Scientific and epidemiological background for radiation risk to the lens of the eye

Norman J. Kleiman, Ph.D.

Department of Environmental Health Sciences
Mailman School of Public Health
Columbia University, New York, NY
$y = 0.067x + 0.317$

$R^2 = 0.481$

Lens injury severity versus dose (cardiologists)
Statement on Tissue Reactions
Approved by the Commission on April 21, 2011

(1) The Commission issued new recommendations on radiological protection in 2007 (ICRP, 2007), which formally replaced the Commission’s 1990 Recommendations (ICRP, 1991a). The revised recommendations included consideration of the detriment arising from non-cancer effects of radiation on health. These effects, previously called deterministic effects, are now referred to as tissue reactions because it is increasingly recognised that some of these effects are not determined solely at the time of irradiation but can be modified after radiation exposure.
(2) The Commission has now reviewed recent epidemiological evidence suggesting that there are some tissue reaction effects, particularly those with very late manifestation, where threshold doses are or might be lower than previously considered. For the lens of the eye, the threshold in absorbed dose is now considered to be \(0.5\) Gy.

(3) For occupational exposure in planned exposure situations the Commission now recommends an equivalent dose limit for the lens of the eye of \(20\) mSv in a year, averaged over defined periods of 5 years, with no single year exceeding \(50\) mSv.
Retrospective Evaluation of Lens Injuries and Dose: “RELID”

Lens injuries induced by occupational exposure in non-optimized interventional radiology laboratories

E VAÑÓ, PhD, L GONZÁLEZ, PhD, F BENYEYETZ, MD and F MORENO, MD

Chernobyl “Liquidators”

Infants treated for facial hemangiomas

Residents of contaminated buildings

Radiological technologists

A-bomb survivors

Interventional cardiologists

Astronauts
Report of Task Group on the Implications of the Implementation of the ICRP Recommendations for a Revised Dose Limit to the Lens of the Eye

Summary

This report was commissioned by the IRPA President to provide an assessment of the impact on members of IRPA Associate Societies of the introduction of ICRP recommendations for a reduced dose limit for the lens of the eye.

The report summarises current practice and considers possible changes that may be required. Recommendations for further collaboration, clarification and changes to working practices are suggested.

May 2013

Radiation Exposure of the Anesthesiologist in the Neurointerventional Suite

Zirka H. Anastasiou, M.D.,* Dorothea Strozyk, M.D.,† Philip M. Meyers, M.D.,‡ Shuang Wang, Ph.D.,§ Mitchell F. Berman, M.D., M.P.H.¶

Anesthesiology 114, 512-520, 2011

Quantitative evaluation of light scattering intensities of the crystalline lens for radiation related minimal change in interventional radiologists: a cross-sectional pilot study

Toshi Abe1,*, Shigeru Furuy1, Hiroshi Sasaki1, Yasuo Sakamoto1, Shigeru Suzuki1, Tatuya Ishitake1, Kinuyo Terasaki1, Hiroshi Kohtake1, Alexander M. Norbash2, Richard H. Behrman2 and Naofumi Hayabuchi1

Radiation Protection Dosimetry (2011), pp. 1–5
doi:10.1093/rpd/ncr209

PRINCIPLES FOR THE DESIGN AND CALIBRATION OF RADIATION PROTECTION DOSEMETERS FOR OPERATIONAL AND PROTECTION QUANTITIES FOR EYE LENS DOSIMETRY

J. M. Bordy1,*, G. Guadagni2, J. Dauzais1 and F. Mariotti2
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Radiation Protection Dosimetry (2011), pp. 1–5
doi:10.1093/rpd/nco010

Radiation-associated Lens Opacities in Catheterization Personnel: Results of a Survey and Direct Assessments

Eliseo Vano, PhD, Norman J. Kleiman, PhD, Ariel Duran, MD, Mariana Romano-Miller, MD, and Madan M. Rehani, PhD

J Vasc Interv Radiol 2013; 24:197–204

Valvular and Structural Heart Diseases

Original Studies

Occupational Radiation Dose During Transcatheter Aortic Valve Implantation

Loes D. Sauren,1* MD, Leen van Guarde,2 MD, Vincent van Ommeren,2 MD, PhD, and Gerrit J. Kemerink,2* MD
CATARACT

A change in transparency of the lens
Why study the lens?

Why do we still care about cataract?
Cataract and World Blindness

- 25 million blind people globally due to cataract
- 119 million individuals visually impaired by lens opacification
- Cataract is still the leading cause of blindness in the 3rd world
- Lens opacities can be found in 96% of all individuals older than 60 yrs
- With an increasingly healthy, aging population, the societal and economic burden of cataract surgery is expected to greatly increase
  - Cataract surgery represents 12% of the U.S. Medicare budget and 60% of all Medicare visual costs

WHO, 2002, Eye Diseases Research Prevalance Group, 2004
Figure 9.22 The pathways leading to lens protein degradation and cataract. (From Harding 1991 with permission.)
RADIATION CATARACT

a specific subset of lens opacities
Classical Radiation Cataract

A lens opacity most often originating near the visual axis, first appearing in the posterior subcapsular region of the lens
radiation cataract
(Scheimpflug image)
Why do we care about radiation cataract?

- Impact on workers
- May be preventable
- Canary in a coal mine?
The lens is one of the most radiosensitive of all tissues.
Radiation cataract provides a model for studying long-term biological effects following low-dose ionizing radiation exposures in environmental or occupational settings.
Potential visual disability and morbidity resulting from radiation cataract and/or its treatment is greatly underappreciated.
Potential Low-Dose Radiation Exposures

• Accidental
  - Chernobyl, Fukushima, future??
  - contaminated buildings (e.g. Taiwan)
  - terrorism

• Occupational
  - interventional physicians
  - associated nurses and technicians
  - nuclear medicine personnel
  - nuclear plant workers
  - industrial workers
  - astronauts
  - uranium miners

• Medical
  - Diagnostic procedures
  - Therapeutic treatments

• Environmental
  - indoor radon
  - geography (Denver, USA; Kerala, India; Ramsar, Iran)
Occupational exposure to the lens

increasing usage

Radiologists
Cardiologists
Gastroenterologists
Orthopedists
Urologists
Vascular medicine
Neurologists
Anesthesiologists
Nurses and technicians
Other workers

...limited study
How much exposure?

• 17 million interventional fluoroscopic procedures (USA) (NCRP-2009)
  - 4.6 million cardiac
  - 3.4 million vascular
  - 8.6 million non-vascular

• 8.6% annual increases

Health Physics 103: 80-99, 2012
- Is there new data on human radiation cataract risk? Are proposed new eye dose limits appropriate?
- What is the relevance of radiation cataract to human radiobiology?
  - Can we utilize radiation cataract as a “biomarker” of radiation exposure?
  - Can we model radiation sensitivity and/or population heterogeneity effects using this approach
    - i.e., can we identify specific genes that confer sensitivity or resistance to radiation cataract?
- Can we find alternative methodologies for quantitating lens opacities for that better estimate any visual disability caused by radiation exposure?
Additional data regarding the dose threshold, if any, for visual disability is essential for better occupational risk assessment and further refinement of suggested exposure guidelines.
Prior to 2012, eye exposure guidelines were based on the view that radiation cataract is a “deterministic” event with a relatively **high** threshold radiation dose.
(2) The Commission has now reviewed recent epidemiological evidence suggesting that there are some tissue reaction effects, particularly those with very late manifestation, where threshold doses are or might be lower than previously considered. For the lens of the eye, the threshold in absorbed dose is now considered to be 0.5 Gy.

(3) For occupational exposure in planned exposure situations the Commission now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv.
Establishing an accurate dose threshold, if any, for radiation cataractogenesis is critical for risk assessment and exposure guidelines.
How did we derive the guidelines for lens exposure limits?
Early Radiation Cataract Studies

“Ophthalmological survey of atomic bomb survivors in Japan in 1949”

“Cyclotron-induced radiation cataracts” Science 110, 1949

- Chalupecky, 1897
- Rohrschneider, 1932
- Hiroshima, Nagasaki, 1945
- Cyclotron, 1940’s
- Poppe, Cogan, 1950’s
- Merriam & Worgul, 1976
Early Radiation Cataract Studies

• Important historical studies that helped define the nature of radiation cataract and establish initial guidelines for safe exposures to the lens.

• Failed to take into account increasing latency period as dose decreases.

• Did not have sufficient sensitivity to detect early lens changes.

• Relatively few subjects with doses below a few Gy.
### Historical Threshold Estimates (Sv)

<table>
<thead>
<tr>
<th>Threshold Dose</th>
<th>Reference</th>
<th># Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 15</td>
<td>anecdotal, pre-1950</td>
<td>100</td>
</tr>
<tr>
<td>2 - 5.5</td>
<td>Merriam and Focht, 1957</td>
<td>276</td>
</tr>
<tr>
<td>0.7 - 1.4</td>
<td>Otake, 1982</td>
<td>2,124</td>
</tr>
<tr>
<td>0.4 – 0.7</td>
<td>Worogul, 2007</td>
<td>8,600</td>
</tr>
</tbody>
</table>
Additional data regarding the dose threshold, if any, for visual disability is essential for better occupational and environmental risk assessment and further refinement of suggested exposure guidelines.
The lens
Three things to remember about the lens

The lens grows throughout life.

The source of that growth is a proliferating subset of the anterior epithelial cell monolayer.

Transparency is dependent on proper division and differentiation of the progeny of this proliferative population.
Radiation Cataract Pathomechanism

Genotoxic damage to the lens epithelium

Lens shielding studies
Mitotic inhibition studies
Irradiation of posterior 2/3 lens
IONIZING RADIATION

Damage to Lens Epithelial DNA

[ dividing cells ] → [ differentiating cells ]

Abnormal Lens Fibers

Loss of Transparency

CATARACT
ANIMAL STUDIES

Irradiation of the mouse lens by 500 mGy X-ray
(Contralateral eye shielded)
Transparency is dependent on proper differentiation of maturing lens fiber cells
The radiation target is a small proliferating subset of the lens epithelial population.
100 mGy Exposure

TIME (weeks)

PREVALENCE (1.0 Cataract)

- Fully Exposed Lens.
- Partially Exposed Portion of Lens
- Fully Shielded Lens
- Partially Shielded Portion of Lens.

Cataract prevalence

Time after irradiation (weeks)

0.5 Gy
Cataract grade: 1.0

ATM Homozygote

ATM Heterozygote

Wild-type

Rad Environ Biophys 45, 2006
Cataract Prevalence vs. Time after irradiation (weeks)

- RAD9+/-, ATM+/-
- RAD9+/-, ATM+/+
- RAD9+/+, ATM+/-
- RAD9+/+, ATM+/+

Cataract grade: 1.0

HUMAN STUDIES

More recent studies of occupational risk: Epidemiological findings
More recent studies are consistent with a very low or even zero threshold model for radiation cataract

<table>
<thead>
<tr>
<th>Category</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic procedures</td>
<td>Klein, 1993</td>
</tr>
<tr>
<td>Radiotherapy</td>
<td>Wilde, 1997</td>
</tr>
<tr>
<td></td>
<td>Hall, 1999</td>
</tr>
<tr>
<td>Astronaut core</td>
<td>Cucinotta, 2001</td>
</tr>
<tr>
<td></td>
<td>Rastegar, 2002</td>
</tr>
<tr>
<td>Atomic bomb survivors</td>
<td>Nakashima, 2006</td>
</tr>
<tr>
<td></td>
<td>Neriishi, 2007, 2012</td>
</tr>
<tr>
<td>Contaminated buildings</td>
<td>Chen, 2001</td>
</tr>
<tr>
<td>Chernobyl</td>
<td>Day, 1995</td>
</tr>
<tr>
<td></td>
<td>Worgul, 2007</td>
</tr>
<tr>
<td>Occupational Risk</td>
<td>Worgul, 2004</td>
</tr>
<tr>
<td></td>
<td>Chodick, 2008</td>
</tr>
</tbody>
</table>
*RSNA News* **14**, 5-6, 2004
• Pilot study involving eye exams of 59 interventional radiologists 29-62 years old

• Frequency and severity of posterior subcapsular cataract increased with age and years in practice

• Nearly half of those examined had early lens changes associated with radiation cataract

• 5/59 had clinically significant posterior subcapsular cataracts (psc)

• 22/59 had posterior dots and vacuoles characteristic of early psc development
Cataracts among Chernobyl clean-up worker: Implications regarding permissible eye exposures

B.V. Worgul, Y.I. Kundiyev, N.M. Sergiyenko, V.V. Chumak, P.M. Vitte, C.P Medvedovsky, E.V. Bakhanova, A.K. Junk, O.Y. Kyrychenko, N.V. Musijachencko, S.A. Shylo, O.P. Vitte, S. Xu, X. Xue and R.E. Shore


The Ukrainian American Chernobyl Ocular Study (UACOS)
Adjusted Odds Ratios for Cataract Outcome Variables (Incidence Data) Among the Chernobyl Liquidators

Dose Group, mSv

- Polychromatic Sheen
- Early pre-cataract changes
- Stage 1-5 cataract
- Stage 1 cataract
- Stage 1-5, excluding nuclear cataracts
- Stage 1, excluding nuclear cataracts

OR

0-49 50-99 100-199 200-399 400-699 700+


*first documentation of clinically relevant visual disability* (cataract extraction) following low dose exposure

threshold dose estimate of 0.45 Gy
95% confidence interval of 0.1-1.0 Gy

*At the time of the study (2005), the youngest survivors were only 57 years old, suggesting that additional cases may occur in future years.*
Risk of Cataract after Exposure to Low Doses of Ionizing Radiation: A 20-Year Prospective Cohort Study among US Radiologic Technologists


- long term, prospective analysis of self-reported cataract diagnosis in 35,700 individuals 22-44 years old at study onset
• adjusted cataract hazard ratio of 1.18 for those in the highest exposure range (60 mGy) as compared to those in the lowest (5 mGy)

• the median occupational ionizing radiation dose to the lens was estimated to be 28.1 mGy for the entire cohort
Conducted at regional meetings of cardiologists and medical workers in Bogotá, Colombia, Montevideo, Uruguay, Bulgaria and Malaysia.

- Detailed questionnaire about medical, ocular and occupational history
- Dilated, comprehensive slit lamp of the lens
- Correlate occupational radiation exposure with radiation cataract risk
Radiation Cataract Risk in Interventional Cardiology Personnel

Eliseo Vano,1,2 Norman J. Kleiman,3,4 Ariel Duran,1 Madan M. Rehani,41 Dario Echeverri1 and Mariana Cabrera1
1 Radiology Department, Complutense University, Madrid, Spain; 2 Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, New York; 3 Intensive Cardiology, University Hospital, Mieres, Asturias, Spain; 4 International Atomic Energy Agency, Vienna, Austria; 5 Fundación Cardio Infantil, Bogota, Colombia; and 6 Fundación Oftalmología Nacional, Bogota, Colombia

ABSTRACT

Purpose: To examine the prevalence of radiation-induced cataract among interventional cardiologists and nurses and correlate with occupational radiation exposure.

Methods: Interventional cardiologists and nurses, and age- and sex-matched unexposed controls were screened by dilated slit lamp examination and posterior lens changes graded using a modified Modified-Focht technique. Individual cumulative lens X-ray exposure was calculated from responses to a questionnaire and personal interview. Results: The prevalence of radiation-associated lens opacities was 23% (95% CI: 18–29) for interventional cardiologists, 4% (95% CI: 16–10) for nurses, and 2.9% (95% CI: 1–5) for controls. Relative risk of lens opacity was 4.2 (95% CI: 1.5–2.2) for interventional cardiologists and 5.0 (95% CI: 1.2–21) for nurses. Estimated cumulative ocular doses ranged from 0.01 to 40 GY with mean and median values of 3.4 and 1.5 Gy, respectively. A strong dose-response relationship was found between occupational exposure and the prevalence of radiation-associated posterior lens changes. Conclusions: These findings demonstrate a dose-dependent increased risk of posterior lens opacities for interventional cardiologists and nurses when radiation protection tools are not used. While study of a larger cohort is needed to confirm these findings, the results suggest ocular radioprotection should be utilized.

Radiation-associated Lens Opacities in Catheterization Personnel: Results of a Survey and Direct Assessments

Eliseo Vano, PhD, Norman J. Kleiman, PhD, Ariel Duran, MD, Mariana Romano-Miller, MD, and Madan M. Rehani, PhD

ABSTRACT

Purpose: To estimate ocular radiation doses and prevalence of lens opacities in a group of interventional catheterization professionals and offer practical recommendations based on these findings to avoid future lens damage.

Materials and Methods: Subjects included 58 physicians and 69 nurses and technicians attending an interventional cardiology congress and were randomized into age-matched groups. Lens dose estimates were derived from combining experimental measurements in catheterization laboratories with questionnaire responses regarding workload, types of procedures, and use of eye protection. Lens opacities were observed by dilated slit lamp examination using indirect illumination and retroillumination. The frequency and severity of posterior lens changes were compared between the exposed and unexposed groups. The severity of posterior lens changes was correlated with cumulative eye dose.

Results: Posterior subcapsular lens changes characteristic of ionizing radiation exposure were found in 50% of interventional cardiologists and 41% of nurses and technicians compared with findings of similar lens changes in < 10% of controls. Estimated cumulative eye doses ranged from 0.1–189.5 Gy. Most lens injuries result after several years of work without eye protection.

Conclusions: A high prevalence of lens changes likely induced by radiation exposure in the study population suggests an urgent need for improved radiation safety and training, use of eye protection during catheterization procedures, and improved occupational dosimetry.

Catheterization and Cardiovascular Interventions 76:829–834 (2010)

Risk for Radiation-Induced Cataract for Staff in Interventional Cardiology: Is There Reason for Concern?

Olivera Cirje-Bjelac,1,2 MD, Madan M. Rehani,2 MD, Kui Hian Sim,2 MBBS, FRACP, Hoong Bang Liew,3 MBBS, FRACP, Eliseo Vano,4 PhD, and Norman J. Kleiman,5 MD

Objective: To examine the prevalence of radiation-associated lens opacities among interventional cardiologists and nurses and correlate with occupational radiation exposure.

Background: Interventional cardiology personnel are exposed to relatively high levels of X-rays and based on recent findings of radiation-associated lens opacities in other cohorts, they may be at risk for cataract without use of ocular radiation protection.

Methods: Eye of interventional cardiologists, nurses, and age- and sex-matched unexposed controls were screened by dilated slit lamp examination and posterior lens changes graded using a modified Modified-Focht technique. Individual cumulative lens X-ray exposure was calculated from responses to a questionnaire and personal interview. Results: The prevalence of radiation-associated lens opacities was 23% (95% CI: 18–29) for interventional cardiologists, 4% (95% CI: 16–10) for nurses, and 2.9% (95% CI: 1–5) for controls. Relative risk of lens opacity was 4.2 (95% CI: 1.5–2.2) for interventional cardiologists and 5.0 (95% CI: 1.2–21) for nurses. Estimated cumulative ocular doses ranged from 0.01 to 40 GY with mean and median values of 3.4 and 1.5 Gy, respectively. A strong dose-response relationship was found between occupational exposure and the prevalence of radiation-associated posterior lens changes. Conclusions: These findings demonstrate a dose-dependent increased risk of posterior lens opacities for interventional cardiologists and nurses when radiation protection tools are not used. While study of a larger cohort is needed to confirm these findings, the results suggest ocular radioprotection should be utilized.

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Key words: cardiac catheterization; fluoroscopy; occupational exposure; posterior subcapsular cataract (PSC); lens opacities.

Prevalence

<table>
<thead>
<tr>
<th>Subjects (n)</th>
<th>Posterior subcapsular opacities in one or both eyes</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interventional cardiologists (58)</td>
<td>22 (37.9%)</td>
<td>&lt; 0.005</td>
</tr>
<tr>
<td>Nurses and technicians (58)</td>
<td>12 (20.7%)</td>
<td>0.13</td>
</tr>
<tr>
<td>Unexposed controls (93)</td>
<td>11 (11.8%)</td>
<td></td>
</tr>
</tbody>
</table>

Subject characteristics and prevalence of posterior lens changes in interventional cardiologists, nurses and technicians (Bogotá/Montevideo cohort)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Mean age (yrs)</th>
<th>Range (yrs)</th>
<th>Mean working time (yrs)</th>
<th>Cumulative occupational lens dose (Sv)</th>
<th>Range (Sv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interventional Cardiologists</td>
<td>46 ± 8</td>
<td>30-69</td>
<td>14 ± 8</td>
<td>6.0 ± 6.6</td>
<td>0.1-27</td>
</tr>
<tr>
<td>Nurses and Technicians</td>
<td>38 ± 7</td>
<td>22-60</td>
<td>7 ± 5</td>
<td>1.5 ± 1.4</td>
<td>0.2-4.5</td>
</tr>
<tr>
<td>Controls</td>
<td>41±10</td>
<td>20-66</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Vano, Rad Res 174:490-495, 2010
The number of interventional cardiology workers (cardiologists or nurses) with posterior lens changes characteristic of ionizing radiation exposure as a function of total cumulative ocular occupational exposure. (Malaysian cohort)

*Ciraj-Bjelac, Cathet Cardio Interv 76:826-834, 2010*
• Most cardiologists with early lens changes reported never or infrequently utilizing eye protection

• Frequency and severity of posterior lens changes increase with age and years in practice
Interventional cardiologists and risk of radiation-induced cataract: Results of a French multicenter observational study

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8 Centre d’Assurance de qualité des Applications Technologiques dans le domaine de la Santé (CAATS), Bourg-la-Reine, France

Article Info

Article history:
Received 29 March 2012
Accepted 22 April 2012
Available online 18 May 2012

Keywords:
Invasive procedure
X-rays
Ionizing radiation
Cardiologist
Eye exposure
Cataract

Abstract

Background: Interventional cardiologists (ICs) are exposed to X-rays and may be at risk to develop cataract earlier than common senile cataract. Excess risk of posterior subcapsular cataract, known as radiation-induced, was previously observed in samples of ICs from Malaysia, and Latin America. The O’CLOC study (Occupational Cataracts and Lens Opacities in Interventional Cardiology) was performed to quantify the risk at the scale of France.

Methods: This cross-sectional multicenter study included an exposed group of ICs from different French centers and an unexposed control group of non-medical workers. Individual information was collected about cataract risk factors and past and present workload in catheterization laboratory. All participants had a clinic eye examination to classify the lens opacities (nuclear, cortical, or posterior subcapsular) with the international standard classification LOCS III.

Results: The study included 106 ICs (mean age = 51 ± 7 years) and 99 unexposed control subjects (mean age = 50 ± 7 years). The groups did not differ significantly in the prevalence of either nuclear or cortical lens opacities (61% vs. 69% and 23% vs. 29%, respectively). However, posterior subcapsular lens opacities were significantly more frequent among ICs (17% vs. 5%, p = 0.006), for an OR = 3.9 [1.3–11.4]. The risk increased with duration of activity but no clear relationship with workload was observed. However, the risk appeared lower for regular users of protective lead glasses (OR = 2.2 [0.4–12.8]).

Conclusions: ICs, in France as elsewhere, are at high risk of posterior subcapsular cataracts. Use of protective equipment against X-rays, in particular lead glasses, is strongly recommended to limit this risk.
The rate of progression of such radiation associated lens changes is slow.

Nevertheless, eye protection is recommended to delay progression and limit future cumulative dose to the lens.
These new studies provide additional support for the hypothesis that the threshold radiation cataract dose in human populations may be significantly lower than currently accepted.
Additional studies, for example in other interventional physician cohorts and associated medical workers, may help further refine appropriate risk guidelines and the radiation cataract “threshold” for occupational exposure.
Future Interventional Medicine Studies

- Large cohort size
- Broad representation age, gender, procedure
- Well documented exposure history
- Appropriate controls (eg; SocioEconomicStatus)
- Real –time eye dose measurements
- Careful dilated slit lamp exam
- Contrast Sensitivity Testing
- Long-term follow-up to study progression rate
Potential visual disability and morbidity resulting from radiation cataract and/or its treatment is underappreciated.
Potential surgical/post-surgical complications of cataract extraction

- Endophthalmitis
- Uveitis
- Hyphema
- Corneal edema
- Choroidal hemorrhage
- Lens dislocation
- Rupture of the posterior capsule
- Retinal detachment
- Glaucoma
- Posterior subcapsular opacification
Potential post-operative visual complications of cataract surgery

- Glare and flare
- Decreased acuity
- Decreased contrast sensitivity
- Photophobia
- Stereopsis
Cataract surgery risk estimates

- **Posterior Sub-Capsular Opacification**
  - 10%
- **Cystoid Macular Edema**
  - 1-10%
- **Retinal Detachment**
  - 0.5%
- **Permanent Vision Loss**
  - 0.1%
- **Death**
  - 0.01%
Issue 2: Occupational Dose Limit for the Lens of the Eye

Q2–2: How should the impact of a radiation-induced cataract be viewed in comparison with other potential radiation effects?

Response: The Society wishes to bring the following information to the attention of the Commission:

“…available data suggests mortality following cataract surgery is on the order of 0.1% and that morbidity, defined both from an ophthalmological as well as medical standpoint, is considerably higher. Of equal import, prior to a documented clinical need for cataract surgery, there may be accompanying progressive decreases in visual acuity, contrast sensitivity and visual function that may negatively impact worker performance”

“In conclusion, the combined morbidity and mortality risks of surgical correction of radiation-induced cataracts (1% or more) and the, as yet unquantified, risk of a physician misdiagnosing or mistreating a patient because of loss of visual acuity due to the presence of an undiagnosed cataract, greatly outweighs the risk of cancer in affected individuals.”
Basil V. Worgul, Ph.D., 1947-2006
Professor of Radiation Biology
Departments of Ophthalmology and Radiology
Columbia University