a few procedure types generate potential cases; from this data:

Neuro embolization
TIPS
Vascular embolization

(no cardiac in RAD-IR)

Approximately what fraction of the average annual per capita effective dose in the US was due to fluoroscopy in 2006?

0% 1. Less than 1%
0% 2. 1-7%
0% 3. 7-12%
0% 4. 12-20%
0% 5. 24%.

10

Approximately what fraction of the average annual per capita effective dose in the US was due to fluoroscopy in 2006?

Correct Answer:

(3) 7-12%

According to NCRP 160, interventional radiology accounted for about 7% of the annual per capita effective dose in 2006 and general diagnostic x-ray and conventional R&F accounted for an additional 5%, so the total contribution from fluoroscopy is in the range 7-12%. CT accounted for about 24%; total medical contribution was 48%.

NCRP Report No. 160: Ionizing Radiation Exposure to the Population of the United States, National Council on Radiation Protection and Measurements (Bethesda, 2009) p. 11.

How is the Joint Commission fluoroscopic sentinel event defined?

0% 1. 3 Gy (300 rad) air kerma at the reference point
0% 2. 3 Gy (300 rad) effective dose in the course of a single procedure
0% 3. 15 Gy (1500 rad) received by a point on the skin over a lifetime
0% 4. 15 Gy (1500 rad) received by a point on the skin over a 6-12 month period
0% 5. 15 Gy (1500 rad) received by a point on the skin during a single procedure

10

How is the Joint Commission fluoroscopic sentinel event defined?

Correct Answer:

(4) 15 Gy (1500 rad) received by a point on the skin over a 6-12 month period

http://www.jointcommission.org/assets/1/6/2011_CAMH_SE.pdf
http://www.jointcommission.org/about/JointCommissionFaqs.aspx?CategoryId=8

Re answer (1): The ACR recommends that if 3 Gy air kerma is recorded at the reference point, then follow-up should be made for determination of radiation effects. (American College of Radiology, ACR TECHNICAL STANDARD FOR MANAGEMENT OF THE USE OF RADIATION IN FLUOROSCOPIC PROCEDURES, 2010. Available at http://www.acr.org/SecondaryMainMenuCategories/quality_safety/RadSafety/RadiationSafety/standard-manage-radiation.aspx)

Data Sources for Dose Reconstruction

Fluoro Unit
Verify # runs to PACS
Verify fluoro times
Verify AK, KAP
Machine logs (internal) with detailed info

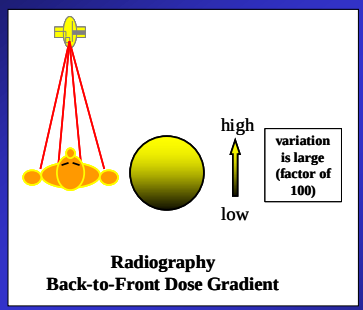
Images from PACS (DICOM Header Info)
Technique factors
Dose (KAP or AK) info
FOV
Table position

Staff Interview
Patient positioning
Fluoro usage
Procedure description

HIS/RIS
Prior fluoro
Case notes
Fluoro time

Database (may be HIS/RIS)
Prior fluoro, equipment

Dose Distribution Pattern in Radiographic/Fluorographic Exams



Radiography
Back-to-Front Dose Gradient

Dose distribution varies with depth in patient due to
-- inverse square law
-- attenuation by the patient's tissues
-- scatter

BROILER MODEL (Fluoro) vs ROTISSERIE MODEL (CT)

General Approaches: Organ Dose Calculations for Fluoro

SIMPLE (CLASSIC)

Percent Depth Dose
Normalized Depth Dose
Tissue Air Ratio

(for skin doses (d=0), all reduce essentially to application of f, the air-to-tissue dose conversion factor and B, the backscatter factor; for other organs [say the fetus], must use appropriate organ depth)

MONTE CARLO RESULTS

Tabulated/calculated organ doses for std phantoms in std projections, referenced to entrance dose, entrance in-air exposure, etc. Examples:

NRPB SR-262, Normalized Organ Doses for Medical X-ray Examinations Calculated using Monte Carlo Techniques (1994) (and others)

FDA (1988), Handbook of Selected Tissue Doses for Projections Common in Diagnostic Radiology. (and others)

Programs such as PCXMC (STUK, [Radiation and Nuclear Safety Authority, Finland], 2008)

Simple Skin Dose Calculations

For each exposure (DA/DSA run or fluoro acquisition)

- **Determine skin field area irradiated** (this is to account for overlap/non-overlap, and may involve much guess work; since the calculation may be to demonstrate that the dose is < 15 Gy, initial calculation may assume 100% overlap of all exposures)
- **Correct for inverse square** from reference point (FRefD, focal-spot to reference) to skin surface (FSD, focal-spot to skin)
- **Calculate skin dose contribution** for this run using TAR or other formalism (essentially backscatter factor and f factor)

$$Dskin = AK_{ref} * (FRefD/FSD)^2 * TAR(0)$$

For each contribution to a given field

Look at maximally exposed skin field to determine dose for sentinel event evaluation

NRPB-SR262 Monte Carlo Results

Cardiac Catherization, LAO View

ORGAN DOSE Relative to Entrance Surface Dose in Air

ORGAN	HVL [mm Al]	Tube Voltage [kVp]							
		50	60	70	80	90	100	110	120
11 Heart	2	1.87E-02	2.75E-02	3.58E-02	4.44E-02	5.26E-02	6.02E-02	6.74E-02	7.40E-02
	2.5	2.13E-02	3.09E-02	3.98E-02	4.89E-02	5.74E-02	6.52E-02	7.24E-02	7.89E-02
	3	2.37E-02	3.40E-02	4.35E-02	5.30E-02	6.17E-02	6.97E-02	7.68E-02	8.33E-02
	4	2.79E-02	3.95E-02	4.98E-02	6.03E-02	6.94E-02	7.72E-02	8.43E-02	9.06E-02
	5	3.16E-02	4.42E-02	5.53E-02	6.59E-02	7.53E-02	8.34E-02	9.05E-02	9.66E-02
Backscat-tered Fraction	2	1.91E-01	2.13E-01	2.30E-01	2.44E-01	2.55E-01	2.64E-01	2.71E-01	2.77E-01
	2.5	2.03E-01	2.26E-01	2.43E-01	2.56E-01	2.67E-01	2.75E-01	2.82E-01	2.86E-01
	3	2.14E-01	2.36E-01	2.54E-01	2.67E-01	2.77E-01	2.85E-01	2.90E-01	2.94E-01
	4	2.30E-01	2.54E-01	2.71E-01	2.84E-01	2.93E-01	2.99E-01	3.03E-01	3.06E-01
	5	2.43E-01	2.67E-01	2.85E-01	2.97E-01	3.05E-01	3.10E-01	3.12E-01	3.13E-01

Example of NRPB-SR262 (Hart et al., 1994) data, showing organ dose for heart (one of 24 specific organs in calculation), normalized to entrance surface dose in air.

$$Dose = Dose_{free\text{-}in\text{-}air,entrance} * (1 + Back\ Scatter\ Fraction) * D_{organ,norm}$$

Backscatter factor

Issues: field size, field center, FSD, projections were set at calculation time (68 views/projections included in data set) – need to find closest fit

NRPB-SR262 Monte Carlo Results

Cardiac Catherization, LAO View

ORGAN DOSE Relative to Entrance Surface Dose in Air

ORGAN	HVL [mm	Tube Voltage [kVp]							
									120
11 Heart									7.40E-02
									7.89E-02
									8.33E-02
									9.06E-02
									9.66E-02
Backscat-tered Fraction									2.77E-01
	2.5	2.03E-01	2.26E-01	2.43E-01	2.56E-01	2.67E-01	2.75E-01	2.82E-01	2.86E-01
	3	2.14E-01	2.36E-01	2.54E-01	2.67E-01	2.77E-01	2.85E-01	2.90E-01	2.94E-01
	4	2.30E-01	2.54E-01	2.71E-01	2.84E-01	2.93E-01	2.99E-01	3.03E-01	3.06E-01
	5	2.43E-01	2.67E-01	2.85E-01	2.97E-01	3.05E-01	3.10E-01	3.12E-01	3.13E-01

NRPB-SR262 also provides results normalized against DAP values

Example of NRPB-SR262 (Hart et al., 1994) data, showing organ dose for heart (one of 24 specific organs in calculation), normalized to entrance surface dose in air.

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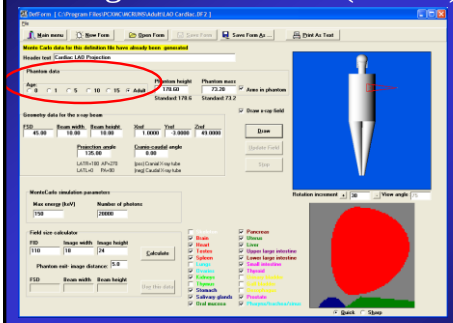
Backscatter factor

Issues: field size, field center, FSD, projections were set at calculation time (68 views/projections included in data set) – need to find closest fit

Example of Monte Carlo Program: PCXMC (STUK)



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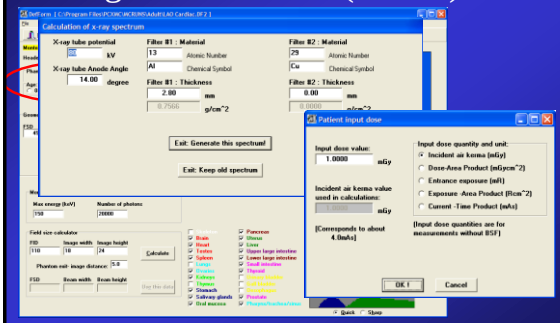

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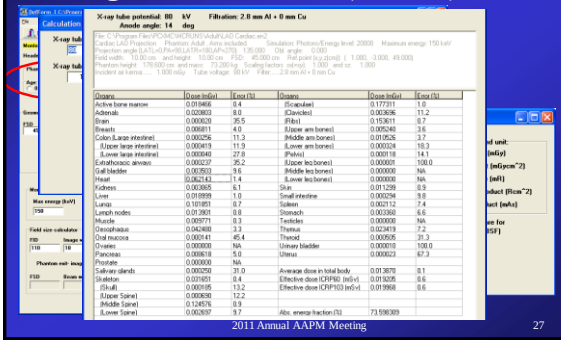
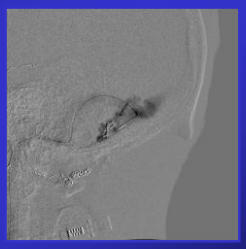


Case Study: Skin Dose in Biplane Fluoro Room With AK Monitor

- **Transvenous embolization for dural arteriovenous fistulas**
- **Bi-plane c-arm fluoroscope equipped with an Air Kerma Monitor (we treat biplane thresholds by adding AK, time values for two planes)**
- **Fluoroscopy time and air kerma exceeded the investigational limits of 150 min and 6 Gy.**



KAP Monitors

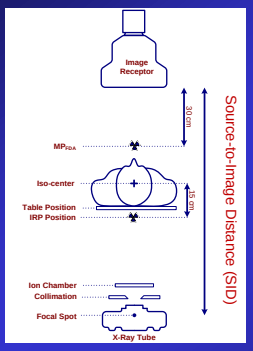
Ion chamber on front of collimator, larger than largest field size at this point

From q and total active area of dosimeter, obtain KAP

Based on field size at interventional reference point, calculate AK_{ref}

Some machines may simply calculate the AK_{ref} based on technique factors, then KAP from collimator sizing.

KAP Monitors: The Reference Point



IRP Position = interventional reference point (15 cm towards focal spot from isocenter or as vendor specified)

MP_{FDA} = measurement point for fluoroscopic dose limit regulations (30 cm from Image Receptor faceplate)

Note: wide separation shown between MP_{FDA} and IRP can occur (say for rotational fluoro)

Case Study: Basic Information

- Unit Equipped with a Dose Monitor
- 18 runs, ~20 frames each
- Cumulative dose (IRP) and fluoro time in Performed Procedure Step file
- Frontal AK_{IRP} 10 Gy, fluoro time 182 min
- Lateral AK_{IRP} 0.5 Gy, fluoro time 10 min
- DICOM tags provided run details
  - KAP per run
  - Technique factors
  - Patient (table) to source distance
  - C-arm angulation
- Fluoroscopy dose preceding DSA run included with run KAP in DICOM tag
- Air Kerma monitor calibration checked

Case Study Calculations

- Spread sheet calculation
- Patient skin dose calculated from KAP data in DSA run DICOM tag
- For each run & associated fluoro:

  AK(at patient) = KAP / $Area_{FOV}$(at patient)
- c-arm angulation and overlap considered (minor effects)

RESULT: Maximum skin dose does not exceed 1500 Rad (15 Gy)

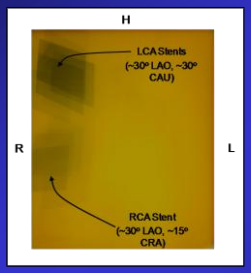
Skin Dose Contributions [mGy_{AK}]*		
	Frontal	Lateral
Fluoro + DSA Runs	9700	400
Rotational	0	0
Total	9700	400
*Corrected for FSD, angulation		

Tissue/Air Ratio
TAR(0) ≈ 1.4 mGy_{tis}/mGy_{air}

Patient Skin Dose (mGy_{tis})	
Frontal	13600
Lateral	600
Max Field*	14200

*assuming 100% overlap!

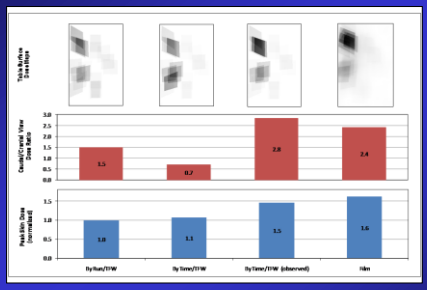
Verification is Good!: A Role for Radiosensitive Films



Absolute calibration of film may be challenging.

- 2.5 hr procedure: 6.1 Gy AK_{ref} and 58 minutes fluoro time
- 43 digital runs @15 fps, ~60 fr/run
- DICOM Information not available
  - No run-by-run dose
  - No fluoro dose breakout
  - No table positions
- GAFChromic film XR-RV3 used to record procedure
- Two strategies possible
  - -Direct use of film dosimetry
  - -Use of field info to validate assumptions

Verification is Good!: A Role for Radiosensitive Films



Comparison with film (last column) allows choosing best of 3 competing assumptions (columns 1-3) on how fluoroscopy was spatially distributed

Estimating Doses for Stochastic Risk Assessment -- What is Effective?

Effective dose is a weighted average of mean equivalent (corrected for type of radiation) organ doses, designed to reflect (be proportional to) the stochastic risk of a gender-averaged reference person

$$E = \sum_T w_T H_T$$

Cancer risk coefficients (ICRP 103) are 5.5%/Sv for the whole population and 4.1%/Sv for the adult population.

Effective doses are provided as results from MC programs or can be estimated from total deposited energy (approximated from DAP)

Organ Weighting Factors W		
Organ	ICRP 103	ICRP 60
Red bone marrow	12%	12%
Colon	12%	12%
Lung	12%	12%
Stomach	12%	12%
Breast	12%	5%
Remainder	12%	5%
Gonads	8%	20%
Bladder	4%	5%
Esophagus	4%	5%
Liver	4%	5%
Thyroid	4%	5%
Bone surface	1%	1%
Brain	1%	
Salivary glands	1%	
Skin	1%	1%

Estimating Doses for Stochastic Risk Assessment -- Effective or Not?

NCRP 168 Recommendation 3:

Effective dose shall not be used for quantitative estimates of stochastic radiation risk for individual patients or patient groups. Effective dose may be used ... for classifying different types of procedures in broad risk categories...

Estimating Doses for Stochastic Risk Assessment -- Issues

- **Effective dose designed as a tool for radiation protection of workers, general population, not for patients.**
- **Effective dose does not take into account the age and specific gender of a patient.**
- **Effective dose is calculated (by and large) using standard man phantoms (not the actual patient).**

Estimating Doses for Stochastic Risk Assessment -- Where to Now?

NCRP 168 suggests the following approach:

- **Calculate the organ doses for the individual**
- **Use risk factors for specific**
  - **exposed organs**
  - **age and gender of patient**
- **Risk factors are found in BEIR VII, Part 2**

TABLE 12D-2 Lifetime Attributable Risk of Cancer Mortality[a]

	Age at Exposure (years)				
Cancer Site	0	5	10	15	20
Males					
Stomach	41	34	30	25	21
Colon	163	139	117	99	84
Liver	44	37	31	27	23
Lung	318	266	219	182	151
Prostate	17	15	12	10	9
Bladder	45	38	32	27	23
Other	400	255	200	162	134
All solid	1028	781	641	533	444
Leukemia	71	71	71	70	67
All cancers	1099	852	712	603	511
Females					
Stomach	57	48	41	34	29
Colon	102	86	73	62	53
Liver	24	20	17	14	12
Lung	643	534	442	367	305
Breast	274	216	167	130	101
Uterus	11	10	8	7	6
Ovary	55	47	39	34	28
Bladder	59	51	43	36	31
Other	491	287	220	179	147
All solid	1717	1295	1051	862	711
Leukemia	53	52	53	52	51
All cancers	1770	1347	1104	914	762

NOTE: Number of deaths per 100,000 persons exposed to a single dose of 0.1 Gy.

Estimating Doses for Stochastic Risk Assessment -- Effective or "Effective"

Still some problems here:

Practically, estimating all the organ doses requires application of Monte Carlo calculations, most of which are based on standard phantoms, not patient specific models.

Personal opinion: For at least a while, the best available estimate in many cases will be a procedure specific "effective" dose based on organ doses in standard phantoms. Age- and gender- specific risk factors can be applied using the organ factors to improve the risk estimate.

Clearly communicate what dose is being presented and limitations of its use!

Estimating Doses for Stochastic Risk Assessment -- Risk Categories for Fluoroscopically Guided Procedures

Effective Dose Range [mSv]	Risk Descriptor NCRP 168	Benefit Required to Justify Exposure
<0.1	Negligible	Describable
0.1-1	Minimal	Minor
1-10	Minor	Moderate
10-100	Low	Substantial
>100	Acceptable in context of benefit	Very Substantial

NCRP 168

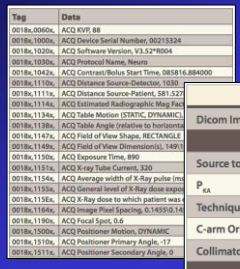
Practical Tidbits: AK Accuracy

- **After 2006, fluoro equipment must have AKR meters; accuracy of reported air kerma at reference point must be +/- 35% (pretty loose!). Best check the calibration against a dosimeter!**
  - **Different field sizes**
  - **Different filtrations**
  - **Different kVp**
- **Pre 2006, AKR meter may be present; no FDA requirement for accuracy (you may be surprised how bad it can get)**

Practical Tidbits: DICOM Data

- **Wide variations over vendors -- need to check conformance statement and verify against data**
- **Some dose report numbers (provided for DA or DSA runs) associated with images include fluoro preceding run, some do not;**
- **Some dose reports are not in the DICOM image headers, but are associated with a DICOM Modality Performed Procedure Step data**
- **PACS may not be configured to save needed private tags**
- **Not all image sets may be on PACS**

Practical Tidbits: DICOM Data



Tag	Data
0018x,0060x	ACQ KVP, 88
0018x,1000x	ACQ Device Serial Number, 00215324
0018x,1020x	ACQ Software Version, V3.52*R004
0018x,1030x	ACQ Protocol Name, Neuro
0018x,1042x	ACQ Contrast/Bolus Start Time, 085816.884000
0018x,1110x	ACQ Distance Source-Detector, 1030
0018x,1111x	ACQ Distance Source-Patient, 581.527
0018x,1114x	ACQ Estimated Radiographic Mag Fac
0018x,1134x	ACQ Table Motion (STATIC, DYNAMIC)
0018x,1138x	ACQ Table Angle (relative to horizont
0018x,1147x	ACQ Field of View Shape, RECTANGLE
0018x,1149x	ACQ Field of View Dimension(s), 149\1
0018x,1150x	ACQ Exposure Time, 890
0018x,1151x	ACQ X-ray Tube Current, 320
0018x,1154x	ACQ Average width of X-Ray pulse (ms
0018x,1155x	ACQ General level of X-Ray dose expos
0018x,115Ex	ACQ X-Ray dose to which patient was
0018x,1164x	ACQ Image Pixel Spacing, 0.1455\0.14
0018x,1190x	ACQ Focal Spot, 0.6
0018x,1500x	ACQ Positioner Motion, DYNAMIC
0018x,1510x	ACQ Positioner Primary Angle, -17
0018x,1511x	ACQ Positioner Secondary Angle, 0

Also note that some header information may be present, but not what you expect it to be!

VENDOR DICOM CONFORMANCE VARIES

Dicom Image Tag	Toshiba Infinix	Philips Allura	GE In-nova	Siemens Artis
Public				
Source to Patient	Y	Y	N	Y
P_{KA}	Y(1)	N	N	Y
Technique Factors	Y	Y	Y/N(2)	Y
C-arm Orientation	Y	Y	Y	Y
Collimator Position	N	N	Y	Y
Proprietary				
Table Position	N	NA	Y	N
Beam Filtration	Y	NA	Y/N(2)	N

Things may change when software is upgraded!

(1) Preceding Fluoroscopy dose included. (2) Varies by machine.

Practical Tidbits: Miscellaneous

- **Interview staff regarding operational practices and, if possible, observe a similar case**
- **Check assumptions regarding table positioning (patient may not be isocentric)**
- **Check assumptions regarding patient positioning on table (positioning blocks, pads may considerably elevate patient, may attenuate)**
- **Fluorosocopy contributes a significant fraction of procedure dose (AK_{ref}), but to unknown locations! Additional data from "machine logs" may be available with help. (Poster SU-E-I-83)**

According to NCRP 168, effective dose can be used for what application in the context of fluoroscopically guided procedures?

0% 1. To classify different fluoroscopic procedures into risk categories

0% 2. To estimate a patient's risk of cancer following a procedure

0% 3. To approximate skin dose from reference air kerma values

0% 4. To provide hard limits on the exposure of patients in fluoroscopic procedures

5. To calibrate the KAP meter

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According to NCRP 168, effective dose can be used for what application in the context of fluoroscopically guided procedures?

Correct Answer:

(1) To classify different fluoroscopic procedures into risk categories

NCRP 168, Recommendation 3 and section 2.6, Radiation Health Effects

(NCRP Report No. 168: Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures, National Council on Radiation Protection and Measurements (Bethesda, 2010) p. 41-42.)

Resources for Fluoroscopic Dose Calculations

Convenient compendium of tables for TAR, % Depth Dose, etc. in *Exposure of the Pregnant Patient to Diagnostic Radiations*, 2nd Ed. LK Wagner et al.

Overview and review of skin dose assessments and Monte Carlo organ dose calculations, backscatter tables, available programs, etc. in Patient Dosimetry for X-rays used in Medical Imaging , Journal of the ICRU 5(2), 1-113 (2005) .

A world of information including dosimetry review in new *NCRP No. 168, Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures* (2010)

Age dependent risk factors based on organ doses are found in BEIR VI, Part 2.

Recent paper: Khodadagegan et al, Automatic Monitoring of Local and Skin Dose with Flouoroscopic and Interventional Procedures, J Dig Img 24 (2011) 626.