ARCADIS Design & Consultancy for natural and built assets

CANADIAN PERSPECTIVE ON EYE DOSE & INTERNATIONAL RECOMMENDATIONS

Presented To:

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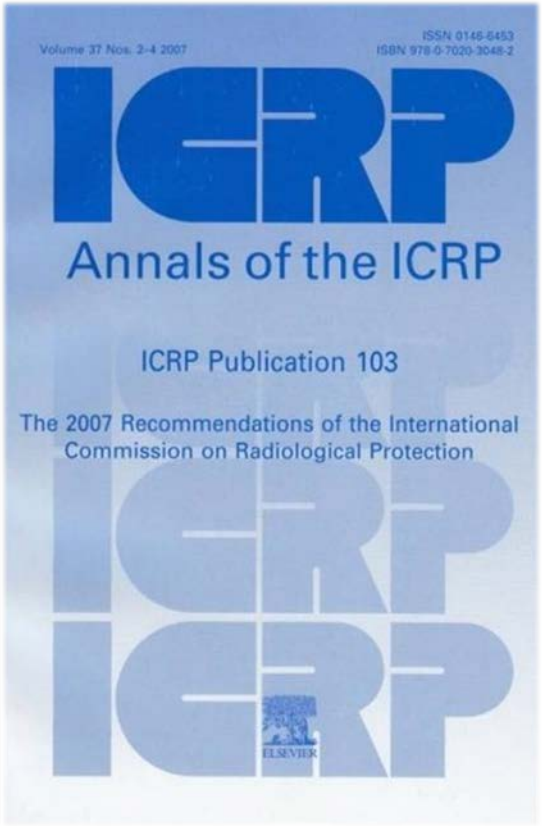
Outline of Presentation

- Background
- Considerations in developing dose limits for the lens of the eye
- Observations on current operational dosimetry
- Regulatory Considerations
- Conclusions

System of Radiological Protection

- Most recently updated in *ICRP Publication* 103 (2007)
- Based on science, value judgments, and experience
- Forms the basis of radiation safety standards, legislation, guidance, programmes, and practice worldwide



Protection of Human Health

Manage and control exposures so that:

- Deterministic effects (harmful tissue reactions) are prevented

- The risks of stochastic effects (cancer or heritable effects) are reduced to the extent reasonably achievable

- *ICRP 103*
  - *"recent studies have suggested that the lens of the eye may be more radiosensitive than previously considered"*

Tissue Reactions

ICRP *Publication 118*

- ICRP Statement on Tissue Reactions
- Early and Late Effects of Radiation in Normal Tissues and Organs
- Threshold Doses for Tissue Reactions in a Radiation Protection Context

ICRP's Statement on Tissue Reactions

The Commission continues to recommend that optimisation of protection be applied in all exposure situations and for all categories of exposure. With the recent evidence, the Commission further emphasises that *protection should be optimised not only for whole body exposures, but also for exposures to specific tissues, particularly the lens of the eye*, and to the heart and the cerebrovascular system.

ICRP 118 Conclusions for Cataract Induction

- Threshold for acute exposure: ~0.5 Gy with 95% CI including zero
- Threshold for protracted exposure: ~0.5 Gy
  - Evidence pertains mainly to opacities rather than cataracts because follow-up times were generally shorter
  - Newer study* from RERF:
    - At 1 Gy, 20-30% excess of cataract surgery
    - Threshold of 0 to 0.8 Gy, if one exists

* Neriishi K, Nakashima E, Minamoto A, Fujiwara S, Akahoshi M, Mishima HK, Kitaoka T, Shore R: Postoperative cataract cases among atomic bomb survivors: Radiation dose response and threshold. Radiation Research 2007; 168:404-8

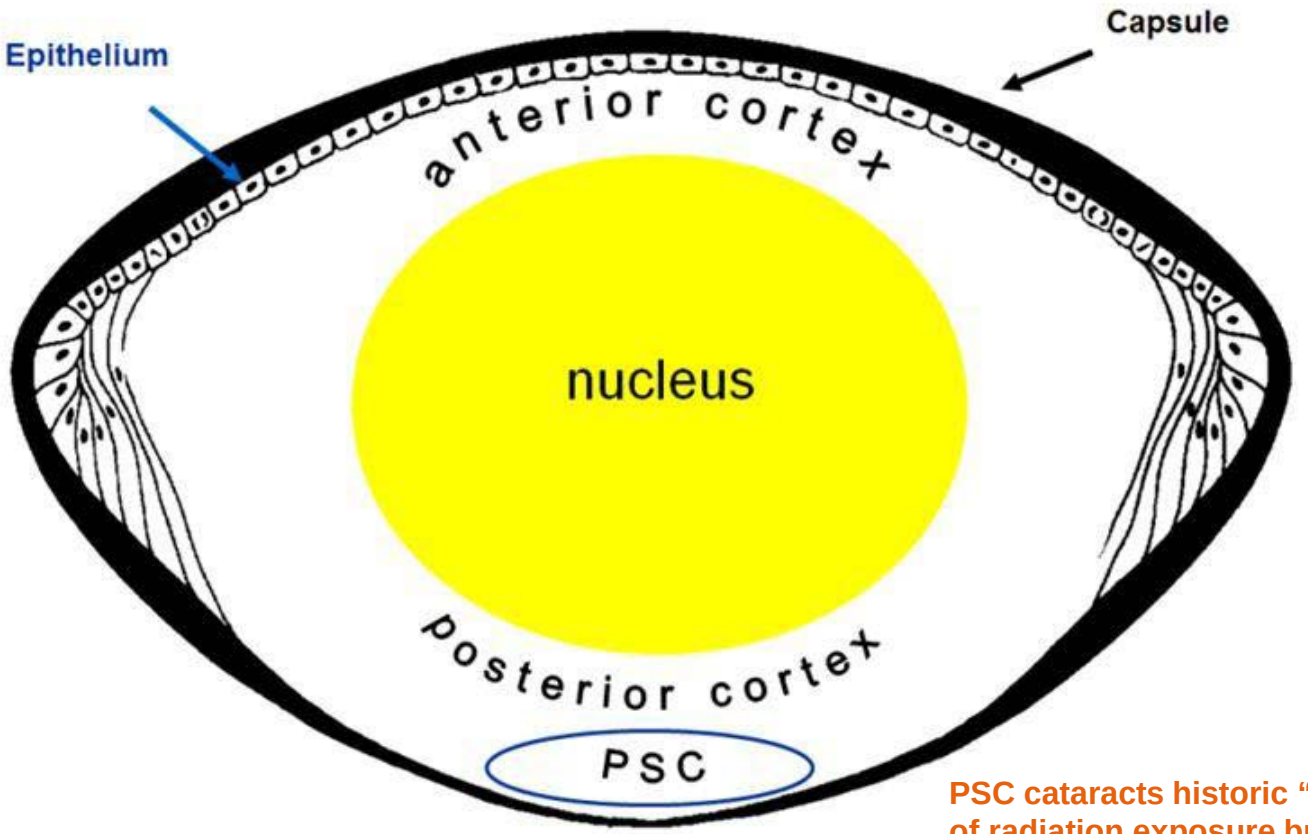
ICRP's Statement on Cataracts Cont'd

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.*

- Proposed new limit of 20 mSv
- Numerically identical to Effective Dose Limit
  - Eye Dose limit more restrictive than Effective Dose limit:
    - Gamma dose to head higher than to trunk, or
    - Beta dose (> 800 keV) is significant
- Given the substantially lower (a factor of 7.5 lower) threshold, a higher limit would not be adequately protective
- Alignment with the effective dose limit facilitates implementation

The Eye



PSC cataracts historic "sentinel" of radiation exposure but also seen in cortical opacities

Picture credit: https://rpop.iaea.org/RPOP/RPoP/Resources/images/content/img -catract1.jpg

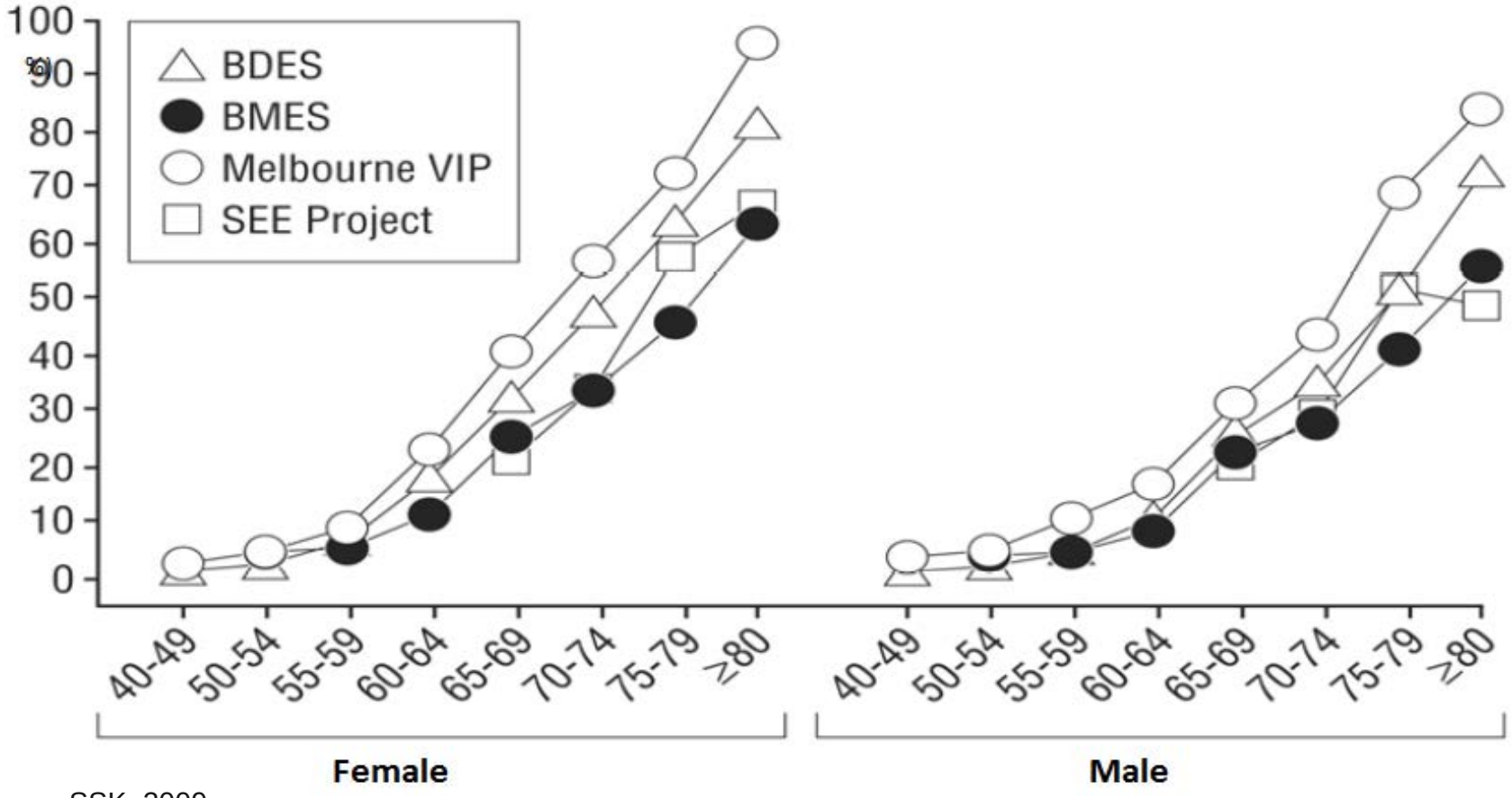
ICRP's New Recommendations

- Observations from recent studies
  - More people at low exposures and longer follow-up (epi studies)
  - "deterministic" effects now referred to as "tissue " effects since some of the deterministic effects may take years to develop
  - Increased risk of cataracts at cumulative doses above 500 mSv
  - No effect of dose rate or fractionation
  - Uncertain threshold (≈ 0.5 Gy)
  - Assumes LNT

Cataracts

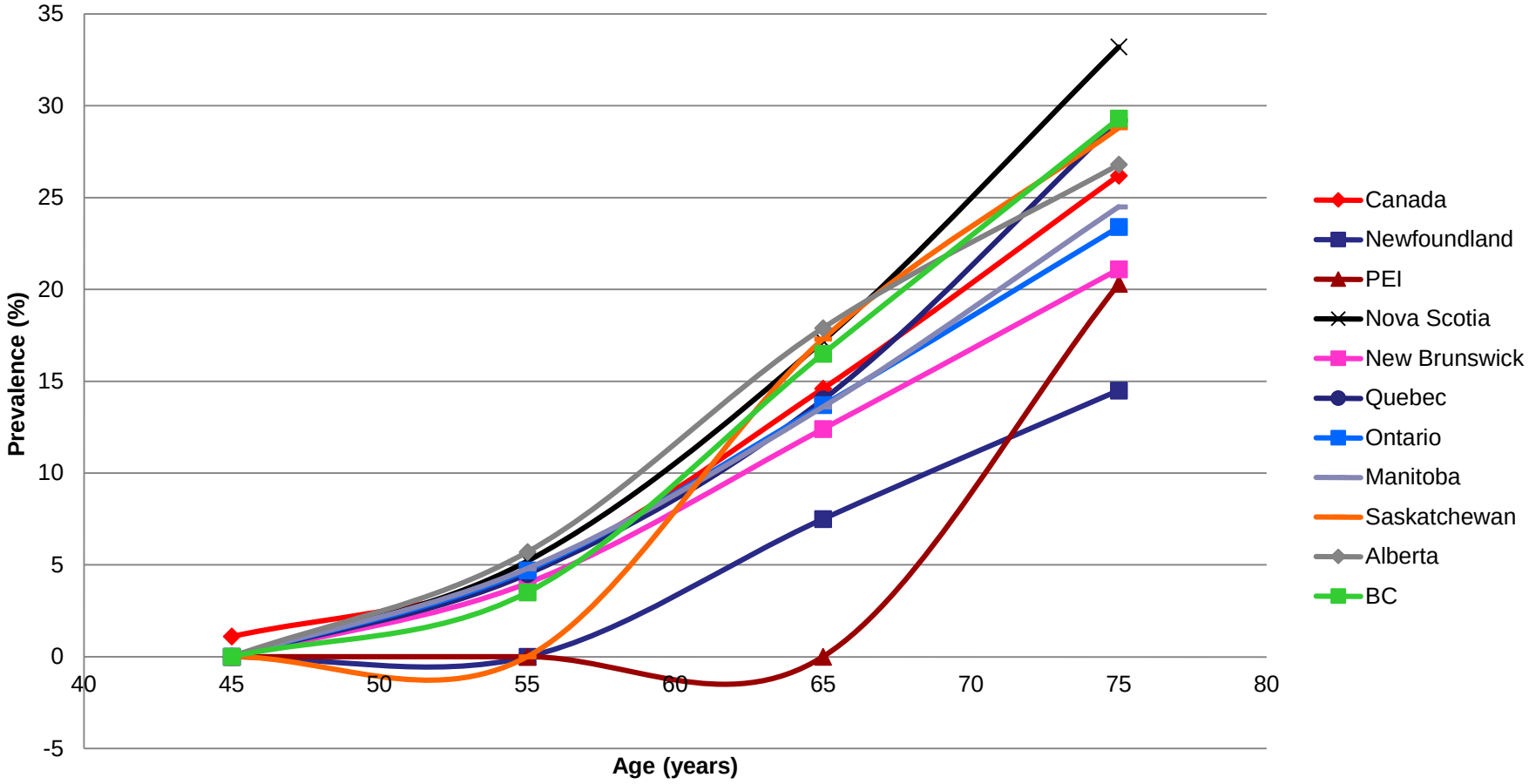
- Most frequent cause of blindness worldwide
  - Classified by location : nuclear, cortical and posterior subcapsular (psc)
- Multifactorial Causes
  - Oxidative stresses
  - age related effect -most cataracts advance after the age of 45, but most cataracts are treatable by surgery
  - Genetic factors
  - Other factors include: Sunlight, alcohol intake, smoking, diabetes, use of corticosteroids …
  - **Ionizing radiation**

Opacity with Age
(Visual impairment in ≈ 50%

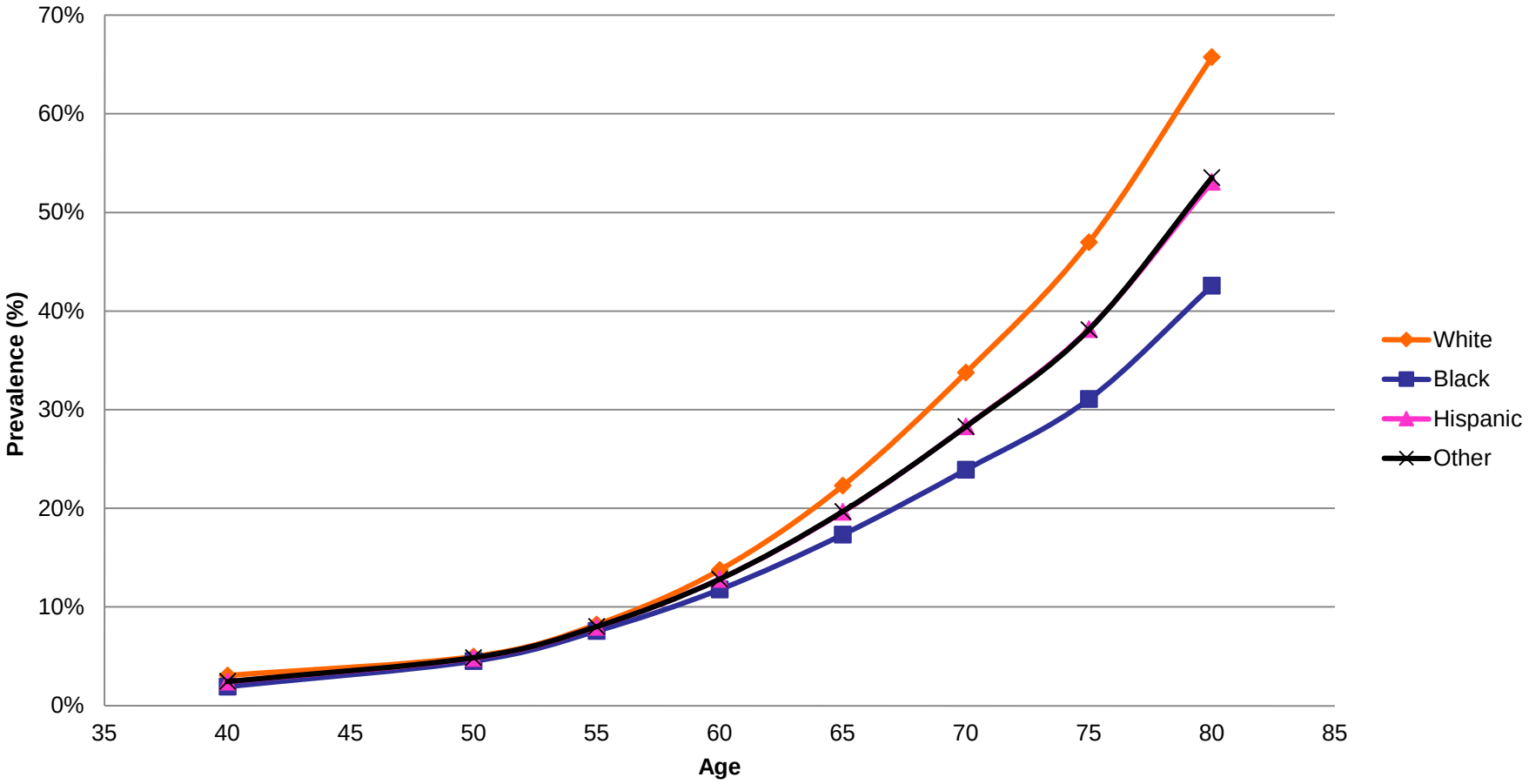


SSK, 2009

Prevalence of Cataracts in Canadian Males



Prevalence of Cataracts as a Function of Age in Males in US

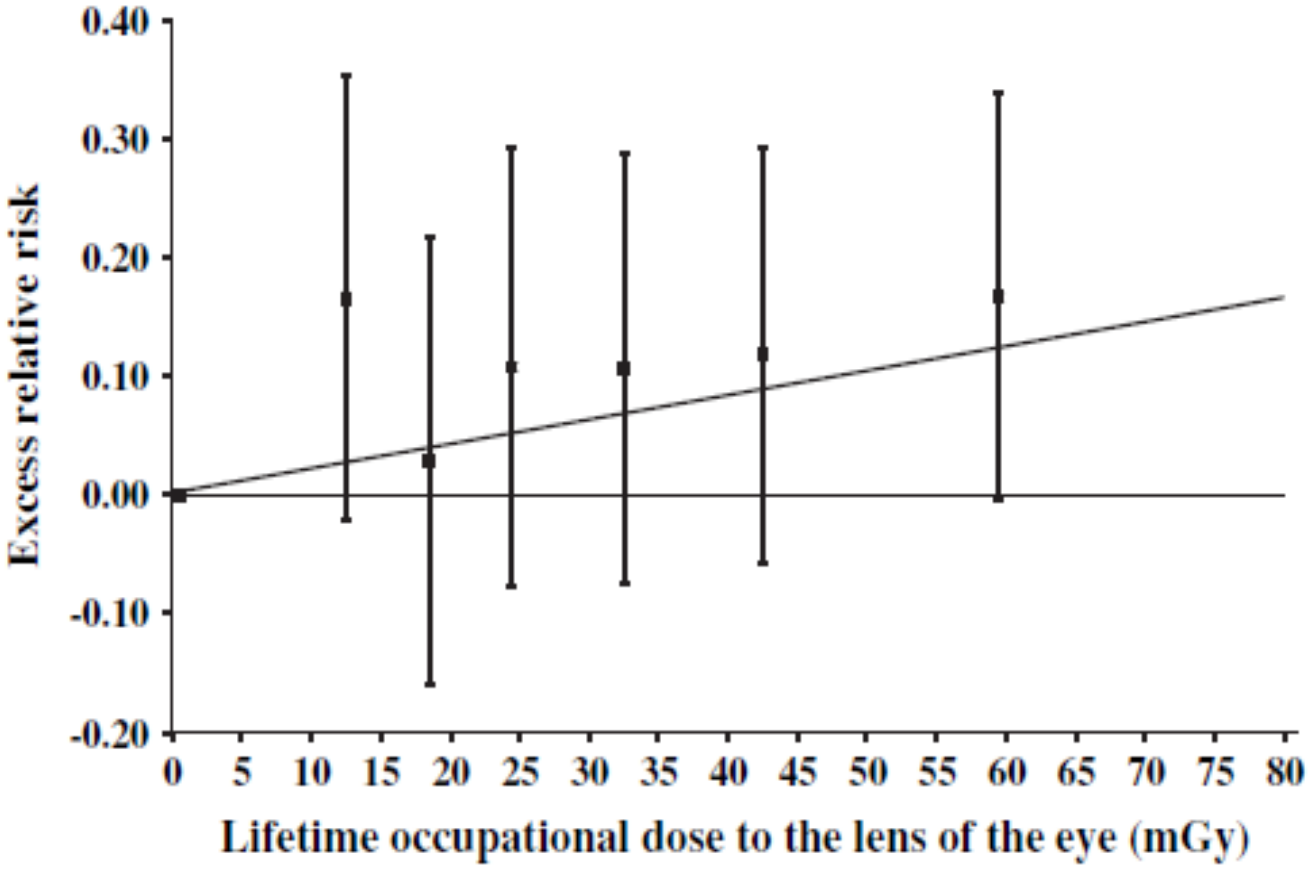


Human Studies

- Atom Bomb survivors
- Clinical exposure
- Chernobyl cleanup workers
- Occupational (e.g., radiologic technologists)
- Commercial airline pilots
- Spaceflight

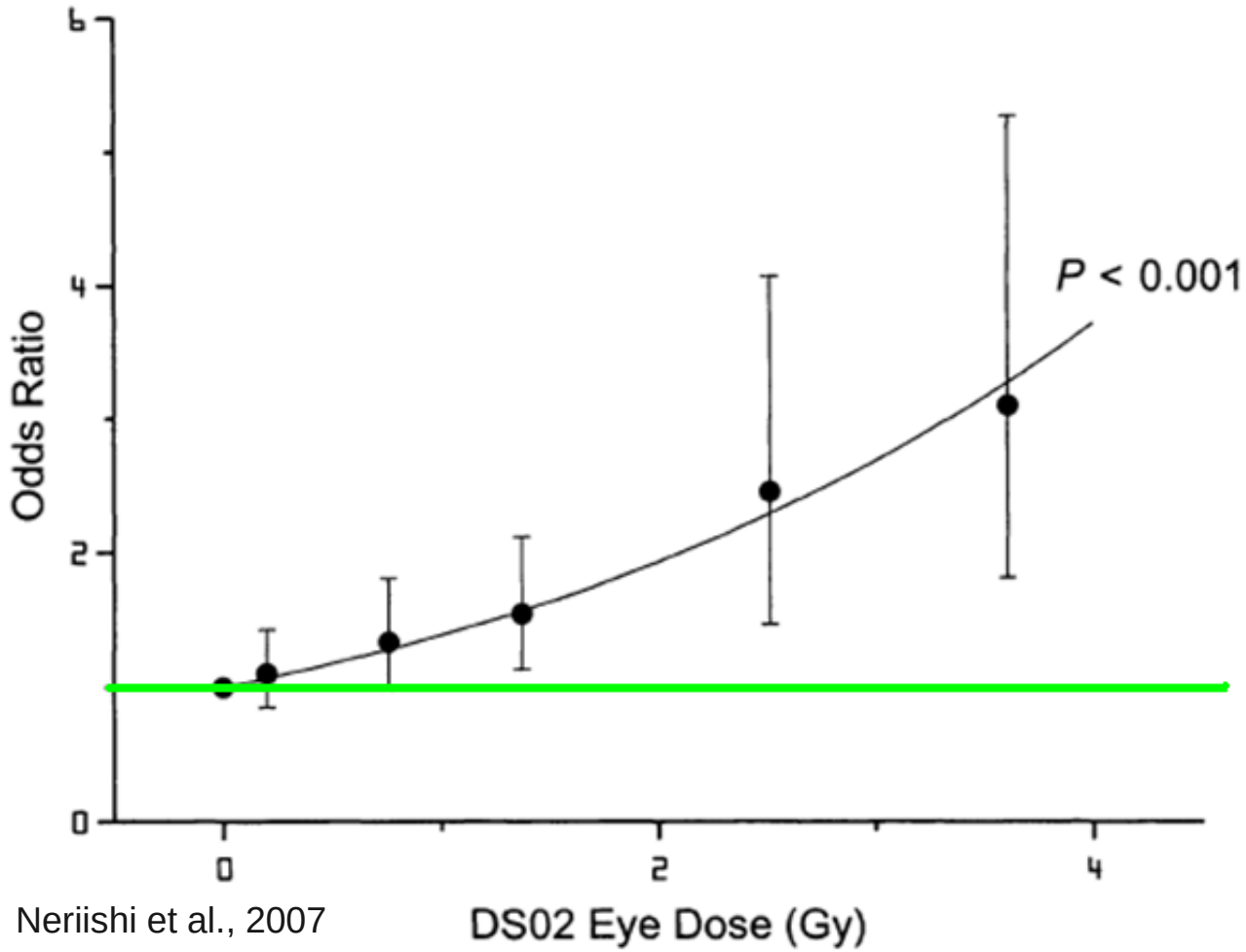
A few examples follow:

Radiation Technologists



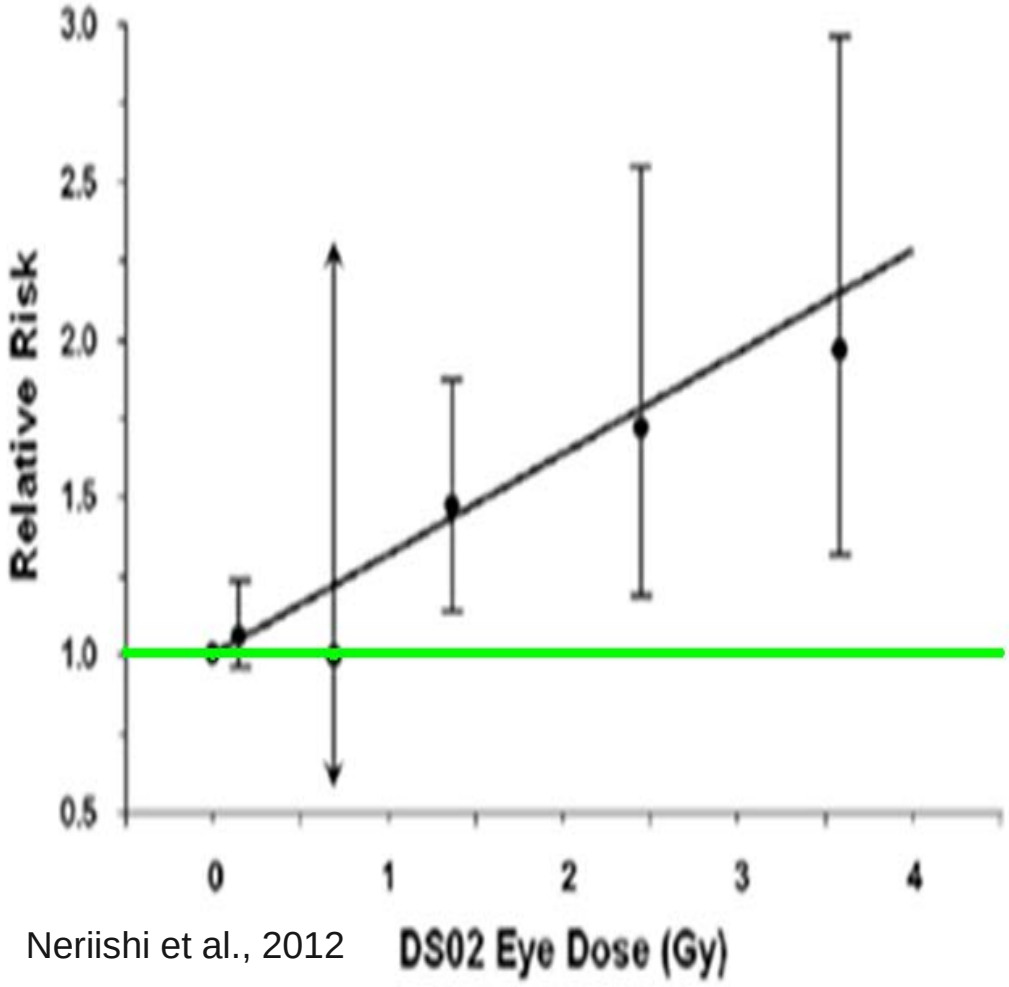
Chodick et al., 2008

Bomb Survivors



Neriishi et al., 2007

Bomb Survivors (cont'd)

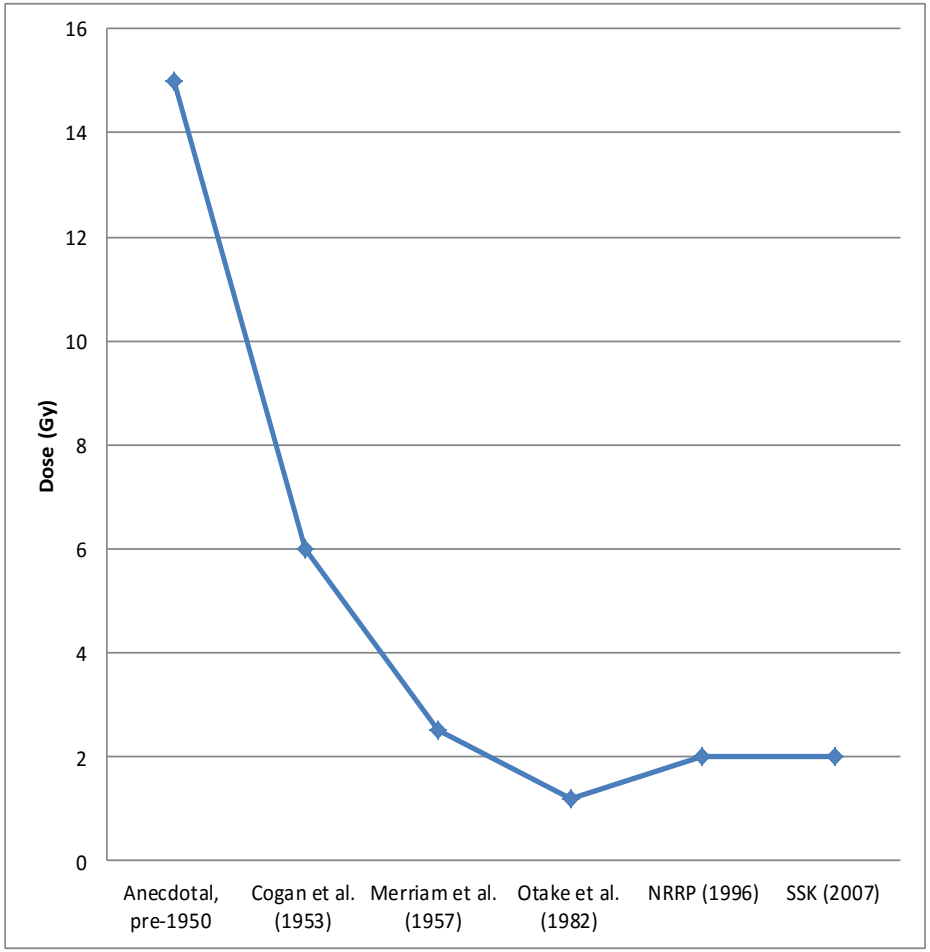


Neriishi et al., 2012

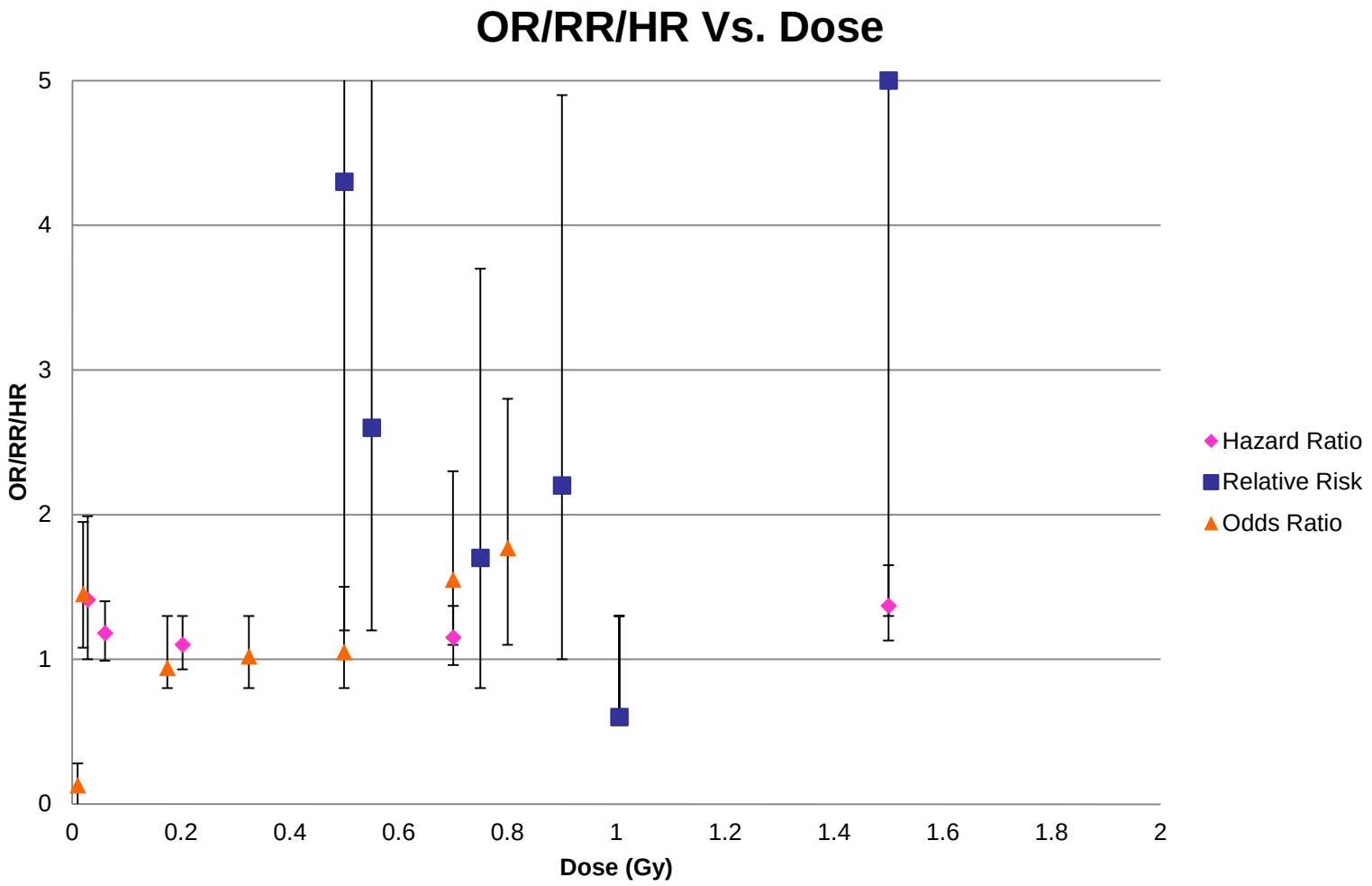
Covariate	HR	95% CI
Dosimetry system 2002 eye dose (Gy)		
0 to <0.005	1‡	. . .
0.005 to <0.4	1.10	0.93, 1.30
0.4 to <1.0	1.15	0.96, 1.37
1.0 to <2.0	1.37	1.13, 1.65
2.0 to <3.0	1.92	1.38, 2.60
≥3.0	2.19	1.52, 3.06

Threshold Estimates Over the Years

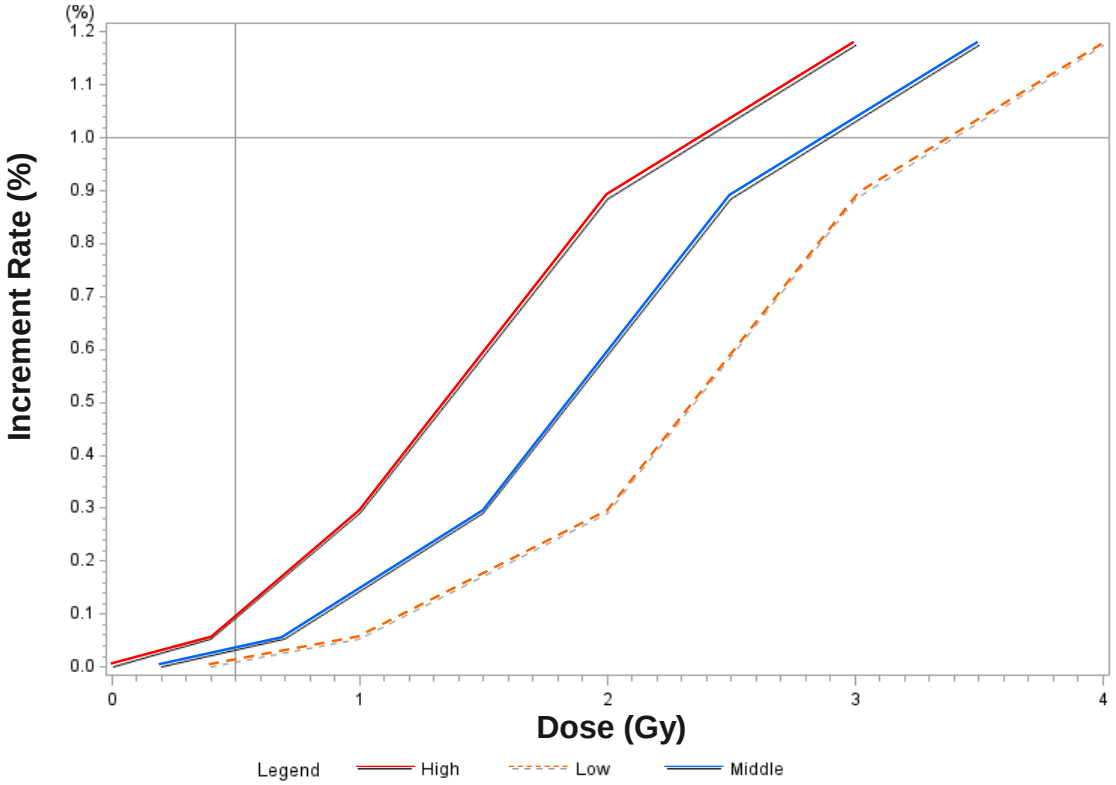
Source	Threshold estimate	End Point
Anecdotal, pre-1950	5-15 Gy	Cataracts
Cogan and Dreisler (1953)	6 Gy	Cataracts
Merriam and Fochet (1957)	2-5 Gy	Cataracts
Otake and Schull (1982)	1.2 Gy	Lens Opacities
UK National Radiological Protection Board (NRPB) (1996)	1.3 – 2 Gy	Cataracts
German Radiation Protection Board (SSK) (2007)	2 Gy	Cataracts



Dose Response



Replot of Neriishi 2012
Effect of Hypothetical Dose Uncertainty
(Upper and Lower Range adapted from Neriishi, 2012)



Neriishi et al., 2012, Radiology, October

Industry Response

- COG Workshop – Radiobiology, Regulation, and Dosimetry of the Lens of the Eye (Oct 2013)
- COG SOR – Radiobiology and Regulations for Eye Doses in CANDU Facilities
- Comments on CNSC Discussion Paper re Changes to RPRs
- COG SOR ⇒ Routine External Dosimetry – Eye Dosimetry in CANDU Facilities
- Utility specific activities
- Co-ordination and collaboration with EPRI, WNA, etc.

Industry Response cont'd

- COG Report
  - COG-13-3001-1, Radiobiology and Regulations for Eye Dose in CANDU Facilities, Doug Chambers, November 2014
- EPRI Report
  - EPRI 2014 Technical Report, Epidemiological and Mechanistic Effects of Radiation on the Lens of the Eye
- Industry comments to IAEA,CNSC ,…
- Ongoing COG and industry research, e.g.,
  - Technical note on dosimetry e.g.,
    - $H_P(3)$ dose coefficients not well developed (especially for betas)
    - OPG/BP WB TLD Badge for eye dose
    - Beta spectra in CANDU plants

Canadian Regulation (1)

- The CNSC developed a discussion document which considered ICRPs publication 118 on Tissue Reactions in making their decision to propose a reduction in the dose to the lens of the eye
- the CNSC's Regulatory discussion document and links to associated materials can be viewed which can be obtained at

  http://nuclearsafety.gc.ca/eng/acts-and-regulations/consultation/history/dis-13-01.cfm

- This web site also provides links to associated documents and comments provided to the CNSC

New ICRP Recommended Occupational Dose Limits for Lens of the Eye

Previous	New[1,2]
150 mSv per year	20 mSv per year, averaged over defined periods of 5 years No single year exceeding 50 mSv

1) Assumed threshold at ***"…the maximum amount of radiation that a tissue can withstand without developing clinical signs of injury in more than few percent of individuals" and the criterion is usually taken from <1% (for cases of induced paralysis) up to a few percent (for less severe and treatable injuries)***

2) Accepted by the IAEA and incorporated into IAEA's *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards Interim Edition* (2011)

Canadian Regulation (2)

A few potential Issues include amongst others:

- Need to develop or identify appropriate dosimetry service
- Potential beta sensitivity for Hp(3) dosimeters
- Record keeping at licencees and with Canada's National Dose Registry
- Communicating implications (and context) to nuclear workers

Conclusions (1)

- Determining dosimetry requirements (when, how accurate) for lens of eye is a challenge
- Using existing Skin and WB dosimeter results to estimate eye dose is problematic
- Examination of past skin dose results can place some limits on past eye dose
- Proper evaluation requires knowledge of beta fields and sophisticated evaluation of dosimeter element response

Conclusions (2)

- Current limits for the lens of the eye are too high

but

- The risk of cataracts seems over-weighted compared to other risks (cancer)
- Substantial effort will be required to meet ICRP recommended eye dose limit, examples:
  - Dosimetry
  - Record keeping
  - communications