Methods for Eye Lens Dosimetry and Studies on Lens Opacities with Interventionalists

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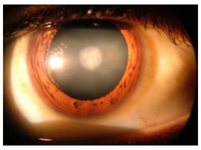
Disclosures

- None

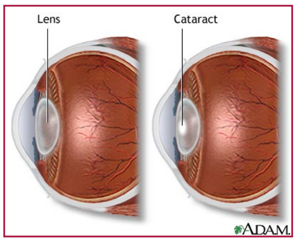
What is cataract?

Clouding or opacification of the natural lens of the eye and obstructing the passage of light



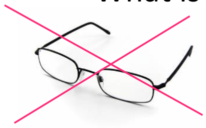
Most frequent cause of blindness worldwide

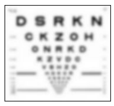
Cataract



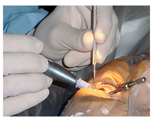
- Lenticular Opacification
- Risk Factors:
  - Corticosteroids
  - Diabetes Mellitus
  - Sunlight exposure (UVB)
  - Trauma
  - Infections
  - Nutritional deprivation
  - Age (~ 50% >65 yrs)
  - Heredity
  - Radiation

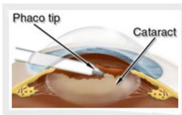
What is treatment?





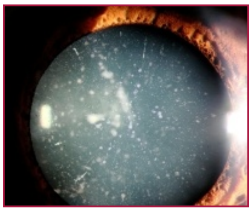
Easily treatable condition –surgery or phacoemulsification





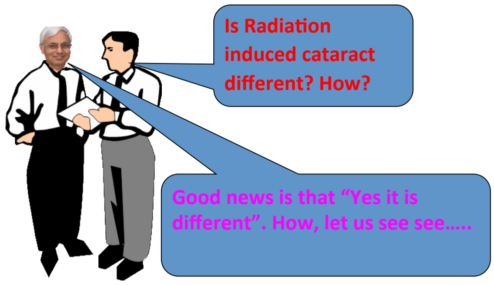
Nothing to match natural

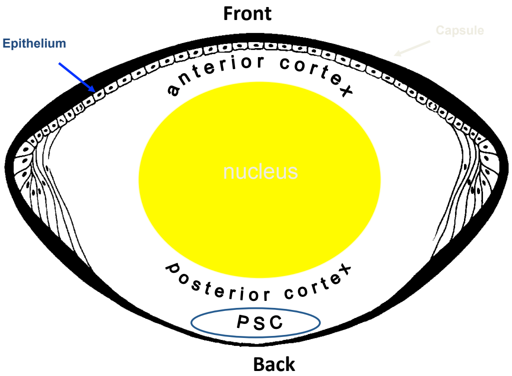
Radiation & Cataract



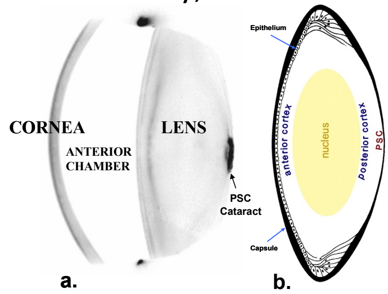
- Dot Opacities
- Latency depends on rate at which damaged epithelial cells undergo fibrogenesis and accumulate.

HOT Topic in Occupational Radiation Protection





Pre-dominantly, not exclusively



Major Cataract Subtypes

- **Cortical**
- **Nuclear**
- **Posterior SubCapsular (psc)**
- **Mixed**

Eye dosimetry

- **Regular eye dosimetry in diagnostic imaging practically does not exist**
- **Accurate assessment of eye lens dose is one of the most important aspects of:**
  - **correlating doses with observed lens opacities** among workers in interventional suites
  - ascertaining **compliance with regulatory limits**

Dose metrics

- The eye lens dose, as organ dose is not directly measurable
- According to ICRU the operational quantity Hp (3) is the most appropriate to monitor the eye lens dose, as the lens is covered by about 3 mm of tissue
- Proposals to use Hp(0.07) for eye lens dose monitoring
- Correlations are being attempted with Hp(10)

Current eye dosimetry challenges

- Which personal dose equivalent quantity is appropriate?
- How it can be used routinely for eye lens dose monitoring?
- What is a suitable dosimeter and calibration procedure?
- How to convert radiometric quantities, as fluence, to equivalent dose to the lens?

Possible approaches

Practical dosimetry:

1. Passive dosimeters
2. Active dosimeters
3. Retrospective dose assessment using scatter radiation dose levels
4. Correlations between patient dose indices and eye doses to the operators

Passive dosimeters

- Dedicated passive dosimeter designed to provide the dosimetric quantity Hp(3)
- Double dosimetry:
  - If a dedicated eye dosimeter is not available, a collar dosimeter calibrated in terms of Hp(0.07)
    - Some studies that claim that collar dosimeter provide a reasonable and conservative estimate of eye lens dose (within 15%)
    - Other studies claiming that a dosimeter at collar level would underestimate the absorbed dose to the eye lens to about 73 %

Problems with Passive dosimetry

- Large number of operators are not wearing personal dosimeters or wear it irregularly
- No passive dosimeter has been accepted for regulatory purpose

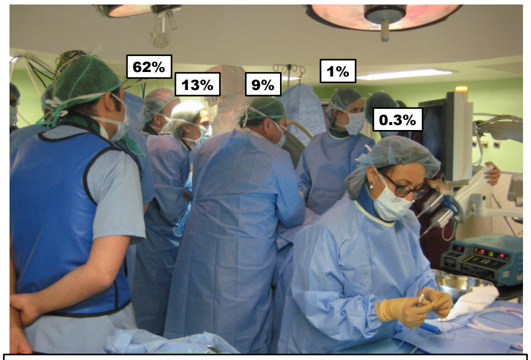
Possible approaches

Practical dosimetry:

1. ~~Passive dosimeters~~
2. Active dosimeters
3. Retrospective dose assessment using scatter radiation dose levels
4. Correlations between patient dose indices and eye doses to the operators

Measuring scatter dose reduction for different goggles (with correct position of ceiling suspended shielding: Only 4-8 % transmitted)

Courtesy E. Vano, Madrid



Vascular surgery procedure % of the scatter dose measured at the C-arm
San Carlos University Hospital Madrid

Courtesy E. Vano, Madrid

Scatter levels (incorrect position of the ceiling shielding) In this case: 20-90 % transmitted (depending of the shielding position)

Courtesy E. Vano, Madrid

Measuring scatter dose reduction for different goggles (frontal protection and lateral protection)



Frontal transmission
5 ± 1 %
(max. 7 min. 4)
Lateral transmission
23 ± 16 %
(max. 48 min. 6)

Courtesy E. Vano, Madrid

Active dosimeters

- Good for
  - educational purpose and
  - for radiation protection
- Not for regulatory compliance

Possible approaches

Practical ~~dosimetry:~~
1. Passive dosimeters
2. Active dosimeters

3. **Retrospective dose assessment using scatter radiation dose levels**
4. Correlations between patient dose indices and eye doses to the operators

Retrospective dosimetry

- **Reconstruction of the laboratory workload (types and numbers of procedures)**
- **Usually with questionnaires and the application of many assumptions about past activity (procedures performed, corresponding doses based on previous dosimetric studies and the use of radiation protection tools)**
- **Currently many times-this is the only possible approach**

Possible approaches

Practical dosimetry:

1. ~~Passive dosimeters~~
2. Active dosimeters
3. Retrospective dose assessment using scatter radiation dose levels
4. **Correlations between patient dose indices and eye doses to the operators**

Correlation of patient's dose with operators' eye lens dose

- **No clear consensus on the correlation between the patient dose and the dose to the eyes of the medical staff**
- **Correlation between the eye dose and kerma-area product strongly depends on two main parameters:**
  - **X-ray tube configuration**
  - **use of radiation protection tools**

Radiation Protection Dosimetry Advance Access published November 14, 2012

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EYE LENS DOSIMETRY IN INTERVENTIONAL CARDIOLOGY: RESULTS OF STAFF DOSE MEASUREMENTS AND LINK TO PATIENT DOSE LEVELS

V. Antic[1], O. Ciraj-Bjelac[2,*], M. Rehani[3], S. Aleksandric[4], D. Arandjic[2] and M. Ostojic[4,5]
[1]Center for Nuclear Medicine, University Clinical Centre of Serbia, Belgrade, Serbia
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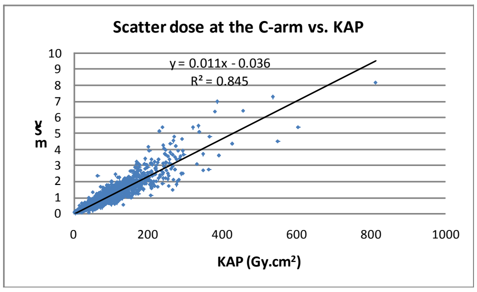
[4]Clinic of Cardiology, University Clinical Centre of Serbia, Belgrade, Serbia
[5]School of Medicine, University of Belgrade, Belgrade, Serbia

From our RPD paper

Normalized eye lens doses per unit kerma–area product:

- 0.94 mSv/Gy cm2 for the first operator, 0.33 mSv/Gy.cm2 for the second operator/nurse and 0.16 mSv/Gy.cm2 for radiographers.
- Statistical analysis indicated that there is a weak but significant ($p < 0.01$) correlation between the eye dose and the kerma–area product for all three staff categories.



Recommendations

- **Use of active dosimeter is most appropriate option for periodic assessment**
- **If a dedicated eye dosimeter is not available:**
  - **estimation of eye dose from patient dose**

- **As per NCRP Report 168, nearly 16 million interventional procedures are performed annually in USA.**

Latest changes in dose limits and dose thresholds

ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

ICRP ref 4825-3093-1464

Statement on Tissue Reactions

Approved by the Commission on April 21, 2011

- Lens of the eye, threshold in absorbed dose is now considered to be 0.5 Gy (against 0.5 to 2 for detectable opacities and 5 for visual impairment) .
- Occupational Exposure Lens of Eye Limit
  - **20 mSv in a y** (against 150), averaged over defined periods of 5 y, with no single y exceeding 50 mSv

ICRP

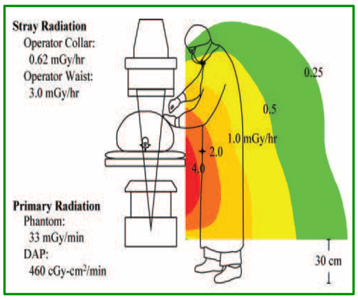
- **Threshold dose: 0.5 Gy (50 rads)**
- **Occupational dose limit: 20 mSv (2000 m rem) averaged over 5 years.**
- **NCRP yet to finalize/accept these**

Recent Studies on lens opacities among Interventionalists

Interventional Radiologists

Haskal & Worgul, RSNA News 2004:14

- Radiologists
- 5/59 posterior subcapsular cataracts
- 22/59 small dot-like opacities (early signs of radiation damage)
- 1/59 had undergone cataract surgery in one eye



Schueller et al, Radiographics 2006

IAEA | Radiation Protection of Patients (RPOP)

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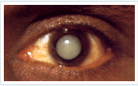
IAEA Cataract study



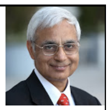
IAEA activity on Retrospective Evaluation of Lens Injuries and Dose (RELID)

The lens of the eye is one of the radiosensitive tissues in the body. Radiation induced cataract has been demonstrated among staff involved with interventional procedures using X rays [ICRP 85; Vano et al., 1998]. A number of studies suggest there may be significant risk of lens opacities in populations exposed to low doses of ionizing radiation. These include those undergoing CT scans [Klein et al., 1993], astronauts [Cucinotta et al., 2001; Rastegar et al., 2002], radiologic technologists [Chodick et al., 2008] radiotherapy [Hall et al., 1999] besides data from atomic bomb survivors [Nakashima et al., 2006; Neriishi et al., 2007] and those exposed in Chernobyl accident [Day et al., 1995]

These observations have clear implications for those working in interventional rooms. Interventionalists and paramedical staff (nurses and to some extent radiographers) remain near the X ray source and within a high scatter radiation field for several hours a day during interventional procedures. During typical working conditions and if radiation protection tools are not routinely used, x-ray exposure to the eyes of interventional physicians and paramedical personnel working in interventional and catheterization laboratories can be high.

The cataract has so far been considered to be a deterministic effect with threshold. The International Commission on Radiological Protection (ICRP) and the U.S. National Council on Radiology Protection

Active collaborators



Eliseo Vano

Norman Kleiman

A Minanoto

Ariel Duran

KH Sim

Olivera Ciraj

Plus a team of local ophthalmologists

IAEA Cataract

IAEA Cataract study - List of Eye testing exercises conducted

No	Place (City, Country)	Dates	Regional/National organization	Links
1	Bogota, Colombia	25-26 Sept.2008	SOLACI[1]	RELID report Colombia [English], [Español]
2	Kuala Lumpur, Malaysia	17-19 April 2009	NAHM[2]	RELID report Malaysia
3	Montevideo, Uruguay	16-17 April 2009	SOLACI[1]	RELID report Uruguay [English], [Español]
4	Varna, Bulgaria	11-12 July 2009	NCRRP[3]	RELID report Bulgaria
5	Sofia, Bulgaria	13-15 July 2009	NCRRP[3]	RELID report Bulgaria
6	Bangkok, Thailand	23-24 December 2009		RELID report Thailand
7	Buenos Aires, Argentina	11-13 August 2010	SOLACI[1]	RELID report Argentina [English], [Español]
8	Kuala Lumpur, Malaysia	6-7 May 2011	NAHM[2]	RELID Malaysia

[1]SOLACI: Latin American Society on Interventional Cardiology

[2] NHAM: National Heart Association of Malaysia

[3]NCRRP: National Centre of Radiation Biology and Radiation Protection

SCORE	APPEARANCE			DESCRIPTION
	Anterior	Posterior	Sagittal	
0				Transparent Lens…**NO** opacities or dots discernible posteriorly **OR** anteriorly
0.5				Anterior **OR** posterior region* has ≤ **4** dots **AND** the other is transparent
1.0				Anterior **OR** posterior region has > **4** dots **AND** the other is transparent
1.5				One region has > **4 AND** the other ≤ **4** dots
2.0				Both anterior **AND** posterior have > **4** dots
2.5				"Cloudy Skies". Vitreous visible through scattered anterior opacification
3.0				Posterior viewable but not vitreous **AND** anterior has scattered opacification
3.5				Total posterior opacity AND anterior near totally opaque with only occasional breaks
4.0				Anterior cortex completely opaque preventing viewing beyond superficial layers

* *Posterior Region* is defined as the superficial cortex, which includes the Posterior Subcapsular (PSC) area.

Radiation induced cataract is a major threat among staff working in interventional suites

Lens Opacities>0.5

- **38-53% main operators (1/3rd to half of main operators)**
- **21-45% in nurses**

Our Publications

1. Rehani MM, Vano E, Ciraj-Bjelac O, Kleiman NJ. Radiation and cataract. Radiat Prot Dosimetry. 2011. http://www.ncbi.nlm.nih.gov/pubmed/21764807
2. Ciraj-Bjelac O, Rehani M, Minamoto A, Sim KH, Liew HB, Vano E. Radiation induced eye lens changes and risk for cataract in interventional cardiology. Cardiology 2012 Oct 31;123(3):168-171.
3. Ciraj-Bjelac O, Rehani MM, Sim KH, Liew HB, Vano E, Kleiman NJ Risk for radiation induced cataract for staff in interventional cardiology: Is there reason for concern? Catheterization and Cardiovascular Interventions. 2010; 76: 826-834.

Our Publications

4. Vano, E., Kleiman, N.J., Duran, A., Rehani, M.M., Echeverri, D. Cabrera, M. Radiation Cataract Risk in Interventional Cardiology Personnel. Radiat Res. 2010; 174: 490-495.
5. Vano E, Kleiman NJ, Duran A, Romano-Miller M, Rehani MM. Radiation-associated Lens Opacities in Catheterization Personnel: Results of a Survey and Direct Assessments. J Vasc Interv Radiol. 2013 Feb;24(2):197-204. Outstanding Clinical Research Paper Award by JVIR

American Journal of Epidemiology Advance Access published July 29, 2008

AJE American Journal of Epidemiology
Published by the Johns Hopkins Bloomberg School of Public Health 2008. DOI: 10.1093/aje/kw

Original Contribution

Risk of Cataract after Exposure to Low Doses of Ionizing Radiation: A 20-Year Prospective Cohort Study among US Radiologic Technologists

Gabriel Chodick[1], Nural Bekiroglu[2], Michael Hauptmann[3,4], Bruce H. Alexander[5], D. Michal Freedman[1], Michele Morin Doody[1], Li C. Cheung[6], Steven L. Simon[1], Robert M. Weinstock[1], André Bouville[1], and Alice J. Sigurdson[1]

- These changes have potential to lead to cataract in future years, as per information from A-Bomb survivors.

RSNA News
December 2010

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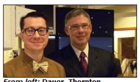
Cataract Risk Points to Need for Better Safety Measures

In light of new research showing increased risk for developing cataracts, interventional personnel are being urged to adopt a number of safety measures. Researchers have found that eye lens opacities can occur even at radiation levels below the currently known threshold values for cataracts.

A study reported during the 2009 meeting of the National Heart Association of Malaysia in Kuala Lumpur showed that interventional personnel have about five times the rate of lens opacities as compared to controls. Published in the June 2010 online version of *Catheterization and Cardiovascular Interventions*, the study showed a dose-dependent, increased risk of posterior lens opacities for interventional cardiologists and nurses when radiation


Rehani


***From left:* Dauer, Thornton**

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Radiation and cataract

Cataract is clouding of the eye lens. The lens is made up of mainly water and protein. Over time, protein can build up, clouding the lens and obstructing and diffusing the light passing through the eye. This makes lens sight blurred or fuzzy which cannot be corrected by wearing glasses. Although most cases of cataract are related to the aging process, occasionally children can be born with the condition, or a cataract may develop after eye injuries, inflammation, and other eye diseases.

Cataract (not related to radiation) is the most frequent cause of blindness worldwide. There are several risk factors, including exposure to sunlight, ionizing radiation, alcohol and nicotine consumption, diabetes and systemic use of corticosteroids.

1. Which part of the eye does cataract affect?
2. Is cataract caused by ionizing radiation different from that caused by age?
3. Is it possible to diagnose radiation-induced eye lens injuries?
4. Is there a unique system of classification of radiation induced opacities?
5. How to treat cataract?
6. How much radiation dose to the eye lens is necessary for the production of radiation injuries?
7. How soon after a radiation exposure can one expect to see radiation-induced eye lens injuries?
8. Is there a specific dose limit for eyes?
9. Which health professionals are at risk of radiation induced eye lens injury?
10. Which factors can affect eye lens dose in fluoroscopy procedures?
11. How can I manage eye lens exposure and prevent eye lens injuries?
12. How efficient are personal protection tools?
13. Is there a risk of cataract after several years of work in a catheterization laboratory?
14. What are the typical eye lens doses associated with diagnostic and therapeutic interventional procedures?
15. How can eye lens dose be measured more effectively?
16. Is there a correlation between staff eye lens doses and patient dose?

Recap

- What is cataract, radiation cataract, PSC
- Eye dosimetry: ICRU [Hp(0.3)]
- Approaches to eye doismetry
- ICRP recommendations dose threshold of 0.5 Gy & occupational dose limit of 20 mSv/y
- Recent studies on lens opacities among interventionists (1/3rd to half of main operators)

Thank You

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