JOINT AAPM/COMP MEETING 2011

Radiation Safety for Staff in Fluoroscopy Suites

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Learning Objectives

- For staff performing fluoroscopically-guided interventional procedures:
  - What are typical radiation exposure levels?
  - How should the radiation exposure to staff be monitored?
  - What type of radiation safety education is needed?
  - Is there anything new and novel available that can help reduce staff exposure levels?

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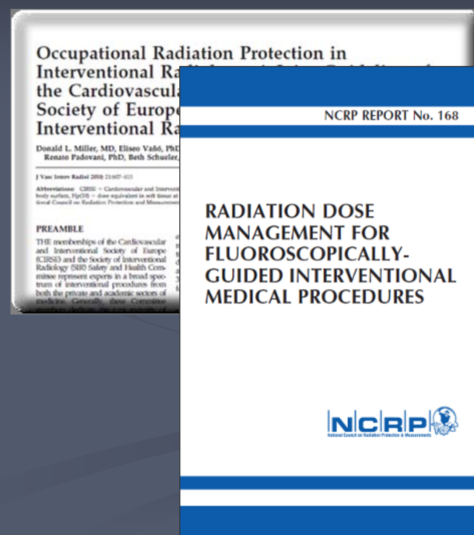
Resources

- Joint SIR / CIRSE Guideline for Occupational Radiation Protection in IR (Miller et al, 2010)
- NCRP Report No. 168 Radiation Dose Management for Fluoroscopically-guided Interventional Medical Procedures, 2011



Operator Exposure During Fluoroscopy Procedures

Procedure Type	Mean Dose per Procedure (µSv)			Reference
	Neck	Lens	Hand	
Mixed general IR	30-325	300	270-400	NCRP 168
ERCP	450	550	640	NCRP 168
Endovascular surgery	300		400	NCRP 168
Percutaneous coronary intervention	10-130	10-170	30-350	Kim et al, 2008
Cardiac ablation	8-200	50-320	40-230	Kim et al, 2008

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Typical Operator Exposure Levels

- Annual doses for a workload of 1000 procedures
  - Neck: 10-450 mSv
  - Lens of the eye: 10-550 mSv
  - Hand: 30-640 mSv
- Survey of interventional radiologists with a mixed workload (Marx et al, 1992)
  - Mean annual dose (dosimeter on chest over protective apron): 49 mSv (range: 3-115 mSv)

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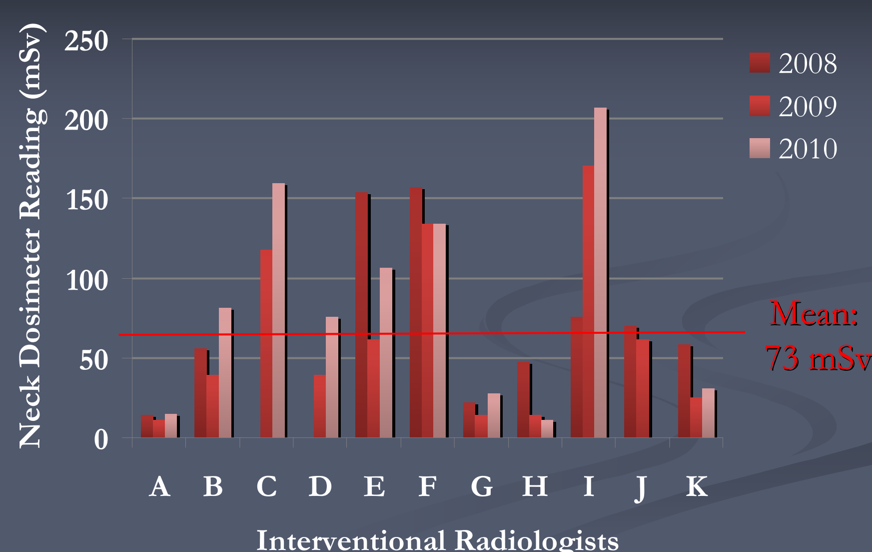

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Operator Exposure Levels

- Typical doses for operators performing fluoroscopically-guided interventional procedures are high
  - May exceed annual dose limits
    - Lens of the eye: 150 mSv
    - Hands: 500 mSv
  - Values generally well exceed those for other healthcare workers
    - Annual US healthcare workers (NCRP Report No. 160): 81% with recordable dose are < 1 mSv

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Personnel Dose Monitoring

- Due to the potential for high occupational doses, appropriate monitoring is critical
- Monitoring considerations:
  - 1-dosimeter or 2-dosimeter monitoring?
  - Dose calculation method?
  - When should dose readings be investigated?

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Personnel Dose Monitoring

1-Dosimeter Method:
At neck, outside apron

2-Dosimeter Method:
At neck, outside apron and at waist or chest, under apron

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Personnel Dose Monitoring

- 2-Dosimeter method recommended (NCRP Report No. 168)
  - Provides an indication of apron attenuation
  - Allows for better estimate of operator effective dose
  - Dosimeters should be clearly labeled to avoid mix-ups

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Dose Assignment with Protective Aprons

- Various calculation models exist and state regulations vary
- CRCPD SSRs (Webster's method)
  - $H_E = 1.5 \times \begin{matrix} under-lead \\ reading \end{matrix} + 0.04 \times \begin{matrix} neck\ over-lead \\ reading \end{matrix}$
    - H_E, effective dose equivalent
- NCRP Report No. 122 recommendation
  - $E = 0.5 \times \begin{matrix} under-lead \\ reading \end{matrix} + 0.025 \times \begin{matrix} neck\ over-lead \\ reading \end{matrix}$
    - E, effective dose

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Operator Exposure During Fluoroscopy Procedures

Procedure Type	Mean Annual Effective Dose* (mSv)	Reference
Mixed general IR	2 - 15	NCRP 168
ERCP	21	NCRP 168
Endovascular surgery	23	NCRP 168
Percutaneous coronary intervention	0.2 - 9	Kim et al, 2008
Cardiac ablation	0.2 - 10	Kim et al, 2008

* assuming workload of 1000 procedures per year

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Annual Dose Limits

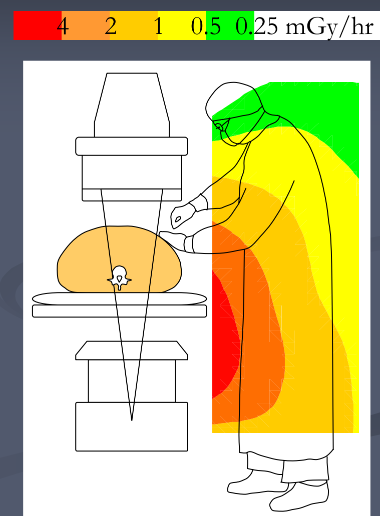
- NCRP Report No. 116 recommendation:
  - Effective dose: 50 mSv
- ICRP Publication 60 recommendation:
  - Effective dose: 20 mSv, averaged over 5 years, not to exceed 50 mSv in a single year

Lens Exposure

- Annual dose limit recommendations (NCRP Report No. 116):
  - Lens of the eye: 150 mSv
- Measurements for an annual workload of 1000 procedures,
  - Lens of the eye (unprotected): 10-550 mSv

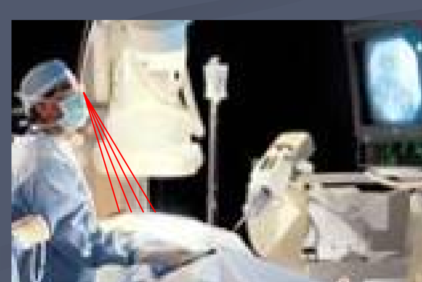
Lens Dose Estimation

- Exposure level at the eye is typically somewhat lower than at the neck
  - Lens:Neck dose ratio varies with C-arm angulation
- Neck dosimeter reading provides conservative estimate (NCRP No. 168)



Leaded Eyewear

- Typical lead equivalent thickness of radiation protective eyewear is 0.75 mm
  - 98% attenuation
- Actual lens dose is higher due to
  - Exposure from the side and from below
  - Backscatter from head



Leaded Eyewear

- Traditional style
  - 0.75 mm lead equivalent lenses
  - 120 g
  - 28 cm^2 surface area

Leaded Eyewear

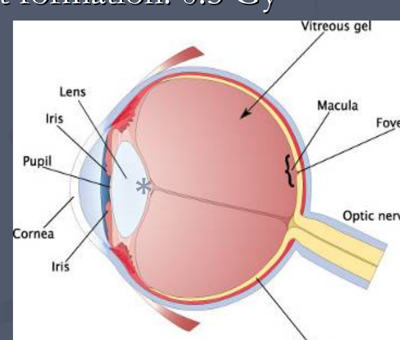
- Sport-wrap style
  - 0.75 mm lead equivalent lenses
  - 59 g
  - 16 cm^2 surface area

Leaded Eyewear Attenuation

Leaded Eyewear Style	Attenuation Factor		
	0° Angle	45° Angle	90° Angle
Traditional	10	5.2	4.0
Sport-wrap	8.3	4.5	1.4

New Guideline on Lens Exposure

- ICRP issued a new recommendation (ICRP, 2011)
  - Lower threshold for cataract formation: 0.5 Gy (previous threshold 2-5 Gy)
  - Lower occupational eye dose limit: 20 mSv/yr averaged over 5 years with no year > 50 mSv



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Radiation-Induced Cataract

- Problems with earlier studies:
  - Short follow-up period – latency period is longer for low doses
  - Insufficient sensitivity to detect early lens changes
  - Few subjects with doses below a few gray
- Significant studies:
  - Chernobyl nuclear reactor accident cleanup workers (Worgul et al, 2007)
  - US radiologic technologists (Chodick et al, 2008)

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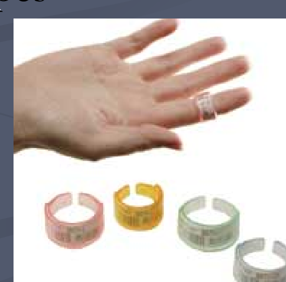
Hand Dose

- Ring dosimeters recommended if hand dose > 50 mSv in a year (NCRP Report No. 168)
- Monitor for a trial period of several months for new staff and new procedure types
- Wear with sensitive area toward exposure source
  - Inward for under-table x-ray tube configurations



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Investigation of Dose Readings

- Recommended investigation trigger level (WHO, 2000):
  - E, effective dose > 0.5 mSv/month
  - Lens dose > 5 mSv/month
  - Hand dose > 15 mSv/month
- Verify validity of measurement
- Look for changes in procedure volume, procedure type, equipment, …

Investigation of Dose Readings

- It is common for personnel who may receive a high occupational dose to not wear their dosimeters to avoid investigations
  - 43% of surveyed interventional radiologists indicate they rarely or never wear monitoring dosimeters (Marx et al, 1992)
- Dosimeter readings that are lower than expected for a specific work assignment should also be investigated (NCRP Report No. 168)

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Radiation Safety Education

- Credentials and privileges for fluoroscopy operators are needed
  - Help for developing a program is coming
  - AAPM TG 124 (Chair – Mary Moore)
    - "A Guide for Establishing a Credentialing and Privileging Program for Users of Fluoroscopic Equipment in Healthcare Organizations" is in the works
    - Will include suggestions to encourage your facility to approve a program, didactic content, evaluating competency and information resources for teaching

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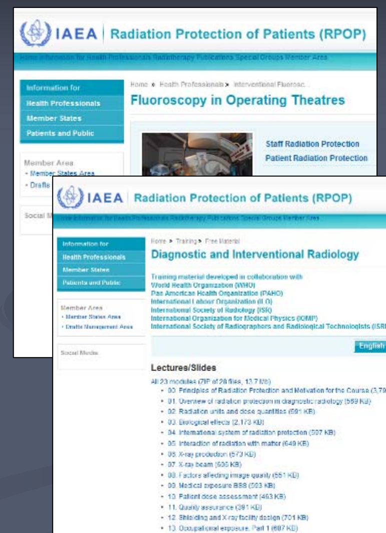
Occupational Radiation Safety Resources

- IAEA RPOP web pages
  - https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/index.htm
- IAEA slide presentation series
  - https://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/Radiology.htm



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Occupational Radiation Safety Resources

- Image Gently pediatric IR presentation
  - http://www.pedrad.org/associations/5364/ig/
- RSNA/AAPM Online physics modules
  - http://physics.rsna.org/default.asp
  - “Radiation Safety and Dose in Interventional Radiology”

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Operator Shielding

- Overhead and table shields can be very effective
- But may be cumbersome for certain procedures:
  - C-arm angulation
  - Biliary or transjugular access

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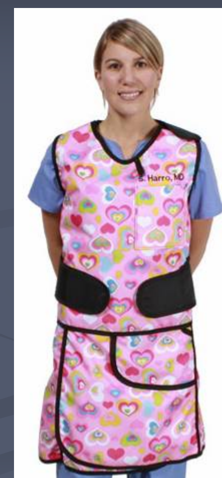
Orthopedic Complications from Lead Apron Use

- Back pain was reported by 50-75% of interventional physicians surveyed (Klein et al, 2009)
  - Compare to typical incidence of 27% in US adults
  - 25-30% reported that back problems had limited their work
- Options for relief
  - Lightweight aprons
  - Vest/kilt design



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Radiation Protective Cabins

- ZeroGravity
  - 1.25 mm lead apron and 0.5 mm lead-equivalent face shield

Marichal et al, 2011

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Radiation Protective Cabins

- CATHPAX
  - 2 mm lead walls and lead-equivalent windows

Dragusin et al, 2007

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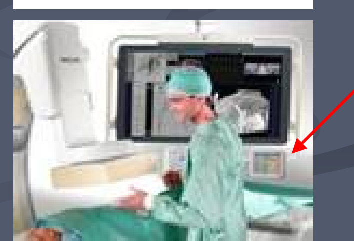
Real-time Personnel Dose Monitoring

- DoseAware
  - Displays cumulative dose and dose rate on a monitor
  - Can be networked between multiple procedure rooms
  - Allows for real-time feedback to avoid high scatter conditions and implement radiation reduction techniques



Sanchez et al, 2010

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Heavy Metal Protective Patient Drapes

- RADPAD
  - Gel pad with tungsten-antimony
  - Sterile, dispose after procedure
  - 12× eye dose reduction
  - 29× hand dose reduction

Dromi et al, 2006

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