Radiation dose reduction in Interventional Radiology

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Radiation dose reduction in Radiology

- Radiation risk in relation to medical imaging has been a growing concern in recent years.

- Radiation dose delivery and reduction will be discussed, with special emphasis on interventional procedures.

- Potential avenues for reduction will be discussed.

Concerns about radiation exposure from medical imaging

• National Council on Radiation Protection and Measurements (NCRP): the U.S. population's total exposure to ionizing radiation has nearly doubled over the past two decades. Per capita exposure to ionizing radiation from all sources was 3.6 mSv. By 2006, that figure had risen to 6.25 mSv.

• In the early 1980's, medical imaging accounted for 15% of the U.S. population's per capita exposure to ionizing radiation from all sources (0.54 mSv of 3.6 mSv). In 2006, medical imaging accounted for 48% of the per capita exposure (3 mSv of 6.25 mSv), with CT, nuclear medicine, and interventional fluoroscopy accounting for 24%, 12%, and 7%, respectively.

• NCRP estimates that 80 million CT scans, 20 million nuclear medicine procedures, and 21 million interventional fluoroscopy procedures were performed in the U.S. in 2015, and the authors predict that these figures will continue to grow.

National Council on Radiation Protection and Measurements, *NCRP Report No. 180*, March 2018.

Radiation risk and Interventional Radiology

- **International Commission on Radiological Protection (ICRP)**
- **National Council on Radiation Protection and Measurements (NCRP)**
- **Professional societies**

- Importance of estimating skin dose during and after fluoroscopically guided interventions

- Prediction of probability and severity of deterministic skin effects to recognize patients who require follow-up for detection of possible skin injuries.

- **A skin dose > 15 Gy is a sentinel event (Joint Commission).**

- **Important to be able to estimate peak skin dose (PSD)—the greatest absorbed skin dose at any point on the patient's skin—during and after procedures**

Stecker MS, Balter S, Towbin RB, Miller DLet al. "Guidelines for patient radiation dose management," J. Vasc. Interv. Radiol. 20, S263–S273 (2009).

The Joint Commission, Radiation Overdose as a Reviewable Sentinel Event, Update March 7, 2006. Available at: http://www.jointcommission. org/assets/1/18/Radiation_Overdose.pdf. Accessed May 18, 2011.

Issues related to medical decision making

- Concerns that physicians may lack important information that could inform their decisions in ordering medical imaging exams that use radiation.

- Ordering physicians may not have access to patients' medical imaging or radiation dose history.

- Ordering physicians may lack or be unaware of recommended criteria to guide their decisions about whether or not a particular imaging procedure is medically efficacious

http://www.pedrad.org/associations/5364/ig/

Deterministic Effects of ionizing radiation

Occur only once a threshold dose has been exceeded

References

Image Wisely: http://www.imagewisely.org/Imaging-Professionals/Imaging-Physicians/Articles/Ionizing-Radiation-Effects-and-Their-Risk-to-Humans
Food and Drug Administration: http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MedicalX-Rays/ucm115359.htm
Little, MP, Risks associated with Ionizing Radiation, Environment pollution and health, British Medical Bulletin, Oxford University Press, 2003, 68 (1): 259-275, http://bmb.oxfordjournals.org/content/68/1/259.full

Radiation injury

Day 3

Day 10

Peruvian patient who inadvertently placed a 26-Ci (0.962-TBq) irridiun-192 (192 Ir) source in his back pocket.for 6.5 hours.
3 days and 10 days postexposure. He sought medical advice and was told he probably had been bitten by an insect. In the meantime, his wife sat on the patient's pants (her case appears on the next page) while breastfeeding the couple's 1½-year-old child. The source was recovered several hours later by nuclear regulatory authorities, and the patient was transported to Lima for treatment. This patient had a drastic reduction in lymphocyte count by day 3, and a 4-by-4-cm lesion appeared on day 4.
Then he suffered a massive ulceration and necrosis with infection, and his right leg was amputated.
Grade II and III CRI was also evident on his hands, left leg, and perineum, but he survived and returned to his family.

http://www.bt.cdc.gov/radiation/criphysicianfactsheet.asp

Types of radiation injury

Phase	Symptom	Whole-body absorbed dose (Gy)				
		1–2 Gy	2–6 Gy	6–8 Gy	8–30 Gy	Greater Than 30 Gy
Immediate	Nausea and vomiting	5–50%	50–100%	75–100%	90–100%	100%
	Time of onset	2–6 h	1–2 h	10–60 min	< 10 min	Minutes
	Duration	< 24 h	24–48 h	< 48 h	< 48 h	N/A (patients die in < 48 h)
	Diarrhea	None	None to mild (< 10%)	Heavy (> 10%)	Heavy (> 95%)	Heavy (100%)
	Time of onset	—	3–8 h	1–3 h	< 1 h	< 1 h
	Headache	Slight	Mild to moderate (50%)	Moderate (80%)	Severe (80–90%)	Severe (100%)
	Time of onset	—	4–24 h	3–4 h	1–2 h	< 1 h
	Fever	None	Moderate increase (10-100%)	Moderate to severe (100%)	Severe (100%)	Severe (100%)
	Time of onset	—	1–3 h	< 1 h	< 1 h	< 1 h
	CNS function	No impairment	Cognitive impairment 6–20 h	Cognitive impairment > 24 h	Rapid incapacitation	Seizures, Tremor, Ataxia, Lethargy
Latent period		28–31 days	7–28 days	< 7 days	none	none
Illness		Mild to moderate Leukopenia Fatigue Weakness	Moderate to severe Leukopenia Purpura Hemorrhage Infections Epilation after 3 Gy	Severe leukopenia High fever Diarrhea Vomiting Dizziness and disorientation Hypotension Electrolyte disturbance	Nausea Vomiting Severe diarrhea High fever Electrolyte disturbance Shock	N/A (patients die in < 48h)
Mortality	Without care	0–5%	5–100%	95–100%	100%	100%
	With care	0–5%	5–50%	50–100%	100%	100%
	Death	6–8 weeks	4–6 weeks	2–4 weeks	2 days–2 weeks	1–2 days

http://en.wikipedia.org/wiki/Acute_radiation_syndrome

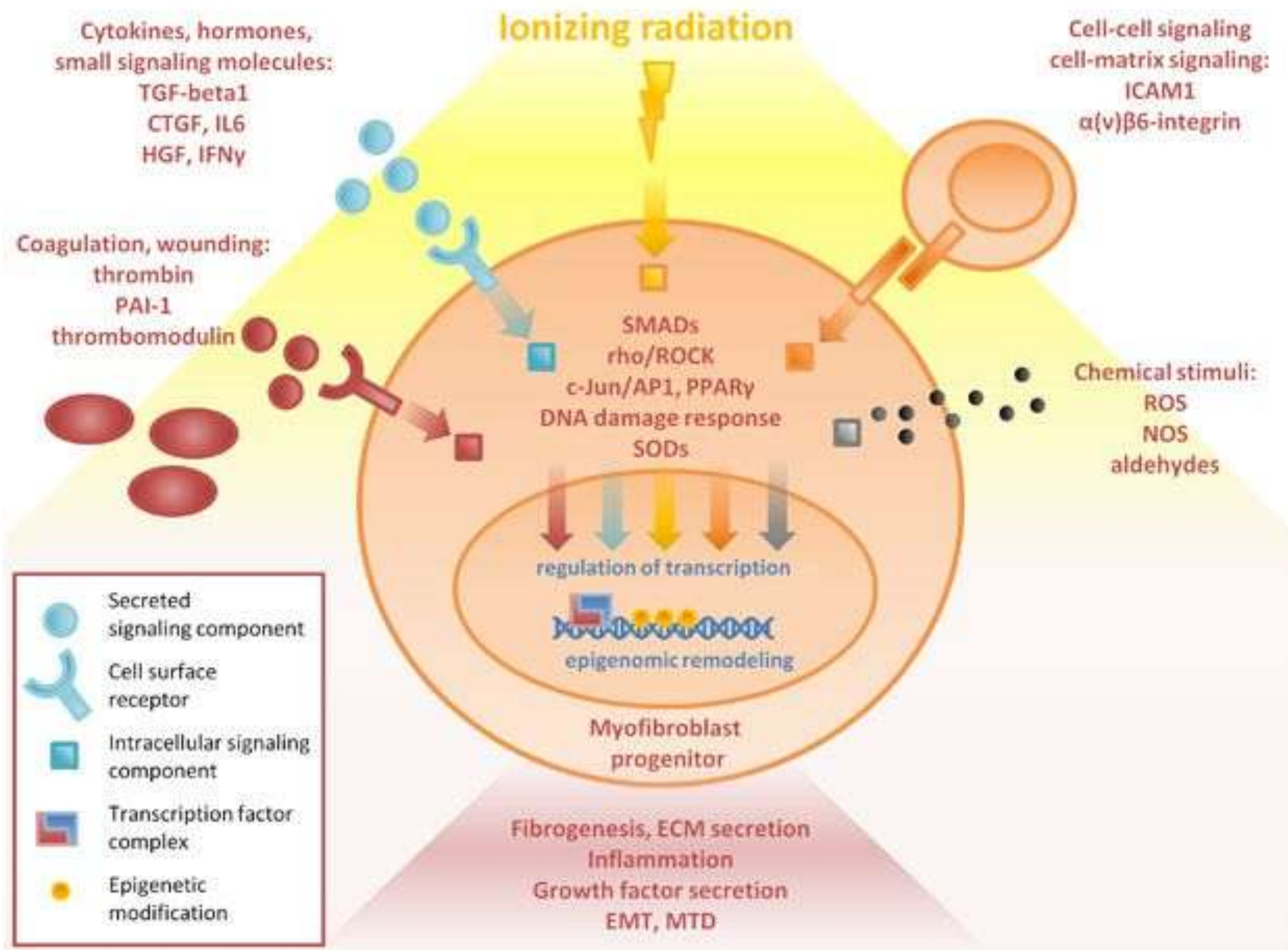
Stochastic Effects of ionizing radiation

Develop years after low levels of exposure

References

Brenner, et al. Computed Tomography-An Increasing Source of Radiation Exposure. *N Engl J Med* 2007*Recommendations of the International Commission on Radiological Protection.* Oxford: Pergamon Press; 1991.
Tubiana M. Letter to the Editor. Br. J Radiol. 2005; 78: 1060.
National Academy of Science. BEIR VII: health risks from exposure to low levels of ionizing radiation. Washington, DC: National Academies Press; 2005
UNSCEAR 2000. The United Nations Scientific Committee on the Effects of Atomic Radiation (Annex D): A/55/46. New York, NY: United Nations, 2000.

Radiation-induced fibrosis



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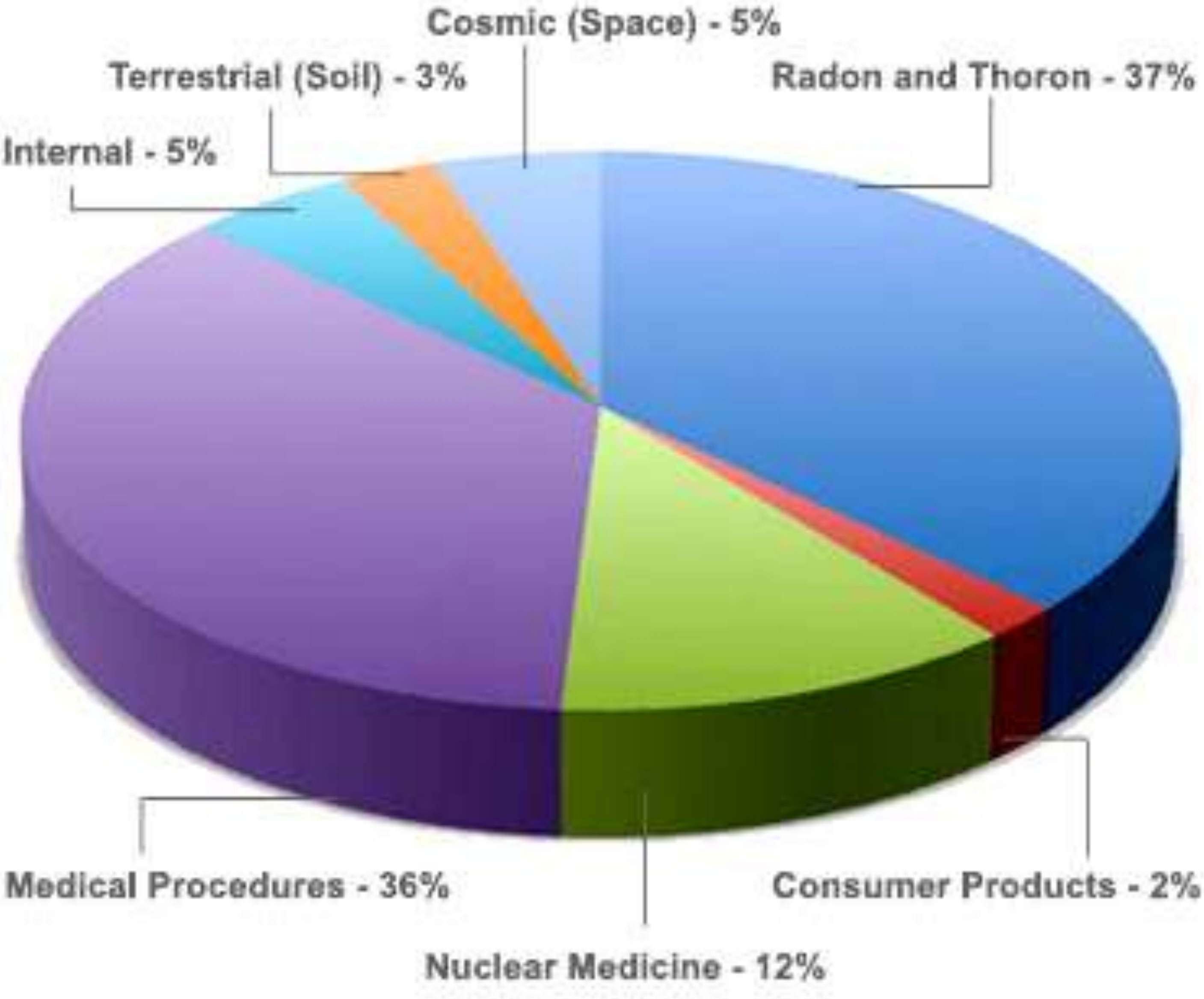
Greatest sources of radiation exposure to U.S. citizens

- The average effective dose from **background radiation** is about **3 mSv** /year.
- 0.02 mSv is the average adult effective dose from a posteroanterior chest x-ray.
- 2 mSv is the average adult effective dose from a CT exam of the head.
- 8 mSv is the average adult effective dose from a CT exam of the abdomen.
- 16 mSv is the average adult effective dose from a CT coronary angiography exam.
- 0.2 mSv is the average adult effective dose from a lung ventilation exam using 99mTc-DTPA.
- 41 mSv is the average adult effective dose from a cardiac stress-rest test using thallium 201 chloride.
- 5 mSv is the average adult effective dose from a head and/or neck angiography exam.
- 70 mSv is the average adult effective dose from a transjugular intrahepatic portsystemic shunt placement.

NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*
http://www.ncrponline.org/Publications/Press_Releases/160press.html

General exposure to radiation



How is dose measured?

• CT dose index (CTDIvol) in milligrays: measure of the intensity of radiation directed at a patient by the CT scanner. CTDIvol calculations are based on scanning of an acrylic phantom with a cross-sectional diameter of 32 cm.
• Dose-length product (DLP) in mGy-cms is the product of the CTDIvol and scan length and represents the integrated dose over the length of exposure.
• CT effective dose is measured in millisieverts. By converting DLP values from milligray-centimeters to mSv, one can obtain an approximate whole-body dose from partial body exposures, a measure that allows comparisons with the approximate whole-body radiation dose from other CT examinations as well as with the background radiation dose.
• DLP values are easily converted to mSv by using conversion factors specific to the anatomic region imaged.
• Conversion factors listed by the American Association of Physicists in Medicine for the chest, abdomen, and pelvis are 0.014, 0.015, and 0.015 mSv/(mGy · cm).
• Conversion factors are periodically updated, so care should be taken to apply the most recent ones.

Morin RL, Gerber TC, McCollough CH. Radiation dose in computed tomography of the heart. Circulation 2003;107(6):917–922.

American Association of Physicists in Medicine. The measurement, reporting, and management of radiation dose in CT. Report No. 96. College Park, Md: American Association of Physicists in Medicine, 2008.

Huda W, Mettler FA. Volume CT dose index and dose-length product displayed during CT: what good are they? Radiology 2011;258(1):236–242.

Radiation Doses from Various Types of Medical Imaging Procedures

Type of Procedure	Average Adult Effective Dose (mSv)	Estimated Dose Equivalent (No. of Chest X-rays)
Dental X-ray	0.005-0.01	0.25-0.5
Chest X-ray	0.02	1
Mammography	0.4	20
CT	2-16	100-800
Nuclear Medicine	0.2-41	10-2050
Interventional Fluoroscopy	5-70	250-3500

Dose reduction

High radiation doses

- Skin injury to patient
- Hair loss
- Cataract/lens opacification in patients
- Fibrosis
- Cancer

Dose reduction measures

- Equipment
- Quality management
- Operator training
- Occupational radiation protection

Miller DL. Efforts to optimize radiation protection in interventional fluoroscopy. Health Phys. 2013 Nov;105(5):435-44. doi: 10.1097/HP.0b013e31829c355a.

Multiple exposures to CTA/CTP

53 yo man, 4 CT/CTA/CTP, 2 DSA within 15 days for aneurysmal SAH

Imanishi et al., *Eur Rad* 2005;15:46

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Dose reduction - Equipment

- Digital imaging allows a wide range of dose values to obtain the desired/required level of quality imaging
- Fluoroscopy dose should be optimized : pulse fluoroscopy
- Collimation
- Filters
- ALARA

Dose reduction

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Dose reduction – Quality management

• Diagnostic Reference Level DRL : “commom examinations” done in standard way
• For fluoroscopically-guided interventions, difficulty in finding standards
  - Variations in procedure types/duration/complexity
  - Variations in patient anatomy and pathology
• Consensus that DRLs can be assessed and used in IR
• Parameters should be defined : fluoroscopy time, number of images, KAP and CK at IRP
• Identification of unacceptable practices
• Optimization process
• Complexity of procedures :
• How to manage high skin doses in non-optimized/multiple procedures?

Miller DL, Kwon D, Bonavia GH. Reference levels for patient radiation doses in interventional radiology: proposed initial values for U.S. practice. Radiology. 2009 Dec;253(3):753-64. doi: 10.1148/radiol.2533090354. Epub 2009 Sep 29.

Kwon D, Little MP, Miller DL. Reference air kerma and kerma-area product as estimators of peak skin dose for fluoroscopically guided interventions. Med Phys. 2011 Jul;38(7):4196-204.

DRL for Interventional Radiology

Type of examination	Reference levels		
	Fluoroscopy time (min)	Number of images	KAP (Gy cm^2)
Transjugular intrahepatic portosystemic shunt creation	60	300	525
Biliary drainage	30	20	100
Nephrostomy for obstruction	15	12	40
Nephrostomy for stone access	25	14	60
Pulmonary angiography	10	215	110
Inferior vena cava filter placement	4	40	60
Renal or visceral angioplasty without stent	20	210	200
Renal or visceral angioplasty with stent	30	200	250
Iliac angioplasty without stent	20	300	250
Iliac angioplasty with stent	25	350	300
Bronchial artery embolisation	50	450	240
Hepatic chemoembolisation	25	300	400
Uterine fibroid embolisation	36	450	450
Other tumor embolisation	35	325	390
Gastrointestinal hemorrhage localization and treatment	35	425	520
Embolisation in the head for AVM	135	1,500	550
Embolisation in the head for aneurysm	90	1,350	360
Embolisation in the head for tumor	200	1,700	550
Vertebroplasty	21	120	120
Pelvic artery embolisation for trauma or tumor	35	550	550
Embolisation in the spine for AVM or tumor	130	1,500	950

Miller DL, Kwon D, Bonavia GH. Reference levels for patient radiation doses in interventional radiology: proposed initial values for U.S. practice. Radiology. 2009 Dec;253(3):753-64. doi: 10.1148/radiol.2533090354. Epub 2009 Sep 29.

Dose reduction – Quality management

• **Complexity** of procedures
• Acquire database and compare with other facilities
• Automatic trigger for analysis for procedures that deliver high doses and low doses

• NCRP 168 defines **high dose procedure** as one when >5% of cases result in CK >3Gy or KAP >300 Gycm2

• **Trigger level** = dose level aimed at alerting IR physician on skin dose which can be comparable to threshold on tissue effects
• TL may be expressed on modern equipment as PSD (peak skin dose)
• Clinical follow-up recommended for patients exceeding TL

• If repeated excessive doses -> procedure protocol/operator behavior

Dose reduction

Dose reduction measures

- Equipment
- Quality management
- Operator training
- Occupational radiation protection

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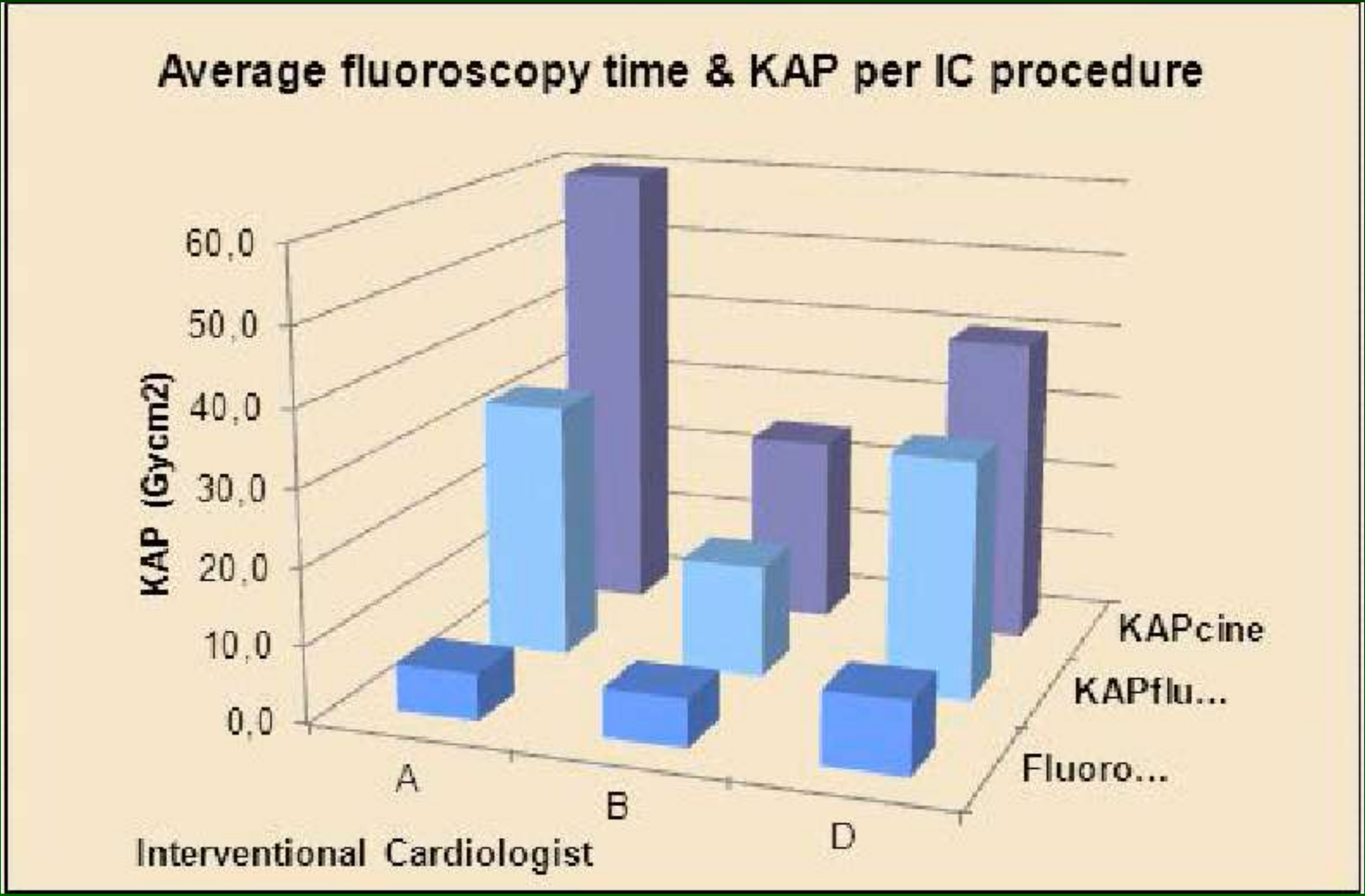
Dose reduction - Operator

Operator behavior = 3 interventional cardiologists work in same hospital with same equipment performing similar mix of procedures

Average KAP for fluoro and cine modes



Dose reduction

Dose reduction measures

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Dose reduction - Occupational

- Dose tracking tools
- IEC, DICOM and IHE developed standards
- Registration, distribution

- Occupational radiation protection

- Is exposure to staff known?
- Poor standards at this time despite >50 years of experience

- Use of dosimeters highly variable from surveys: wearing, position of dosimeters,
- Over apron-> estimates eye exposure
- Probably large numbers of IR MD have annual eye doses > 20 mSv/y
- Use of eye shields, dosimeter position, X-ray protection

Conclusion

- Radiation exposure during interventional procedures is a problem
- Equipment optimization
- Quality Control
- Need to improve staff monitoring
- Training/monitoring of procedural patterns
- Dosimetry
- Reduce staff exposure: training theoretical and practical
- 2013 IAEA formal recognition of E&T in RP required by new BSS -> diplomas and qualifications