Radiation Cataract & Eye Dosimetry

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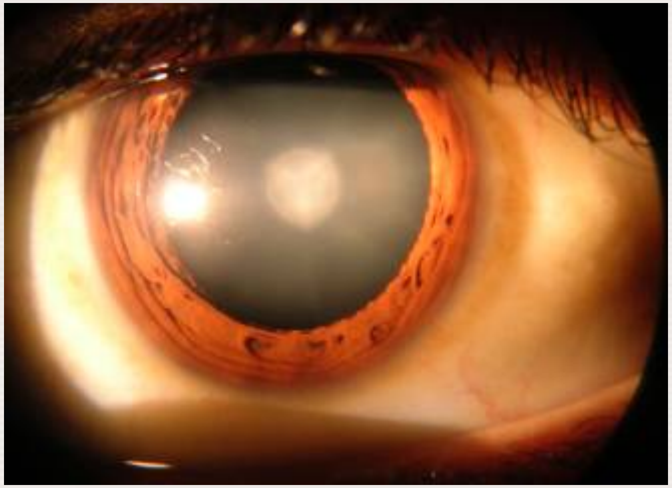
Atoms for Peace: The First Half Century

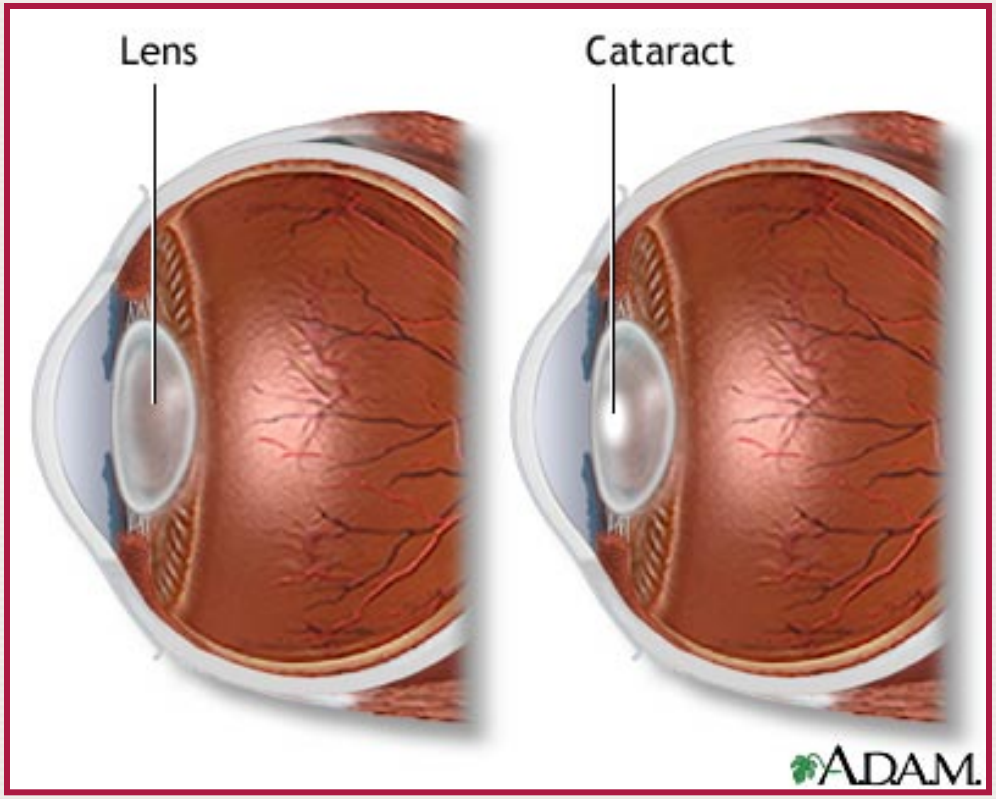
1957–2007

What is cataract?

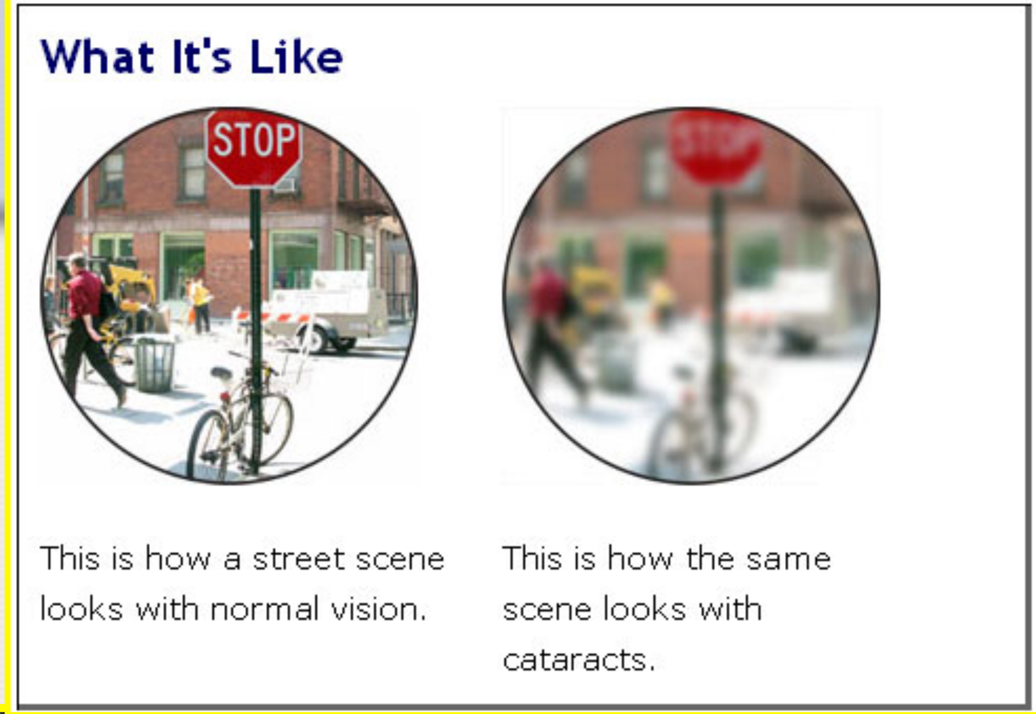
Clouding or opacification of the natural lens of the eye and obstructing the passage of light

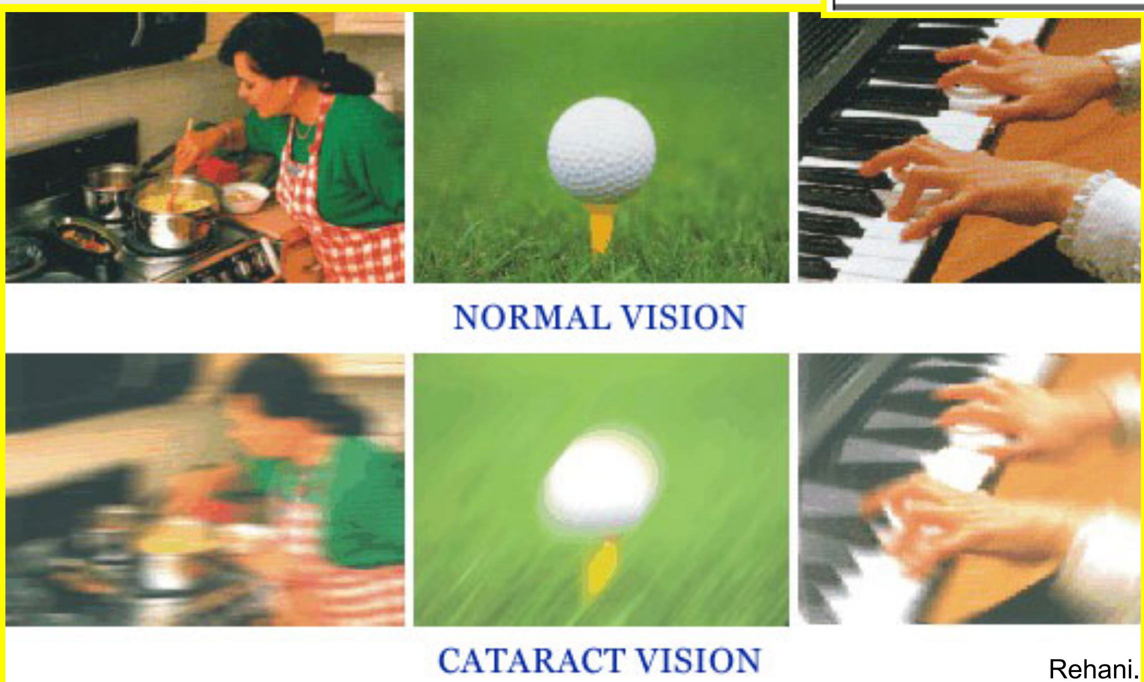


Cataract



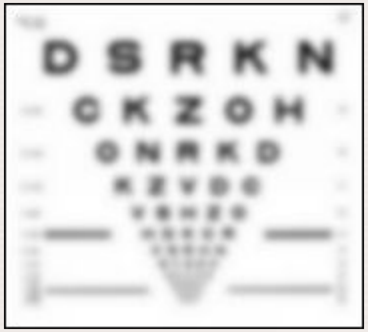
- Lenticular Opacification
- Risk Factors:
  - Corticosteroids
  - Diabetes Mellitus
  - Sunlight exposure (UVB)
  - Trauma
  - Infections
  - Nutritional deprivation
  - Age (~ 50% >65 yrs)
  - Heredity
  - Radiation


What It's Like
STOP
This is how a street scene looks with normal vision.
This is how the same scene looks with cataracts.

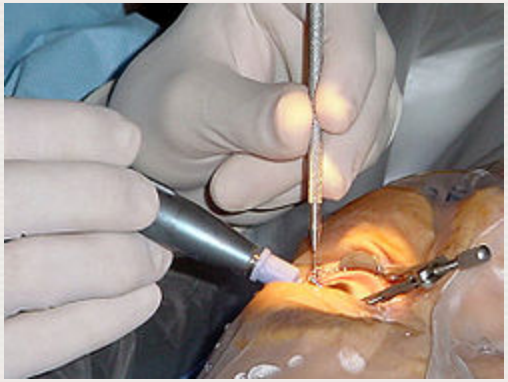

NORMAL VISION
CATARACT VISION

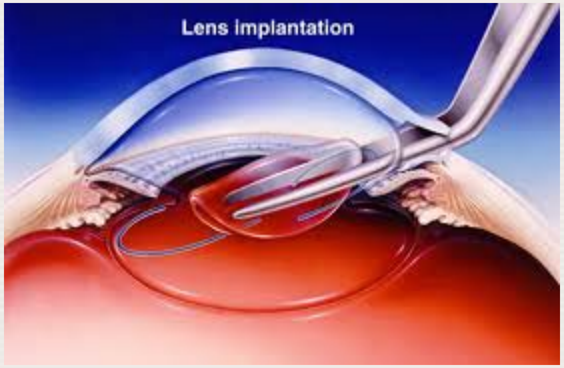
1957–2007

What is treatment?



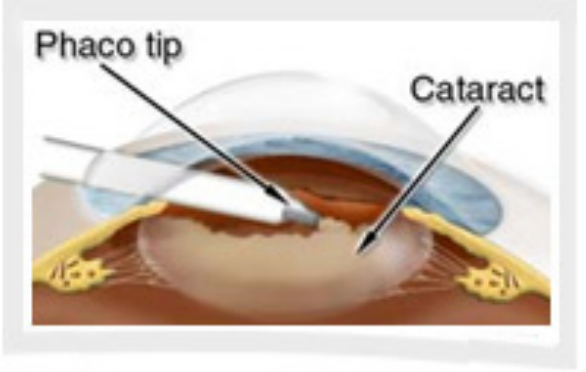
Easily treatable condition -surgery





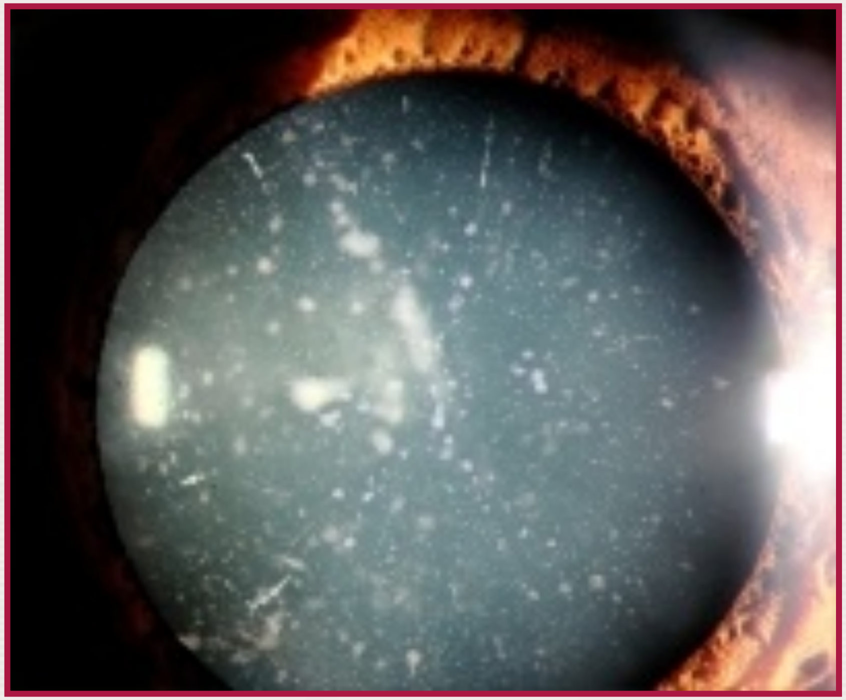
Nothing to match natural

Phacoemulsification



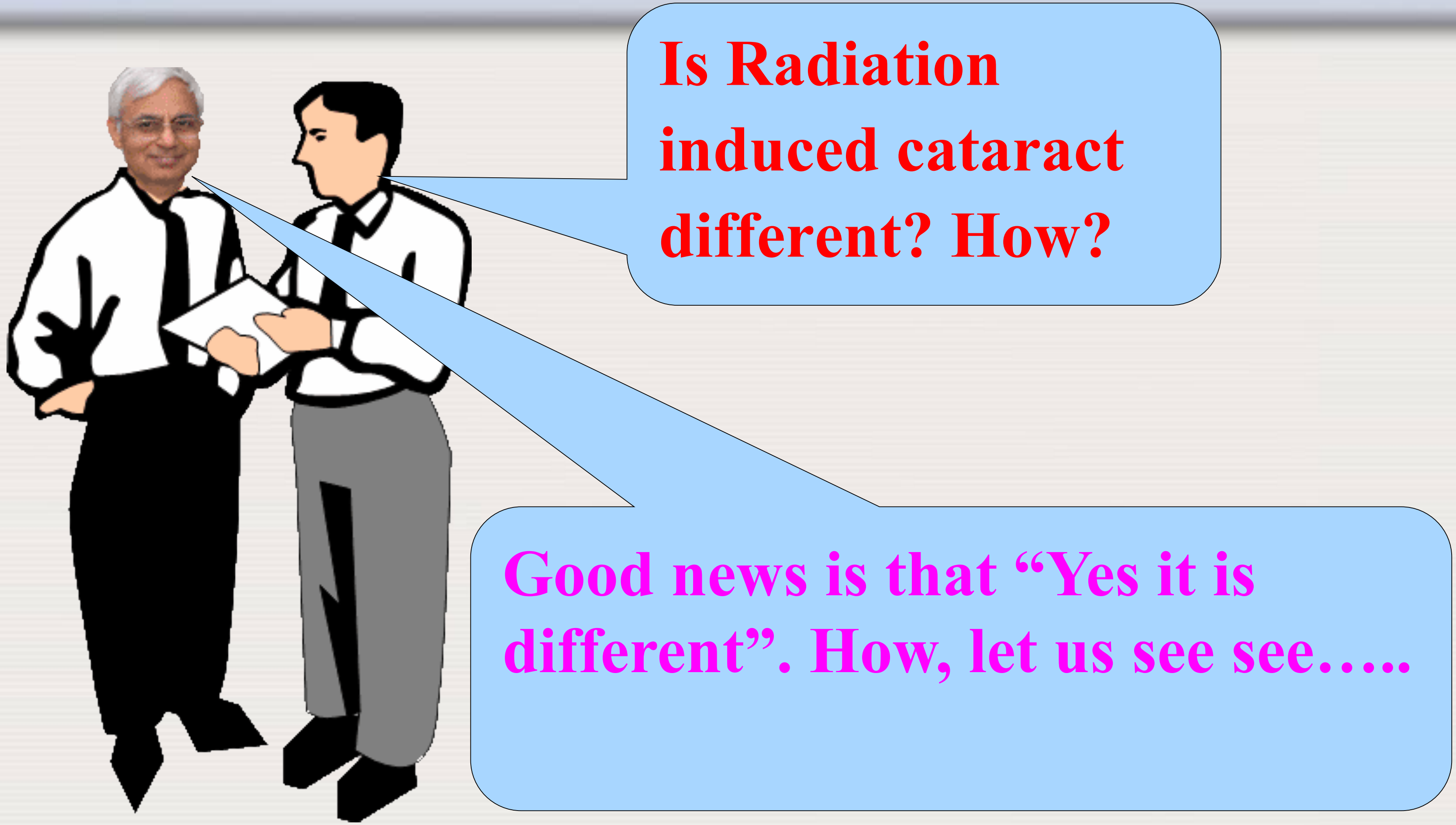
- Eye's internal lens is emulsified with an ultrasonic hand piece
- Aspirated from the eye.
- Aspirated fluids replaced with irrigation of balanced salt solution

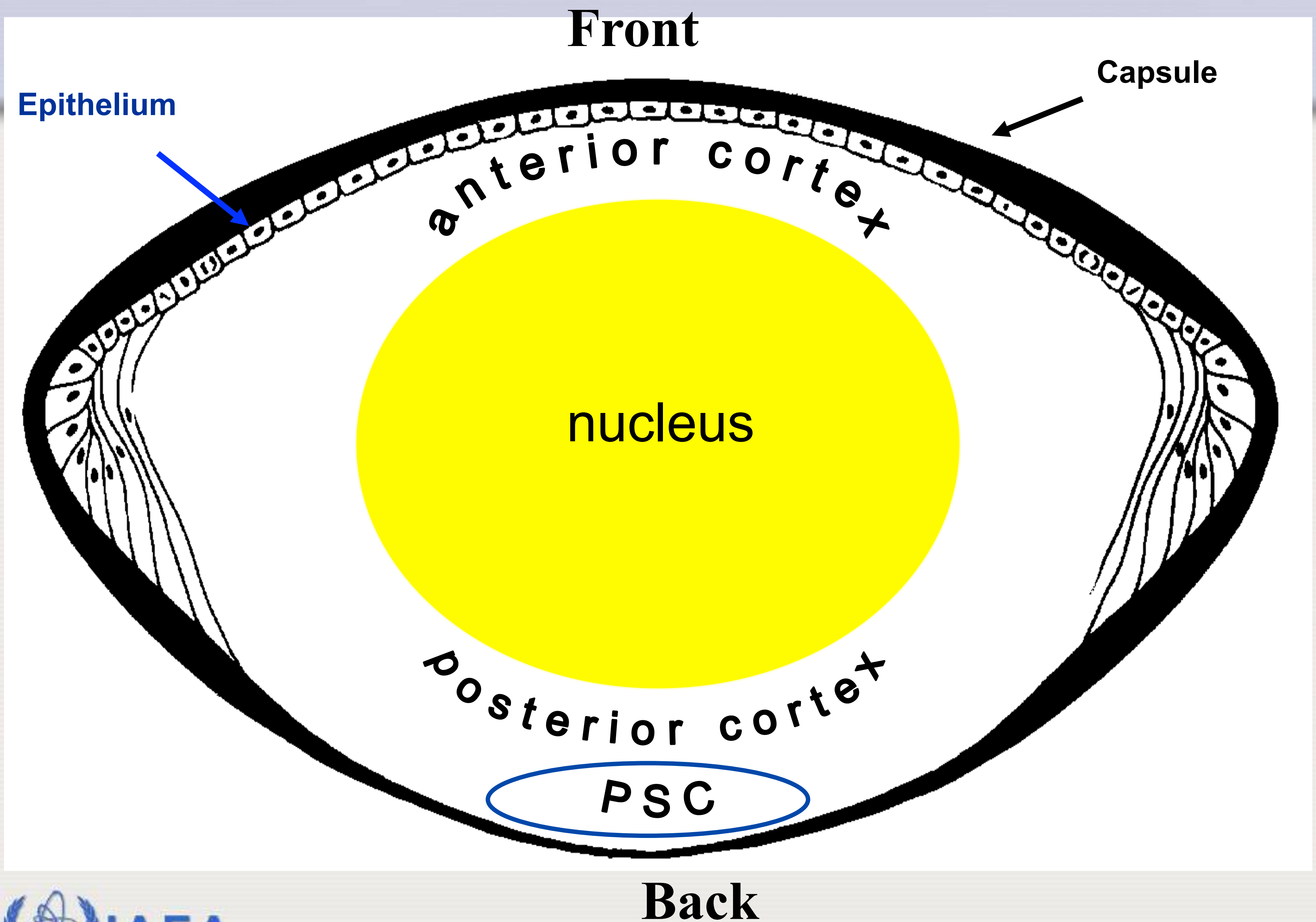
Radiation & Cataract



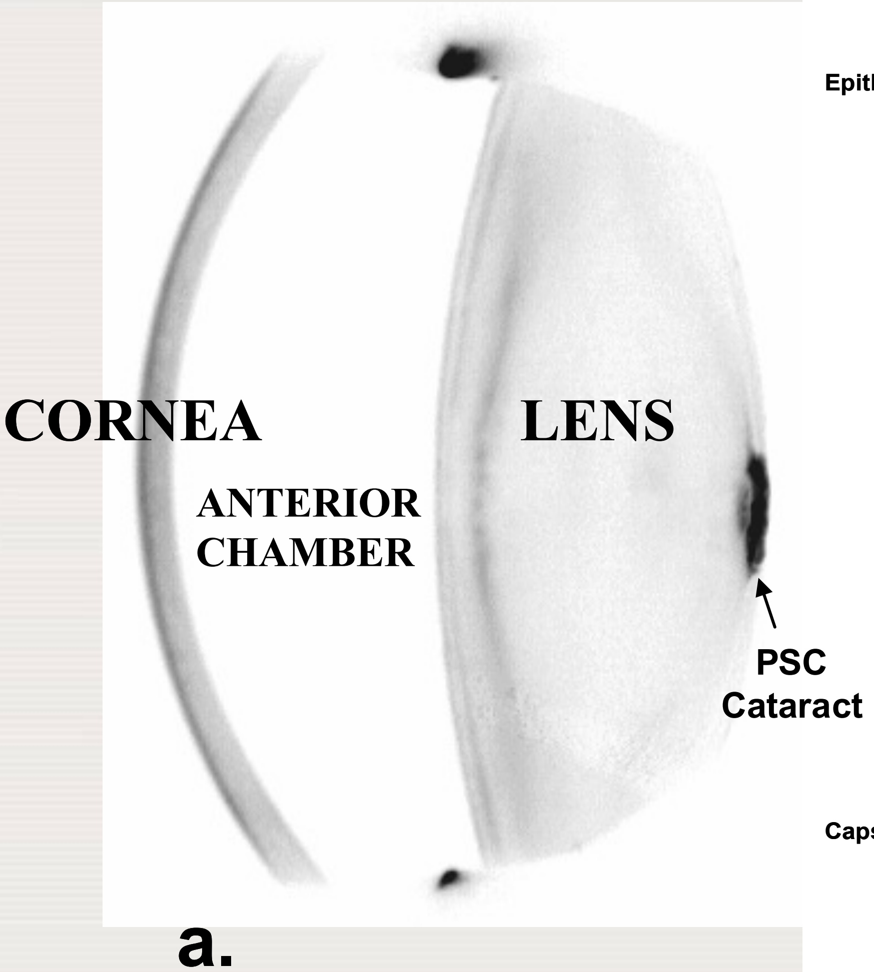
- Dot Opacities
- Latency depends on rate at which damaged epithelial cells undergo fibrogenesis and accumulate.

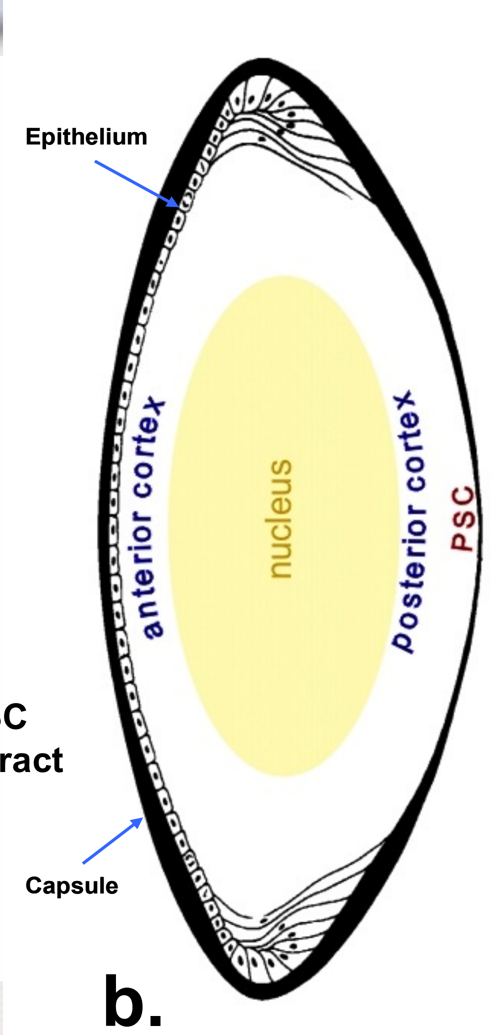
HOT Topic in Occupational Radiation Protection


Is Radiation induced cataract different? How?
Good news is that “Yes it is different”. How, let us see see…..


Front
Capsule
Epithelium
anterior cortex
nucleus
posterior cortex
PSC
Back

Pre-dominantly, not exclusively





Major Cataract Subtypes

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

Table 6. Recommended dose limits in planned exposure situations[a].

Type of limit	Occupational	Public
Effective dose	20 mSv per year, averaged over defined periods of 5 years[e]	1 mSv in a year[f]
Annual equivalent dose in:		
Lens of the eye[b]	150 mSv	15 mSv
Skin[c,d]	500 mSv	50 mSv
Hands and feet	500 mSv	–

[a] Limits on effective dose are for the sum of the relevant effective doses from external exposure in the specified time period and the committed effective dose from intakes of radionuclides in the same period. For adults, the committed effective dose is computed for a 50-year period after intake, whereas for children it is computed for the period up to age 70 years.

[b] This limit is currently being reviewed by an ICRP Task Group.

…However, new data on the radiosensitivity of the eye with regard to visual impairment are expected.

What New?

Lens opacities reported at dose levels below the mentioned threshold in ICRP 60 and 103

Odds Ratio

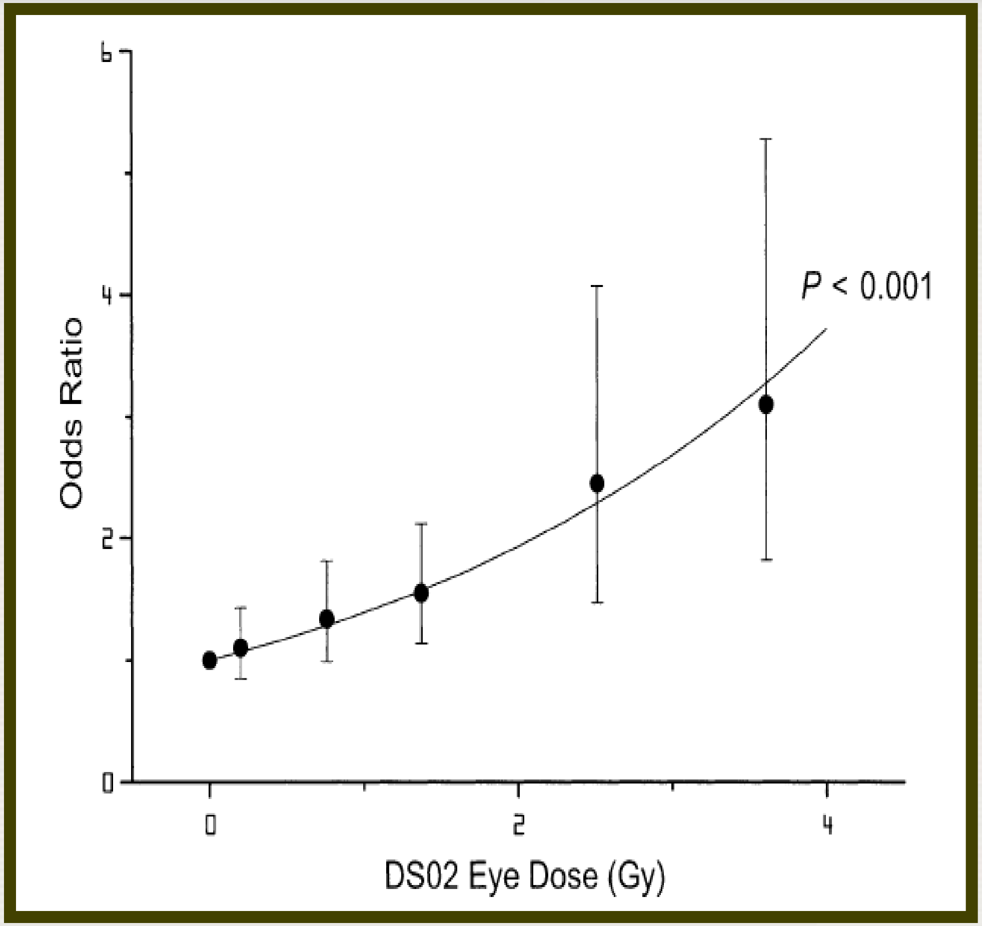
- Is a measure of effect size, describing the strength of association or non-independence between two binary data values.
- Ratio of the odds of an event occurring in one group to the odds of it occurring in another group

A-Bomb Survivors

Neriishi et al, Rad Research 168:2007

- Operative Cataract odds ratio of

  ~1.4 at 1 Gy
- **Dose threshold seen at 0.1 Gy (upper bound of 0.8 Gy).**



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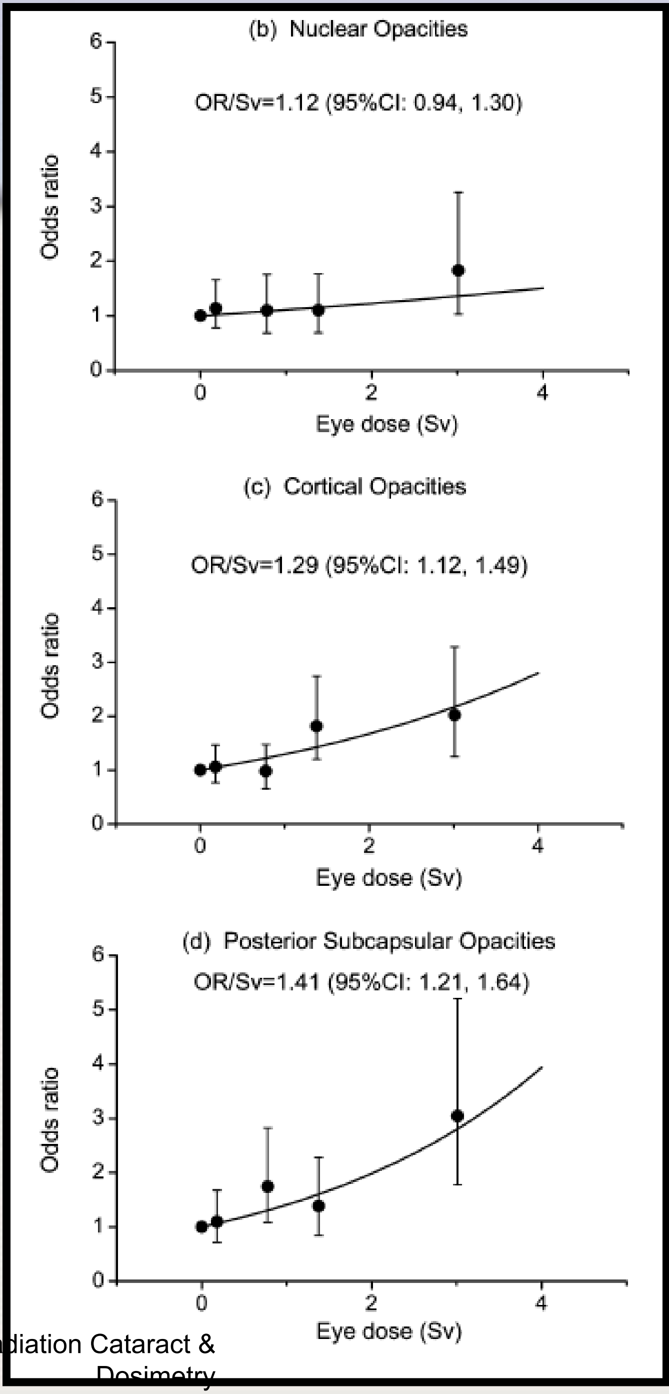
A-Bomb Survivors

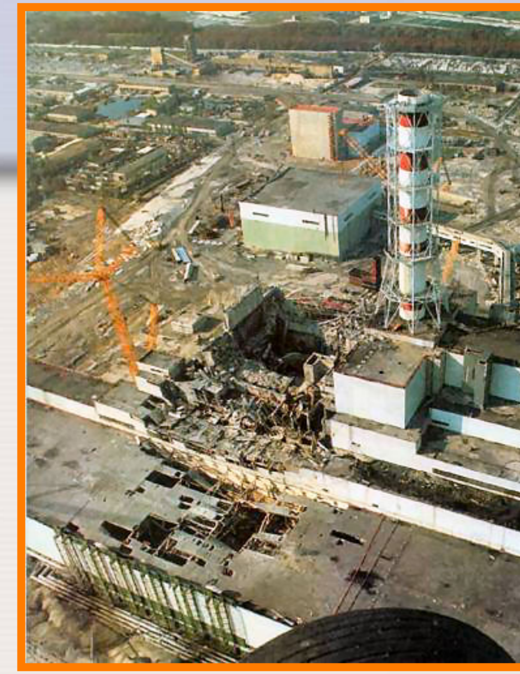
Minamoto et al, Int. J Rad Biol 80(5):2004

- Prevalence of cortical and posterior subcapsular opacities showed significant correlation with radiation dose
- Odds ratios of

  ~1.3 at 1 Gy



Chernobyl



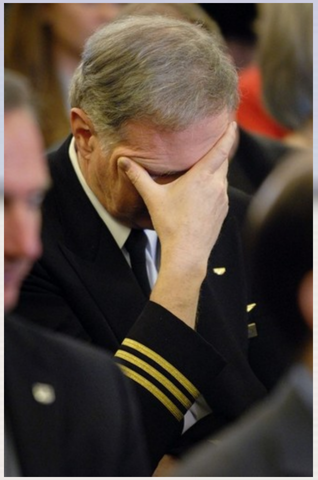
Worgul et al, Rad Research 167:2007

- Dose effect threshold

  < 1 Gy

- UN Chernobyl Forum 2006
  - **Even low doses of 0.25 Gy may also be cataractogenic**.

Airline Pilots



Rafnsson et al, Arch Ophthalmol. 123:2005

- Cosmic radiation may be a causative factor in nuclear cataracts.
- Note – some have disagreed with this assertion

Table 2. Age-Adjusted Odds of Nuclear Cataract Risk According to Cumulative Radiation Dose Sustained Before the Age of 40 Years, Divided Into Quartiles

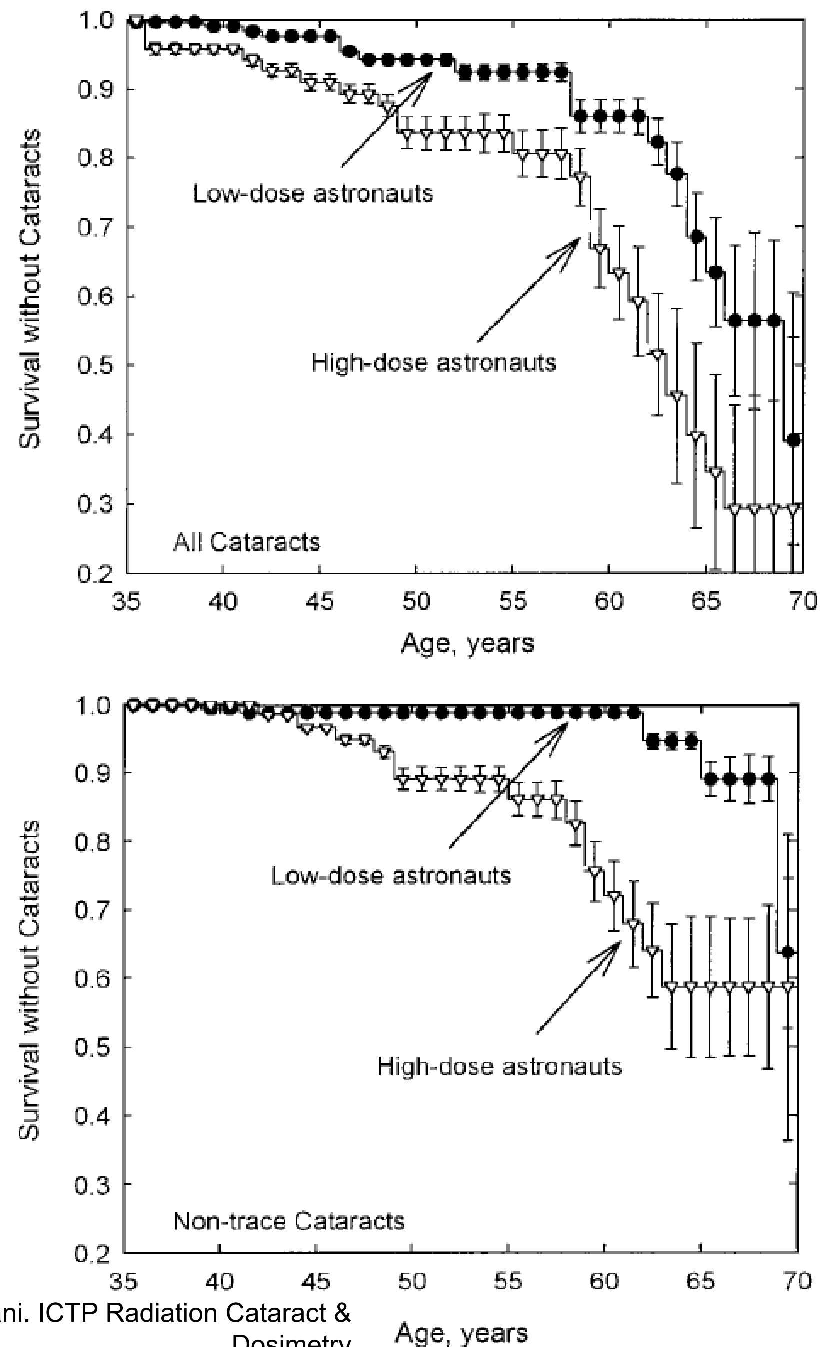
Variable	Controls (n = 374)*	Cases (n = 71)*	Odds Ratio (95% Confidence Interval)
Age, y	NA	NA	1.16 (1.11-1.21)
Cumulative radiation dose			
Not exposed†	310	56	1.00
First quartile (1-7 mSv)	13	6	2.82 (0.95-8.41)
Second quartile (8-15 mSv)	18	3	2.60 (0.67-10.11)
Third quartile (16-21 mSv)	18	3	2.48 (0.64-9.70)
Fourth quartile (22-48 mSv)	15	3	4.19 (1.04-16.86)

Abbreviation: NA, data not applicable.
*Data are given as number in each group.
†Reference group.

Astronauts

Cucinotta et al, Rad Research 156:2001

- Relatively low doses of space radiation are causative of an increased incidence and early appearance of cataracts
- Increased risk with higher lens doses **> 8 mSv**



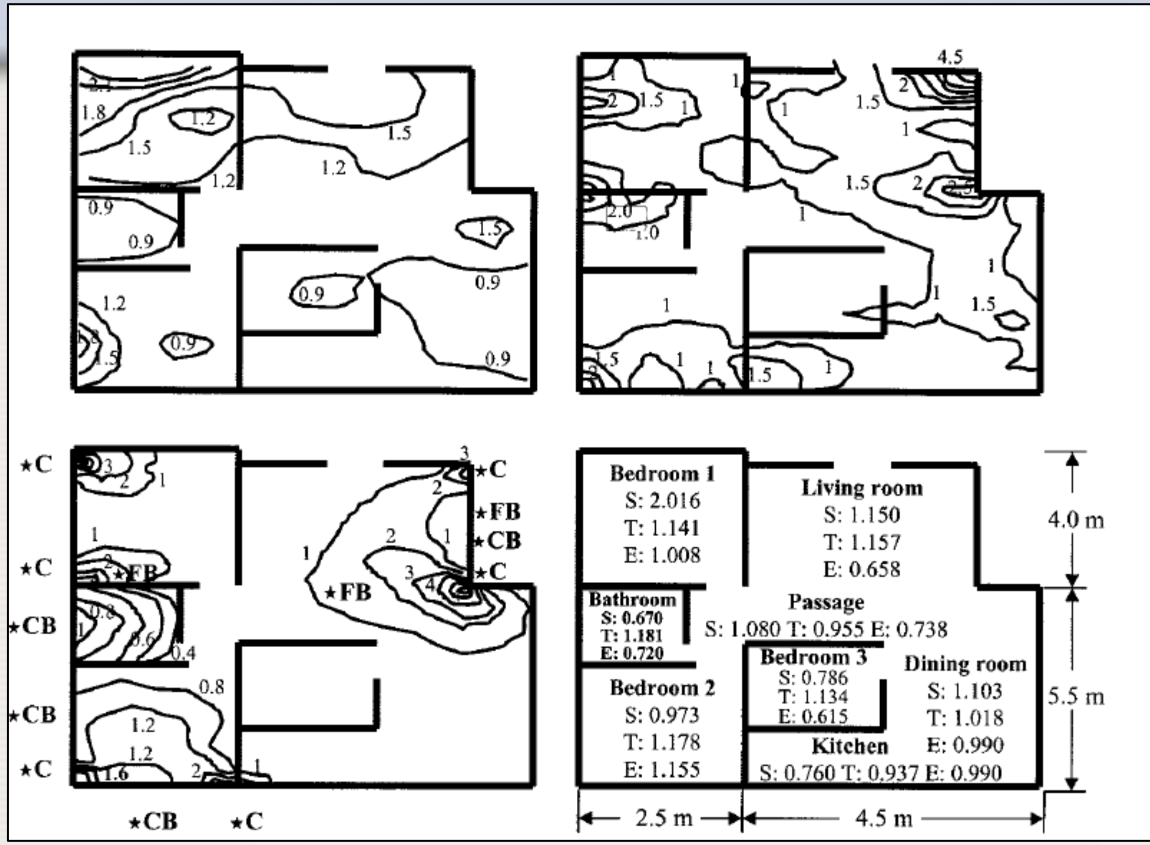
Infancy Exposures

Hall et al, Rad Research 152:1999

- Children exposed to lenticular doses during skin hemangioma treatments 1920-1959
- Odds ratio for developing posterior subcapsular cataract **1.5 at 1 Gy**
- Odds ratio for developing cortical opacity

  1.35 at 1 Gy

Chronic Low Dose Exposures



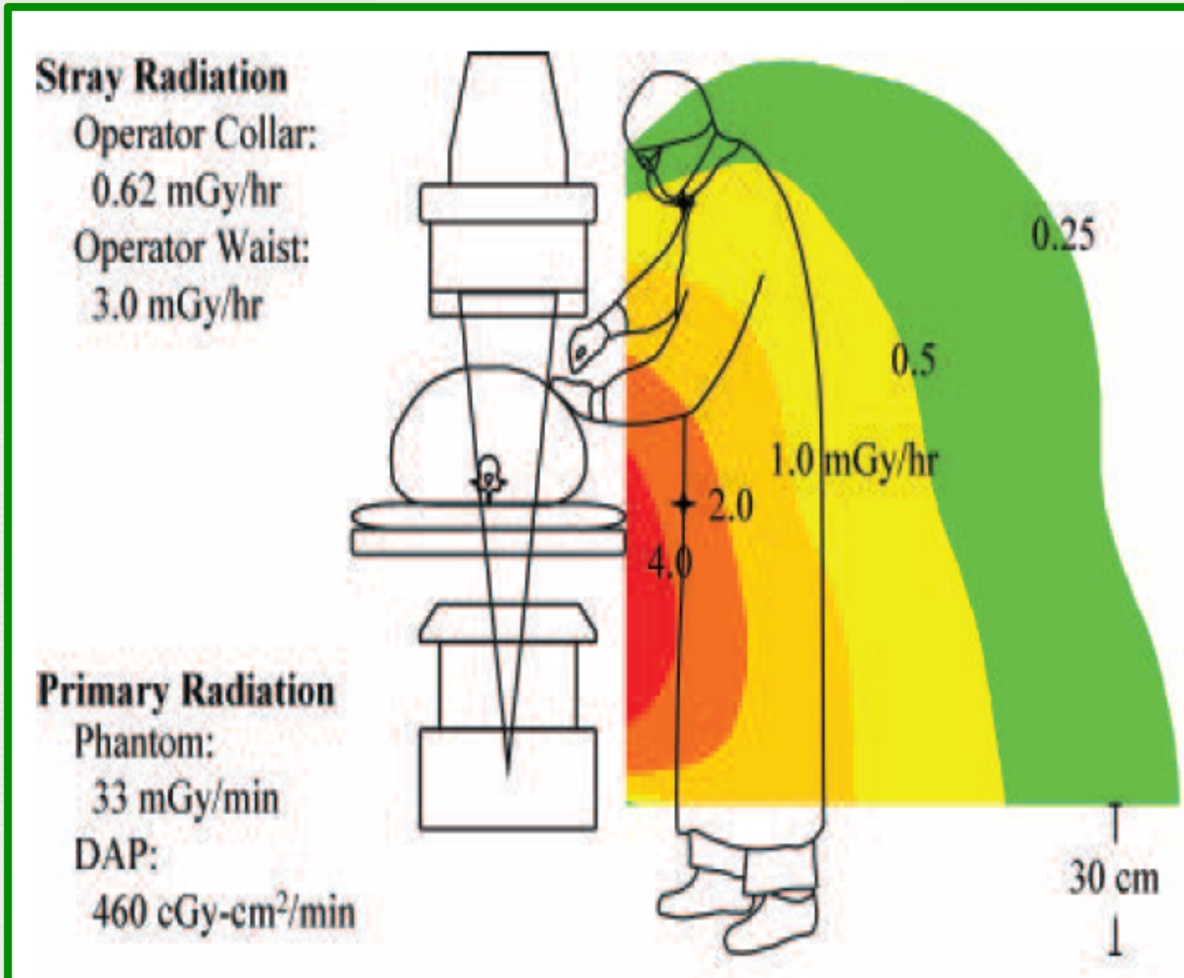
Chen et al, Rad Research 156:2001

- Contaminated buildings in Taiwan
- Minor lenticular changes in lenses of young subjects

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

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- Patients

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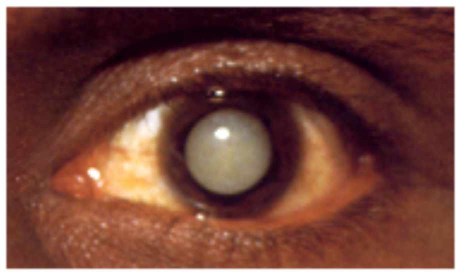
IAEA Cataract study



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

Raul Ramirez

A Nader

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

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Objective

To examine the prevalence of radiation-associated lens opacities among interventional cardiologists and technical staff and correlate with occupational radiation exposure

- **Not purely a doismetry or effect study**
- **Dose and effect**


MAY 4-8 , 2011
Kuala Lumpur Convention Centre, Malaysia
18th
Asian
Pacific
Congress of
Cardiology
International Atomic Energy Agency
RELID @ APSC 2011
Eye Examination
ROOM 301
Limited places only!
First-come-first served basis


International Atomic Energy Agency
RELID @ APSC 2011
Eye
Examination
ROOM 301
Limited places only!
First-come-first served basis


7 9:05AM


7 9:12AM


7 9:06AM

Assessment of lens change

- Dilatated slit lamp examination
- Merriam-Focht scoring system
- Scores: 0-3.0
- Scores >2.0 correlate with visual acuity

A CLINICAL AND EXPERIMENTAL STUDY OF THE EFFECT OF SINGLE AND DIVIDED DOSES OF RADIATION ON CATARACT PRODUCTION*

BY *George R. Merriam, Jr.*, M.D.† AND (BY INVITATION) *Elizabeth F. Focht*, M.A.**

TR. AM. OPHTH. SOC., vol. 60, 1962

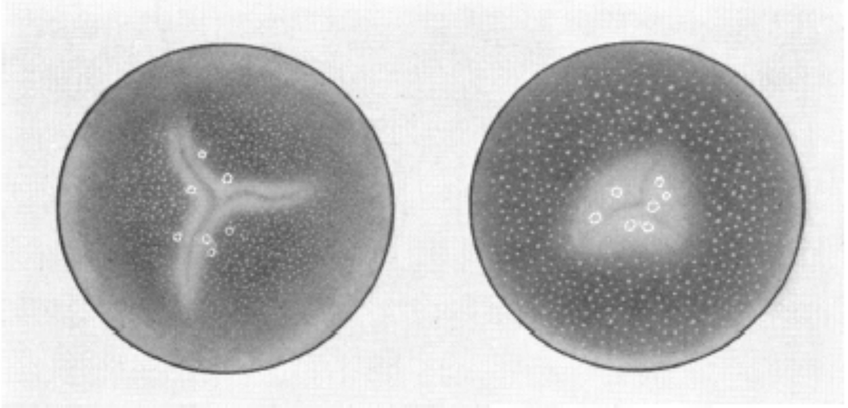
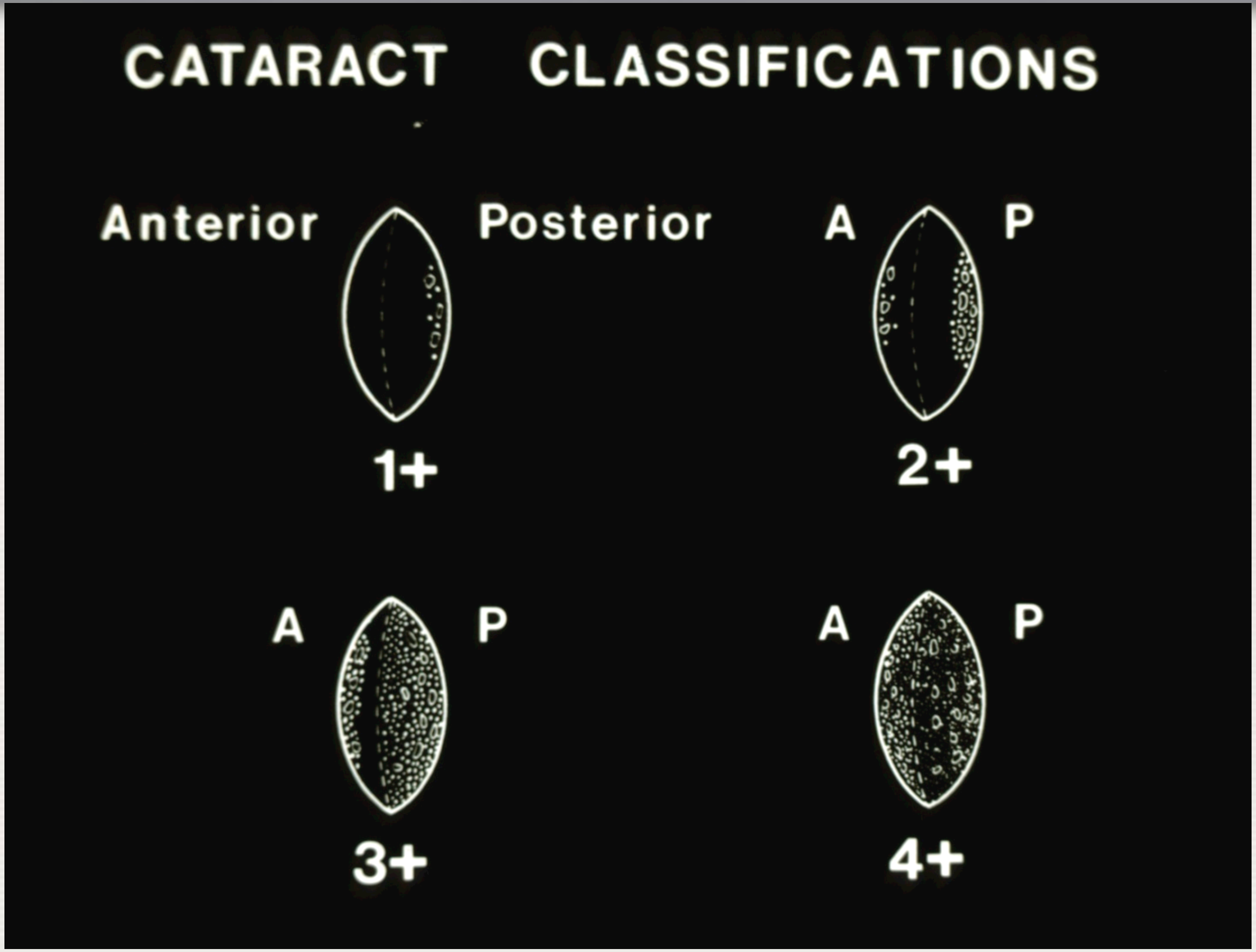
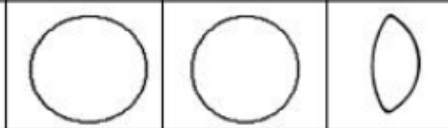
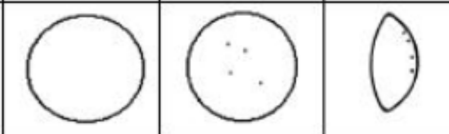
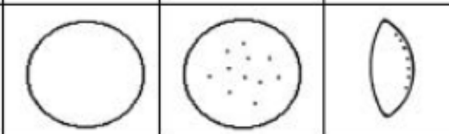
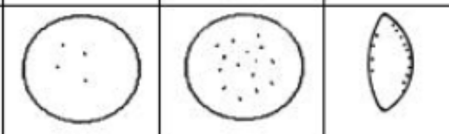
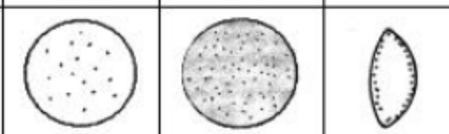
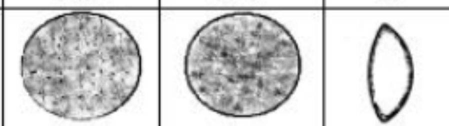
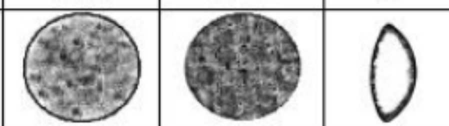
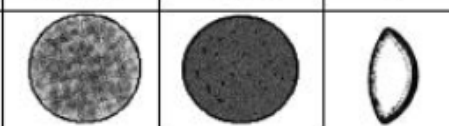
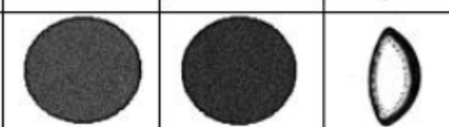


FIGURE 3

Two characteristic 1+ cataracts showing the early central posterior subcapsular vacuoles and dots with widening of the suture lines and an increase in the light reflex.


CATARACT CLASSIFICATIONS
Anterior
Posterior
1+
A
P
2+
A
P
3+
A
P
4+

SCORE	APPEARANCE (Anterior / Posterior / Sagittal)	DESCRIPTION
0		Transparent Lens…**NO** opacities or dots discernible posteriorly **OR** anteriorly
0.5		Anterior **OR** posterior region* has <u><</u> **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 <u><</u> **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.

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

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

ORAMED Project

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**
- **It is generally only one badge with uncertain position on the body**

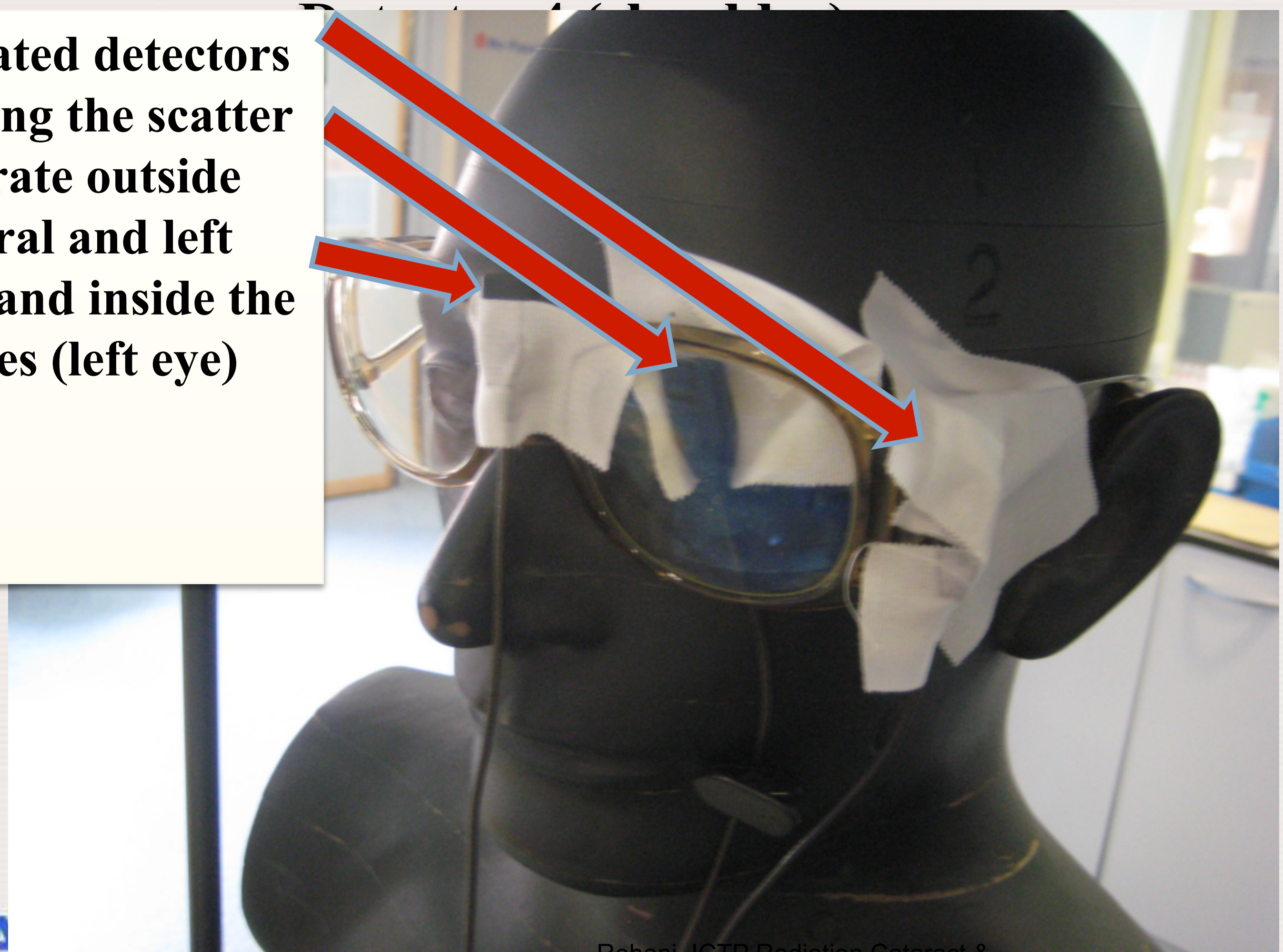
Possible approaches

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
Detector 1 (left lateral goggles not protected)
Detector 2 (central goggles not protected)
Detector 3 (inside goggles, protected)

Solid stated detectors measuring the scatter dose rate outside (central and left lateral) and inside the goggles (left eye)



Courtesy E. Vano, Madrid

Typical dose levels

- **CA and PCI: (157±126)µSv with range 0.72-600 µSv for cardiology**
- **Electrophysiology procedures: (30±19) µSv with range 7.7-70 µSv**
- **Gastroenterology interventions (various stenting procedures): (211±202) µSv with range from 42-976 µSv**

Upcoming publication in Health Physics by E Vano

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

Dose information for various studies (I)

Model	Value	Unit	Source	Remark
n/a	59	µSv/proc	Tsapaki ate all, PMB, 2004	CA, 5 countries, shoulder dose
n/a	89	µSv/proc	Tsapaki ate all, PMB, 2004	PTCA, 5 countries, Shoulder dose
Philips Optimus M 200 Poly C	260	mSv/y	Vano, et al, BJR, 2006	5000 procedure/y
Philips Integris HM 300	31	mSv/y	Vano, et al, BJR, 2006	5000 procedure/y
Philips Integrtis N-5000	18	mSv/y	Vano, et al, BJR, 2006	5000 procedure/y
Philips Integrtis Allura	3.5	mSv	Kuipers et al, Cardiovas Int Rad, 2008	4 weeks, TLD above the apron
Philps Polydiagnost C2	0.21-0.37	mSv/proc	Steffino, et al BJR 1996	Ceiling screen in place
Not available	0.11	mSv/proc	Pratt and Shaw, BJR, 1993	Ceiling screen and Goggles in place
CGR DG 300	0.014	mSv/proc	Marshall et al, BJR 1995	Eye dose, lead shield
Siemens Angioskop D	0.28	mSv/proc	Calkins et al, circulations, 1991	Eye, Ceiling screen in place
Philips Alura 10FD/20FD. GE Advantix, Philips Intergris 3000/5000, Siemens Axiom bip A	Table 1	Sv//h	Vano et al. Radiology 2008.	Dose rate at 1 m. h=1.6 m for different modes (fluoro. cine..)

Remarks

- Reported eye lens doses:
  - 0.3-11 mGy/study (without use of protective devices)
  - 0.011-0.33 mGy/study (with protective devices)
- In literature multiple dosimetry quantities: air kerma, H*(10), Hp(10), Hp(3)…)

Protection tools/activity	Dose modification factor	Remark
Ceiling screen	1.6-2.3	Reduction ratio in terms of Hp(0.07)/KAP for left and middle eye
Ceiling screen	1.8-2.5	Dose ratio without and with ceiling shield
Ceiling screen	54	Dose rate ratio without and with ceiling shield, phantom study
Ceiling screen	38%	Dose reduction by1.0 to 1.5 mm lead equivalent screen
Ceiling screen	20	Dose rate reduction factor
Ceiling screen	2-7	Dose reduction factor for the eye dose
Ceiling screen/upper body shield	40-90%	Dos reduction, depending on upper body shield position
X-ray tube orientation (biplane vsundrecoch)	0.4	Ratio of Hp(0.07)/P_{KA} for biplane and undercouch geometry
X-ray tube orientation (AP vs PA)	7/8.1	Dose ratio for thorax irradiation for femoral/radial access
X-ray tube orientation (AP vs PA)	2-27	Dose ration for factor
X-ray tube orientation (LAO 90^{o}vs RAO 90^o)	7.0	Dose ratio for thorax irradiation
Lead glasses	0.13-0.30	Dose ration with and without glasses depending on the type of glasses and x-ray tube orientation, Monte Carlo simulations
Lead glasses	0.2	Dose reduction factor
Lead glasses	2 (1.8-5.3)	Dose reduction factor
Collimation	No influence	Monte Carlo simulations
Beam quality	No influence	Monte Carlo simulations
Access route	2-7	If the shields are properly used, lower dose for femoral access

Our Decision

- Typical doses if protective devices are not used
  - *0.5 mGy/procedure for interventional cardiologists*
  - *0.15 mGy/procedure for and nurse*
- This exposure corresponds to a typical procedure of 10 min of fluoroscopy and 800 cine frames

Radiation dose assessment

Typical doses if protective devices are not used:
- *0.5 mGy/procedure for interventional cardiologists*
- *0.15 mGy/procedure for and nurse*

Workload:
- *number of procedures per week*
- *fluoroscopy time*
- *number of cine series per procedure*
- *number of frames per series*

Use of protective devices:
- *ceiling suspended screens (factor: 0.1)*
- *leaded glass eyewear (factor: 0.1)*

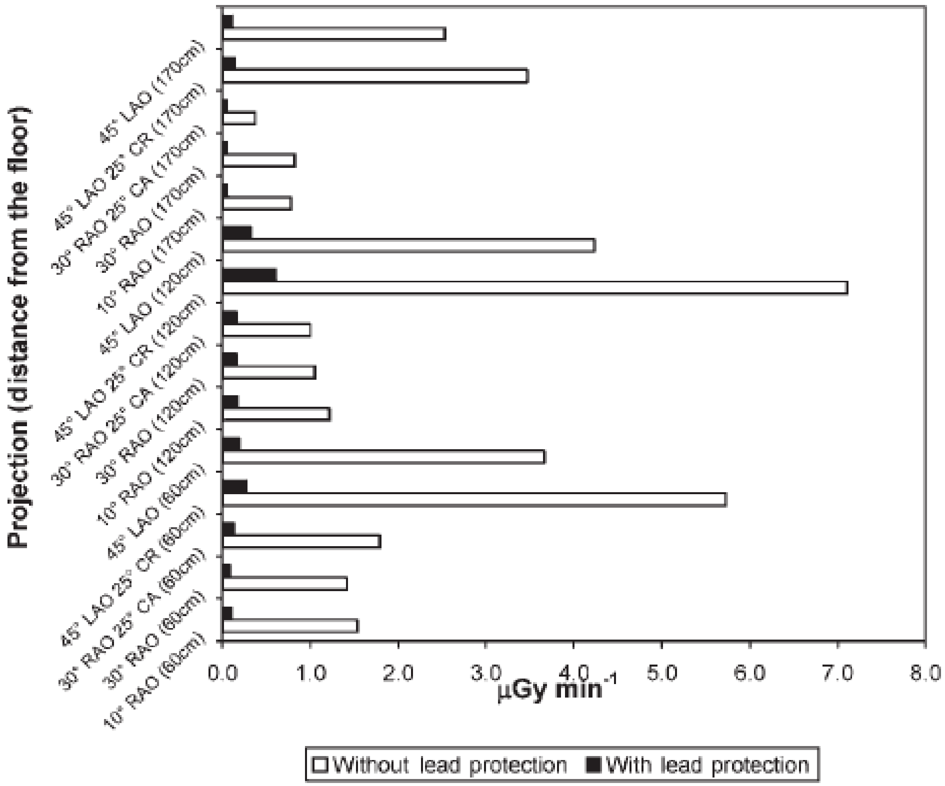
Angulations *(factor: 1.8)*
Radial access *(factor: 2.0)*

Dose related parameters (II)

Parameter	Source	Value	Factor
Attenuation of goggles, A	literature	90%	$1-\frac{G(1-A)}{100}$
Attenuation of ceiling suspended screen, B	literature	90%	$1-\frac{S(1-B)}{100}$
Distance from isocenter	literature	75 cm	ISL
For particular procedure. for different models of interventional systems at eye level scatter dose: • Dose rate [Sv/h] • Normalized dose rate [Sv/mAs] • Total dose for typical procedure [Sv/study]	literature; different sources to match the model of the system		
Angulations	literature: Vano, 2006 Batsou, 1998 Morrish, 2008	1.8	
Radial access	literature: IAEA, 2004 Vano, 2008	2	

Angulation for typical procedure (CA)

	Betsou et al. BJR, 1998	Vano et al. Radiology, 2008.	Average
PROJECTION	TIME (%)	mSv/h	mSv/h
PA	11.50	1.00	0.12
PA CD	0.50	1.00	0.01
PA CR	5.90	1.00	0.06
RAO	7.50	1.00	0.08
RAO CD	15.80	1.00	0.16
RAO CR	4.20	1.00	0.04
LAO	26.30	2.00	0.53
LAO CD	11.90	2.50	0.30
LAO CR	15.10	3.00	0.45
L LAT	1.30	5.00	0.07
	100.00		**1.8**



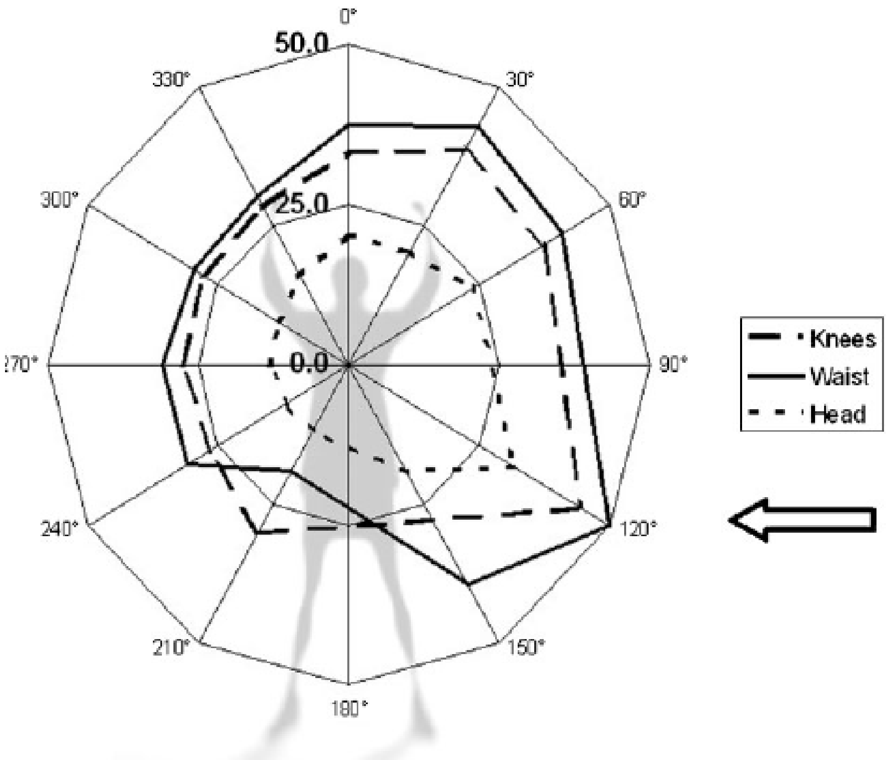


Figure 4. Measurements during fluoroscopy at the 210° position (cardiologist's position) with and without lead protection. RAO, right anterior oblique; LAO, left anterior oblique; CA, caudal; CR, cranial.

Figure 8. Distribution of scattered radiation from digital acquisition on the 10° right anterior oblique (RAO) projection at 68 kVp. The radial axis shows the dose in $\mu Gy\ min^{-1}$, whereas the ionization chamber position is indicated on the circumference. The figure shows the patient position from above, and the arrow shows the direction of the primary beam. Data for points not measured at 90°, 180° and 150° at 60 cm have been interpolated.

O W E Morrish and K E Goldstone

The British Journal of Radiology, January 2008

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. doi: 10.1016/j.jvir.2012.10.016. Epub 2013 Jan 28. http://www.ncbi.nlm.nih.gov/pubmed/23369556

Lens Opacities>0.5

- **30-50% main operators**
- **Upto 30% in nurses**

RSNA News™
December 2010

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.

Rehani

From left: **Dauer, Thornton**

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 protection tools were not used. Another study from the

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

Radiation Protection Dosimetry (2012), pp. 1–9 doi:10.1093/rpd/ncs236

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
[2]Vinca Institute of Nuclear Science, University of Belgrade, Belgrade, Serbia
[3]International Atomic Energy Agency, Vienna, Austria
[4]Clinic of Cardiology, University Clinical Centre of Serbia, Belgrade, Serbia
[5]School of Medicine, University of Belgrade, Belgrade, Serbia

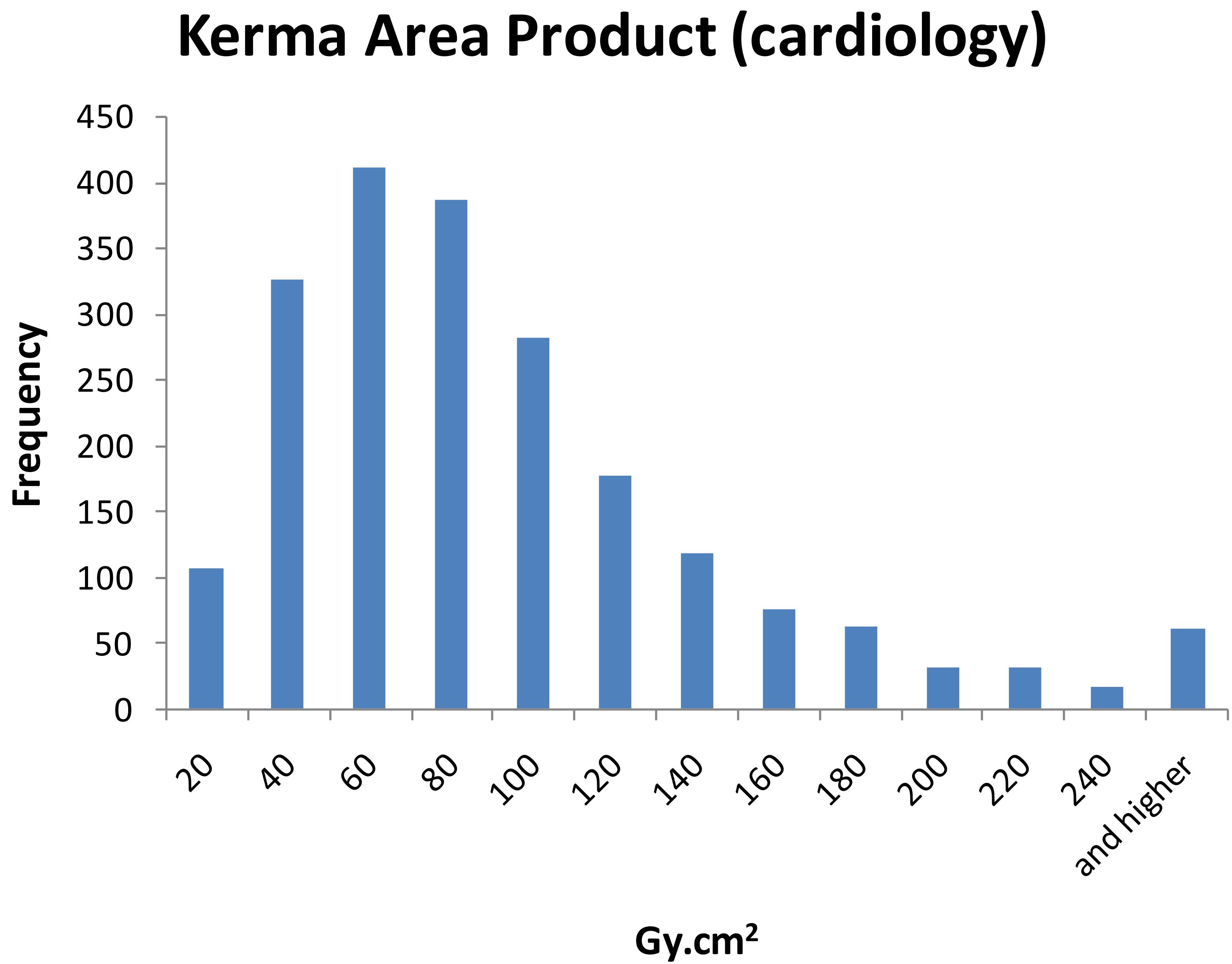
From our RPD paper

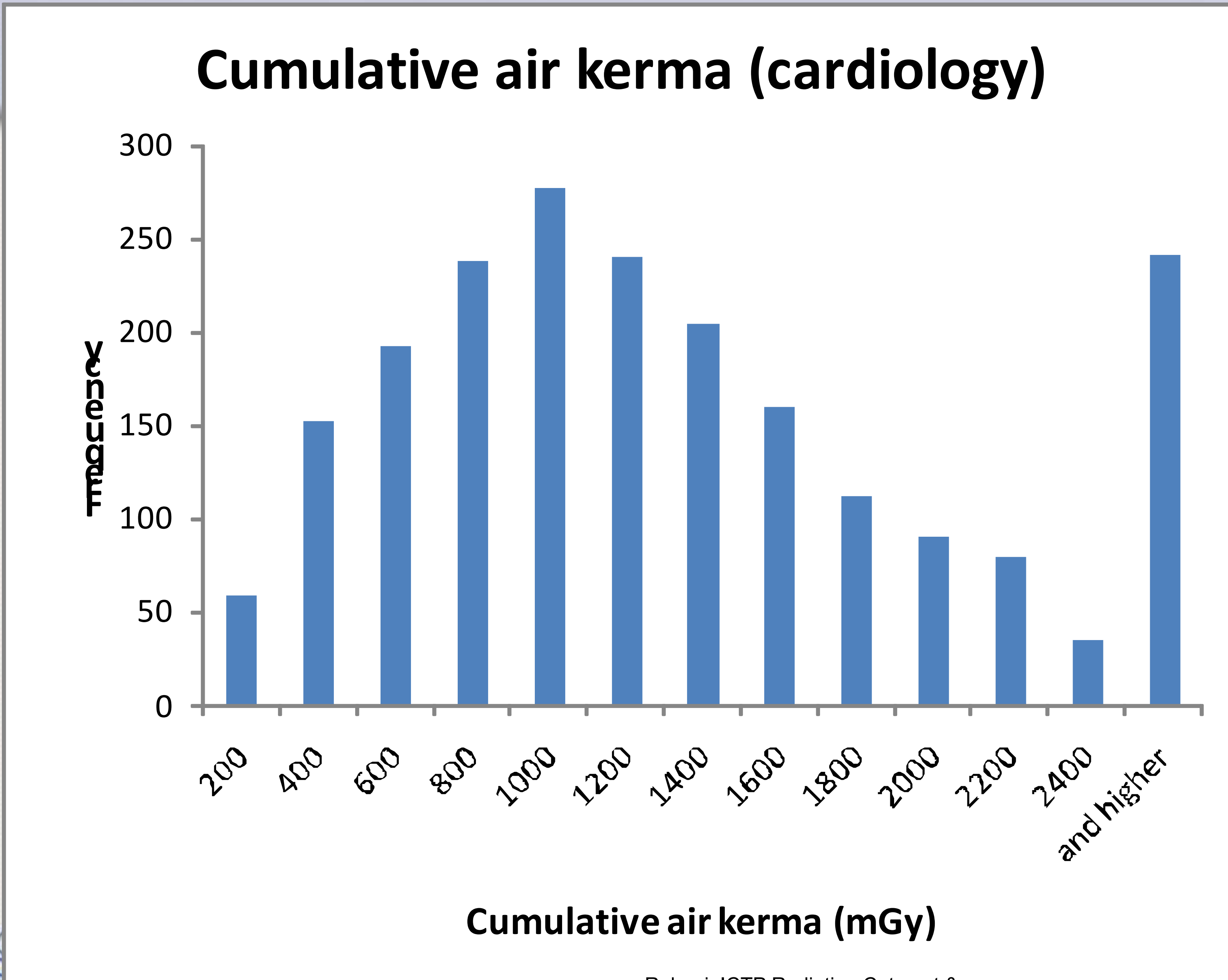
Normalised eye lens doses per unit kerma–area product:

- 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.

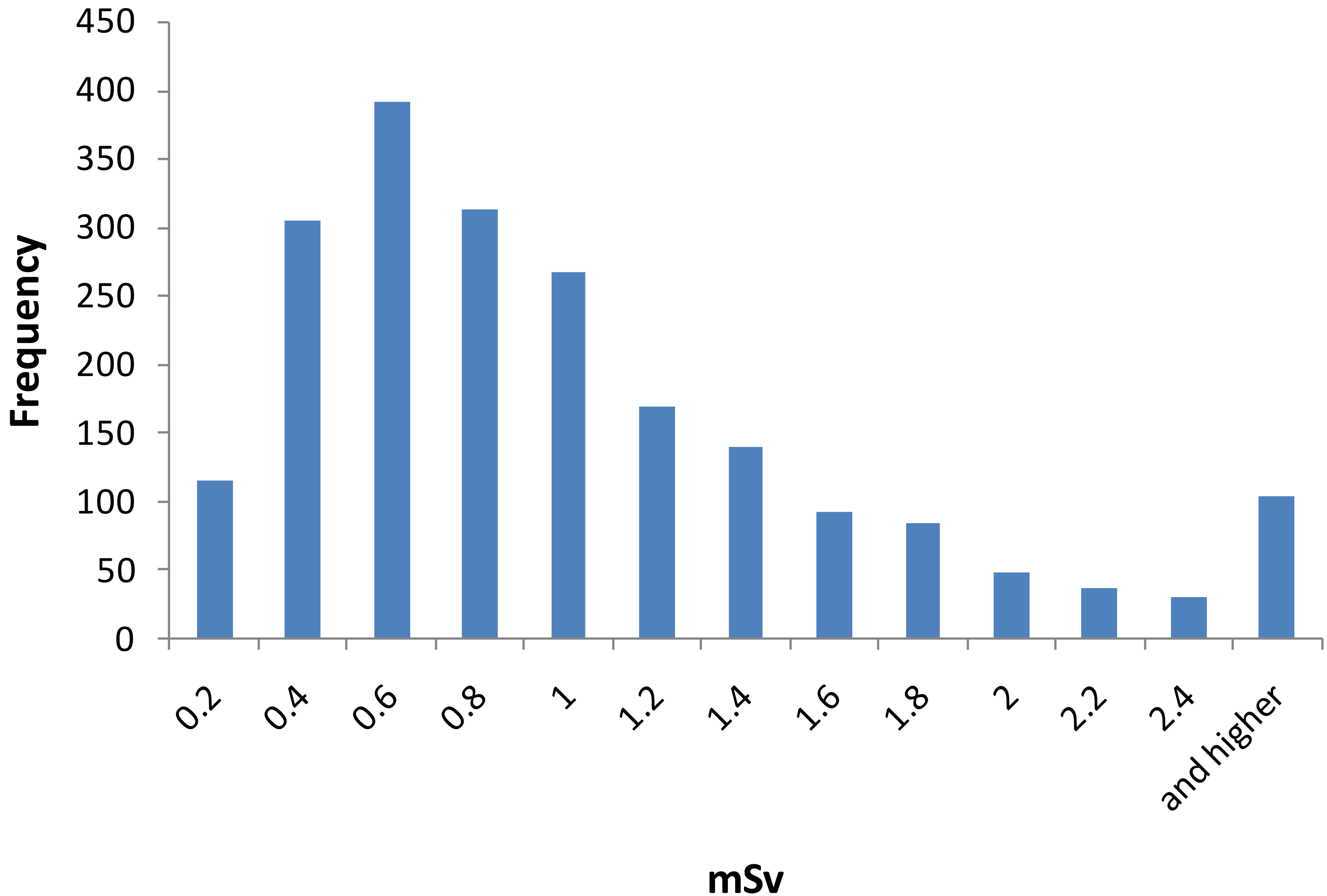
Eye doses and eye dose normalized to respective kerma-area product for interventional cardiology procedures for position of the first operator

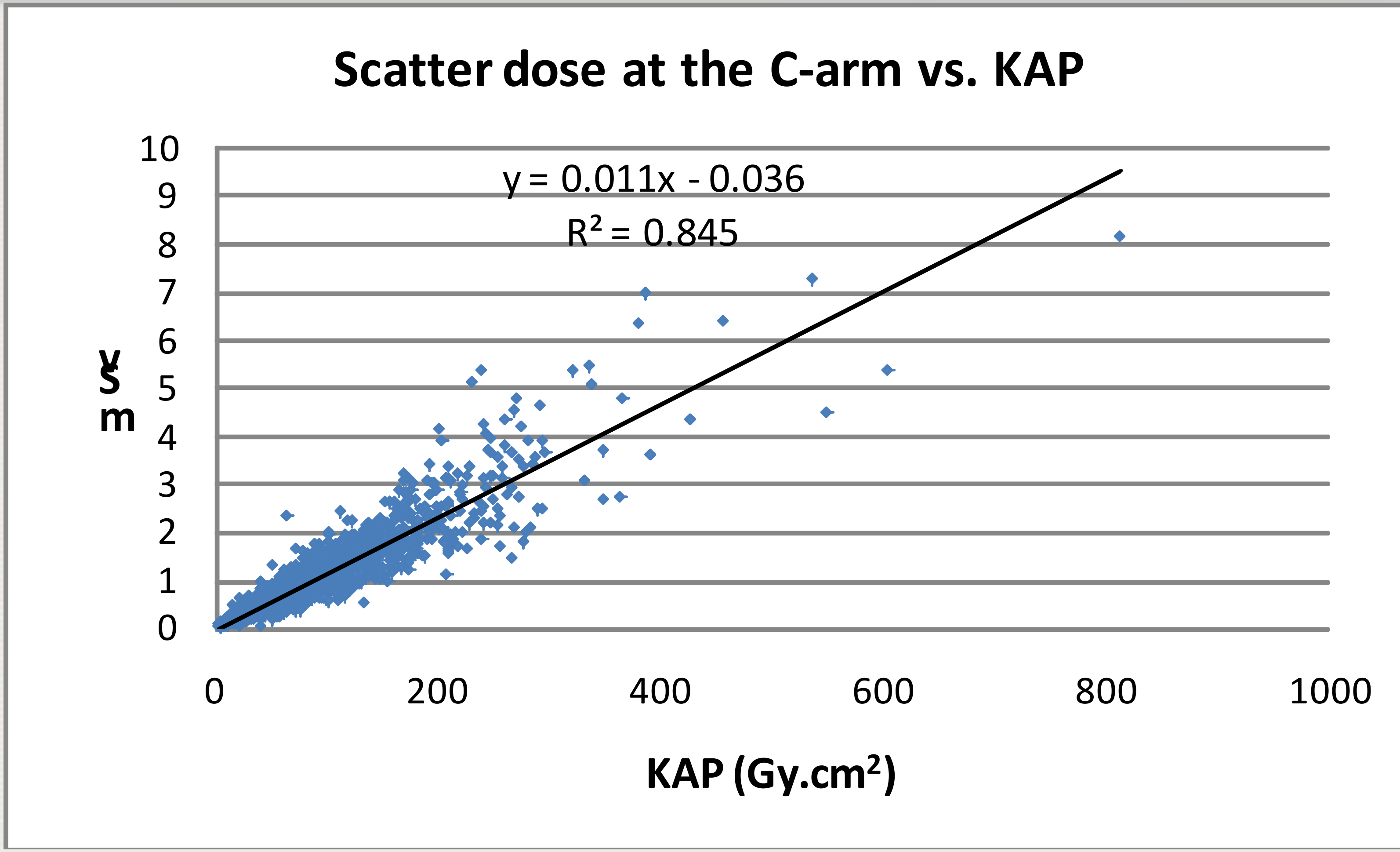
Source	Eye dose (μSv)	Eye dose/ P_{KA} (μSv/ (Gycm^2))
Antic et al [10]	121±84 (4.5-370)	0.94±0.61
Donadille et al[48]	52±77 (4-644)	1.0
Kim et all 2008[49]	170-439	/
Vanoet al [50]	170 (53-460)	3.3-6.0
Efstathopoulos et al[19]	13	1.37
Bor et al [44]	72 (32-107)	0.86 (0.46-1.25)
Martin [16]	66 (5-439)	1.0
Vanhavere et al [40]	/	1.0
Pratt et al [47]	15-53	/
Jacob et al [14]	14-439	/
Oydis et al [30]	44 (10-223)	0.6 (0.2-2.6)


Kerma Area Product (cardiology)
Frequency
450
400
350
300
250
200
150
100
50
0
20
40
60
80
100
120
140
160
180
200
220
240
and higher
Gy.cm2


Cumulative air kerma (cardiology)
300
250
200
150
100
50
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
and higher
Cumulative air kerma (mGy)

Scatter cumulative dose (cardiology)




Scatter dose at the C-arm vs. KAP
y = 0.011x - 0.036
R² = 0.845
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
KAP (Gy.cm²)

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

Future challenges

- **Development of practical methods for regular monitoring of individual eye doses**
- **Development of better techniques to estimate eye dose from measurements at some reference points**

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

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?

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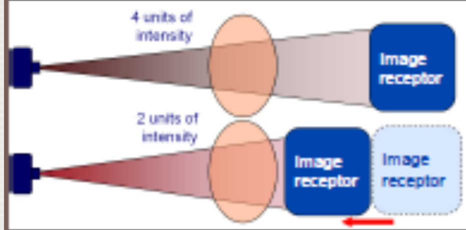
10 Pearls: Radiation protection of *patients* in fluoroscopy

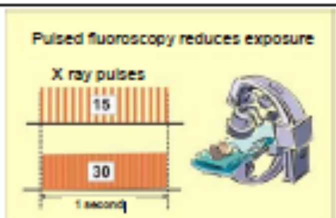
1. Maximize distance between the X ray tube and the patient to the extent possible



2. Minimize distance between the patient and the image receptor

3. Minimize fluoroscopy time

Keep records of fluoroscopy time for every patient



4. Use pulsed fluoroscopy with the lowest frame rate possible to obtain images of acceptable quality

5. Avoid exposing the same area of the skin in different projections

Vary the beam entrance port by rotating the tube around the patient

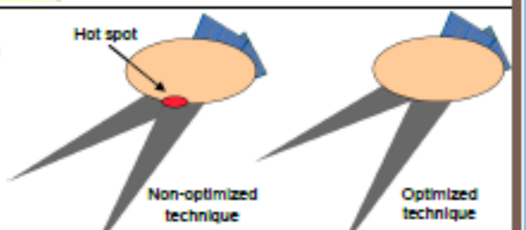


Figure adapted from L. K. Wagner

IAEA RPOP Radiation Protection of Patients

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[illegible]

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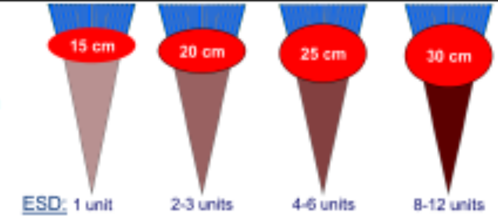
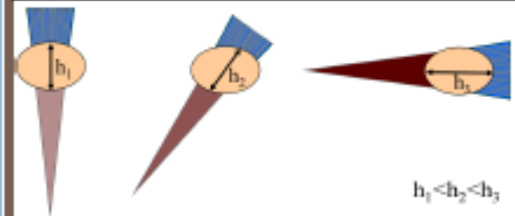
Fluoroscopy
Patient Radiation Protection

10 Pearls: Radiation protection of *patients* in fluoroscopy

6. Larger patients or thicker body parts trigger an increase in entrance surface dose (ESD)





7. Oblique projections also increase ESD

Be aware that increased ESD increases the probability of skin injury

INTENSIFIER Field-of-view (FOV)	RELATIVE PATIENT ENTRANCE DOSE RATE FOR SOME UNITS
12" (32 cm)	100
9" (22 cm)	200
6" (16 cm)	300
4.5" (11 cm)	400

8. Avoid the use of magnification

Decreasing the field of view by a factor of two increases dose rate by a factor of four

9. Minimize number of frames and cine runs to clinically acceptable level

Avoid using the acquisition mode for fluoroscopy

Documentation should be performed with last image hold whenever possible and not with cine images

10. Use collimation

Collimate the X ray beam to the area of interest

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10 Pearls: Radiation protection of *staff* in fluoroscopy

Reducing patient dose always results in staff dose reduction

1. Use protective devices!

Advisable skirt type lead apron to distribute weight

0.25 mm lead equivalence but with overlap on front to make it 0.5 mm on the front and 0.25 mm on the back (Provides >90% protection)

Lead glass eyewear with side protection

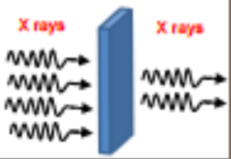
Thyroid protection

2. Make good use of time-distance-shielding (TDS) principle

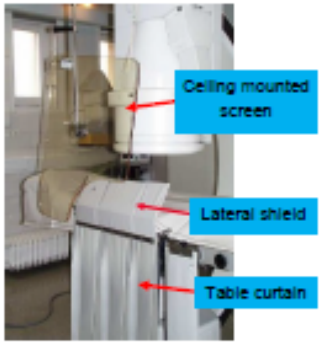
Minimize time

Maximize distance as much as clinically possible

Use shielding

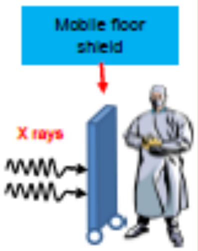


3. Use ceiling suspended screens, lateral shields and table curtains



They provide more than 90% protection from scattered radiation in fluoroscopy

Mobile floor shielding is advisable when using cine acquisition



4. Keep hands outside the primary beam unless totally unavoidable

Hands inside the central area of the primary beam will increase exposure factors (kV, mA) and doses to patient and staff

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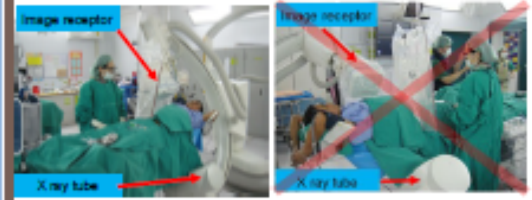
10 Pearls: Radiation protection of *staff* in fluoroscopy

Reducing patient dose always results in staff dose reduction



Right! Wrong!

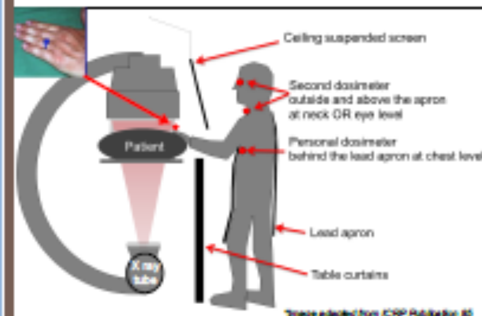
5. Only 1-5% of radiation falling on the patient's body exits the other side

Stand on the side of the *transmitted* beam (i.e. by the *detector*), which contains only 1-5% of the incident radiation and its respective scatter

6. Keep X ray tube under the patient table and not over it

Undercouch systems provide better protection from scattered dose

Right! Wrong!



7. Use personal dosimetry

Use at least two dosimeters

- One inside the apron at chest level
- One outside the apron at neck or eye level
- Additional finger ring dosimeter for procedures requiring hands close to primary beam

Real time dosimetry systems are useful

8. Update your knowledge about radiation protection

9. Address your concerns about radiation protection to radiation protection specialists (medical physicists)

10. REMEMBER!

- Quality control testing of fluoroscopy equipment enables safe and stable performance
- Know your equipment! Using the equipment's features appropriately will help reduce doses to patients and staff
- Use injector devices

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Page 2 of 2 Fluoroscopy Staff Radiation Protection

IAEA Atoms for Peace: The First Half Century 1957–2007

Recap

- What is cataract, radiation cataract, PSC
- Earlier ICRP recommendations
- Newer studies (including IAEA) necessitating revision of ICRP recommendations
- New recommendations of ICRP
- Material from IAEA to support implementation

Thank You

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