

# **Cataract Risk after Low to Moderate Doses of Low-LET Radiation**

**EURADOS Conference  
Braunschweig  
28 Jan 2009**

**Roy Shore  
Shore@rerf.or.jp  
Radiation Effects Research Foundation**



# ICRP Guidance on Cataract Induction

	Brief Exposures (Sv)	Fractionated / Protracted (Sv)	Annual Dose Rate (Sv)
Detectable Opacities	0.5 – 2	5	> 0.1
Visual Impairment	5	> 8	> 0.15

ICRP 60 (1991) and ICRP 103 (2007).



# Questions to be Addressed to Studies

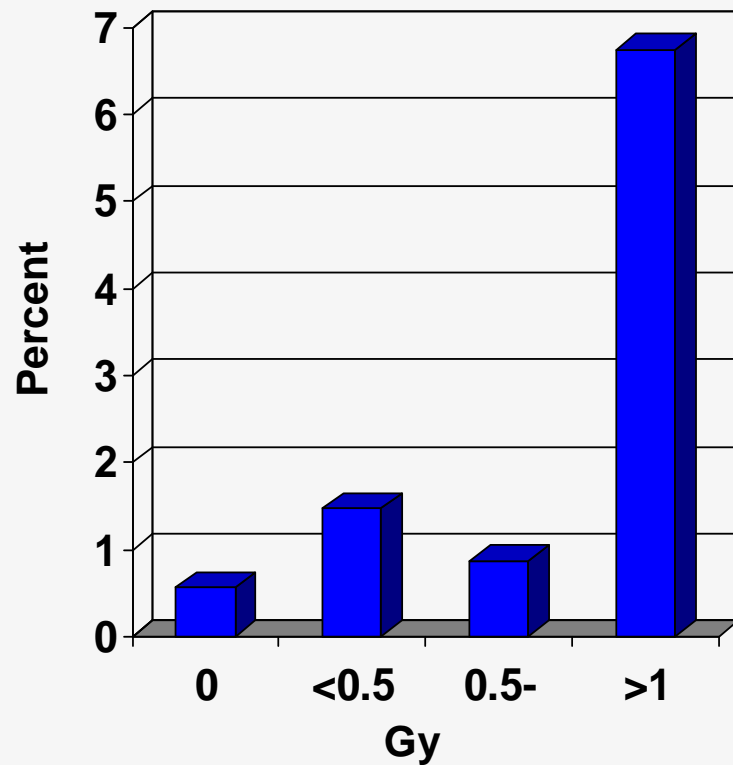
- **Epidemiologic Flaws**: Does the study have serious methodologic flaws or limitations?
- **Age**: What does the study tell us about effects among working age persons?
- **Dosimetry**: What is the quality of the dose estimates?
- **Dose Protraction**: Are the results applicable to workers with fractionated/protracted, low dose-rate exposures?
- **Impaired vision**: Is the study informative regarding serious cataracts (visual impairment) or only about minor opacities?



# Dose-Response for Lens Opacities after Radium Plaques for Hemangioma in Infancy

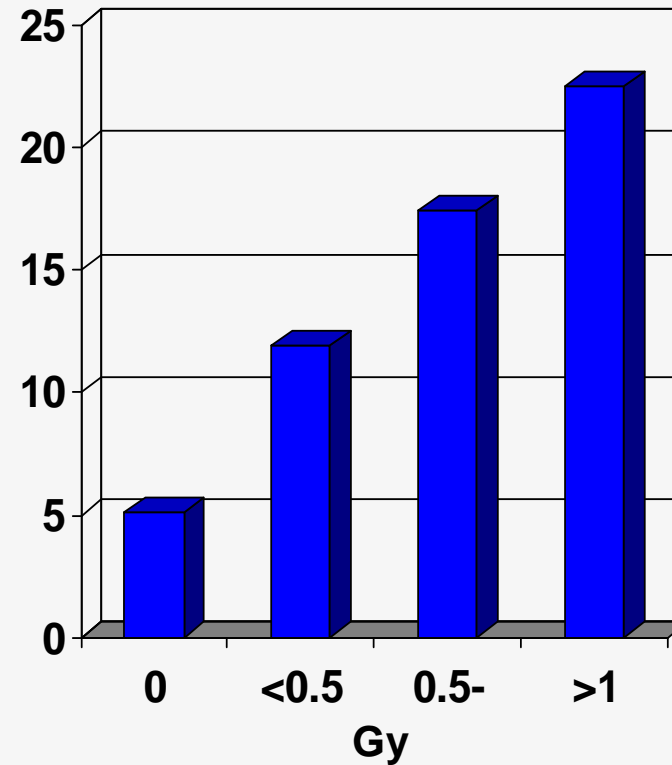
## Posterior Subcapsular

$OR_{1Gy} = 1.49$  (CI: 1.1-2.1)



## Posterior Subcapsular + Cortical

$OR_{1Gy} = 1.50$  (CI: 1.1-2.0)



Hall P, et al. *Radiat Res*, 1999; 152:190-95

**Lens Opacities  
after Chronic Low-Dose-Rate Gamma  
Irradiation from Radiocontaminated  
Buildings, Taiwan**

**Chen W-L, et al. *Radiat Res*, 156:71-, 2001**



# Radiocontaminated Buildings: Clinical Examination for Lens Opacities

- Received  $>5$  mGy/y during 1983-1997
- For those of ages  $<20$  (n=61):
  - Mean dose  $\sim 170$  mGy. Dose range 1-1200 mGy.
  - Dose-response association for minor lenticular opacities: **OR at 1 Gy = 1.18 (95% CI: 1.02, 1.36)**
- Saw no association for those of ages 20-40 or  $>40$ .



# Chernobyl Childhood Study of Lens Opacities – Subjects and Methods

- Ophthalmological screening in Ukraine of children ages 5-17 in 1991 (i.e., ages 0-12 at the time of the Chernobyl accident)
- 996 examined from contaminated areas & 791 from areas with little Chernobyl exposure

Day, Health Phys. 68:632, 1995



# Chernobyl Childhood Study – Results

	Exposed (N=996)		Unexposed (N=791)		
	No. with Opacities	Percent	No. with Opacities	Percent	Approx. RR (95% CI)
<b>Cortical opacities (Grade ≥2)</b>	<b>15</b>	<b>1.5</b>	<b>10</b>	<b>1.3</b>	<b>1.2 (0.5-2.6)</b>
<b>Posterior subcapsular opacities (Grade ≥1)</b>	<b>28</b>	<b>2.8</b>	<b>8</b>	<b>1.0</b>	<b>2.8 (1.3-6.1)</b>
<b>Any posterior lens change</b>	<b>36</b>	<b>3.6</b>	<b>9</b>	<b>1.1</b>	<b>3.3 (1.6-6.7)</b>

Day, Health Phys. 68:632, 1995

# Chernobyl Clean-up Worker Study

Worgul B, et al. *Radiat Res*, 167:233-43, 2007

Chumak V, et al. *Radiat Res*, 167:606-14, 2007



## Clean-up Workers: Study Design and Methods

- 8,607 Ukrainian clean-up workers during 1986-87, with official dose records
- Obtained questionnaire on Chernobyl work: locations, time after accident, type of work
- Gave standardized ophthalmologic exams 12 and 14 y after exposure
- Ophthalmologists blinded to doses and dosimetrists to ophthalmologic outcomes

(Worgul, *Radiat Res*, 167:233-43, 2007)



# Dose Assessment Issues: Estimates & Not Measurements

- Official doses mostly estimated & not measured.
- Estimates based on:
  - Dose measurements (14%)
  - Time & motion studies,
  - Projected task dose estimates, or
  - Group dosimetry (1 dosimeter for group of workers)
- Estimated doses were calibrated against EPR measurements of tooth enamel for >100 workers. Derived dose correction factors & uncertainties.

(Chumak, *Radiat Res*, 167:606, 2007)



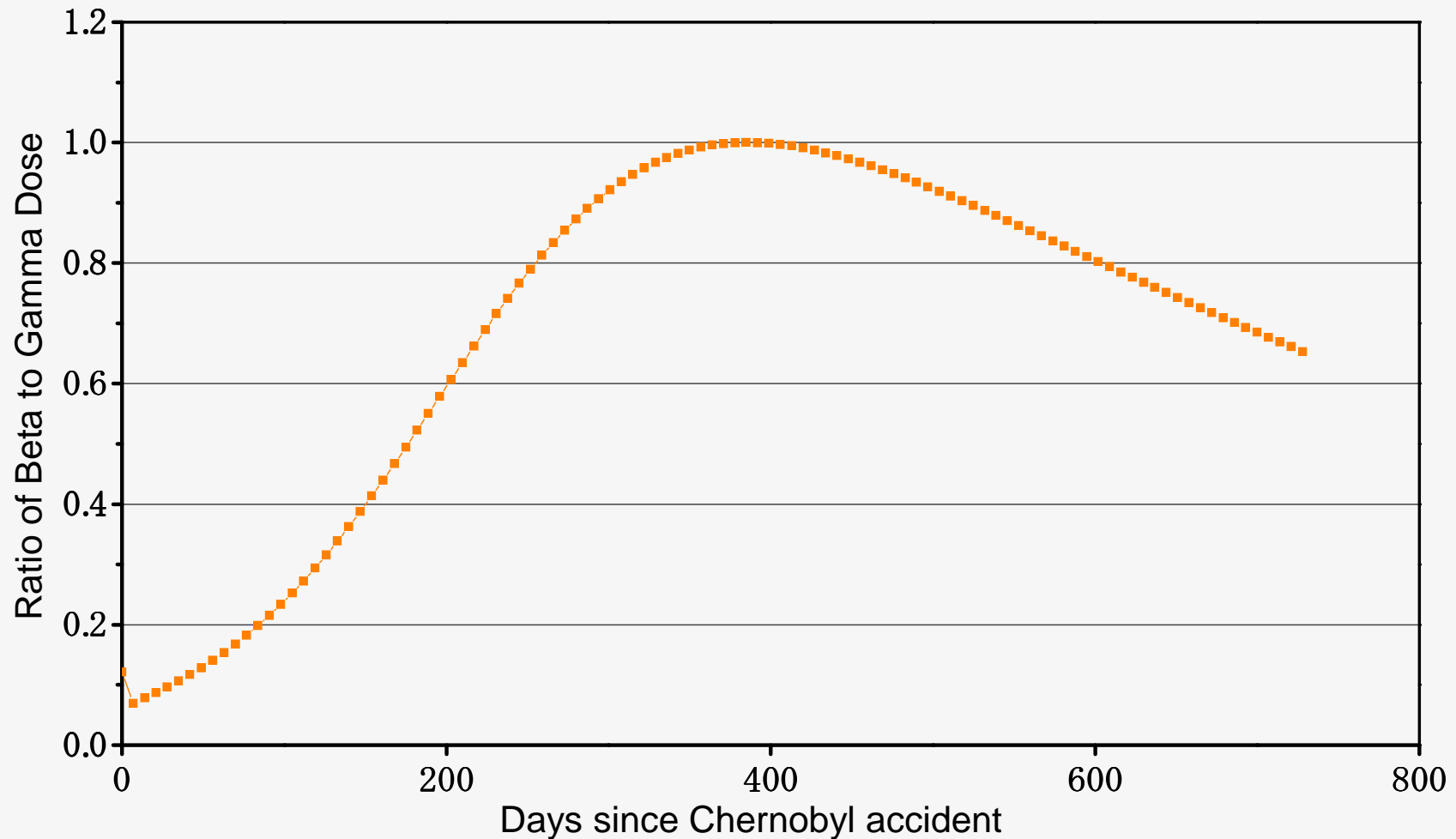
## Dose Assessment Issues: Beta Doses

- In some locations there were substantial beta doses, to which standard dosimeters were not sensitive.
- From available beta exposure estimates, we **derived estimated ratios of beta/gamma lens doses** – based on work location, type of work, time since accident, protective measures and depth of lens tissue.

(Chumak, *Radiat Res*, 167:606, 2007)



# Temporal Pattern of Average Beta/Gamma Dose Ratios

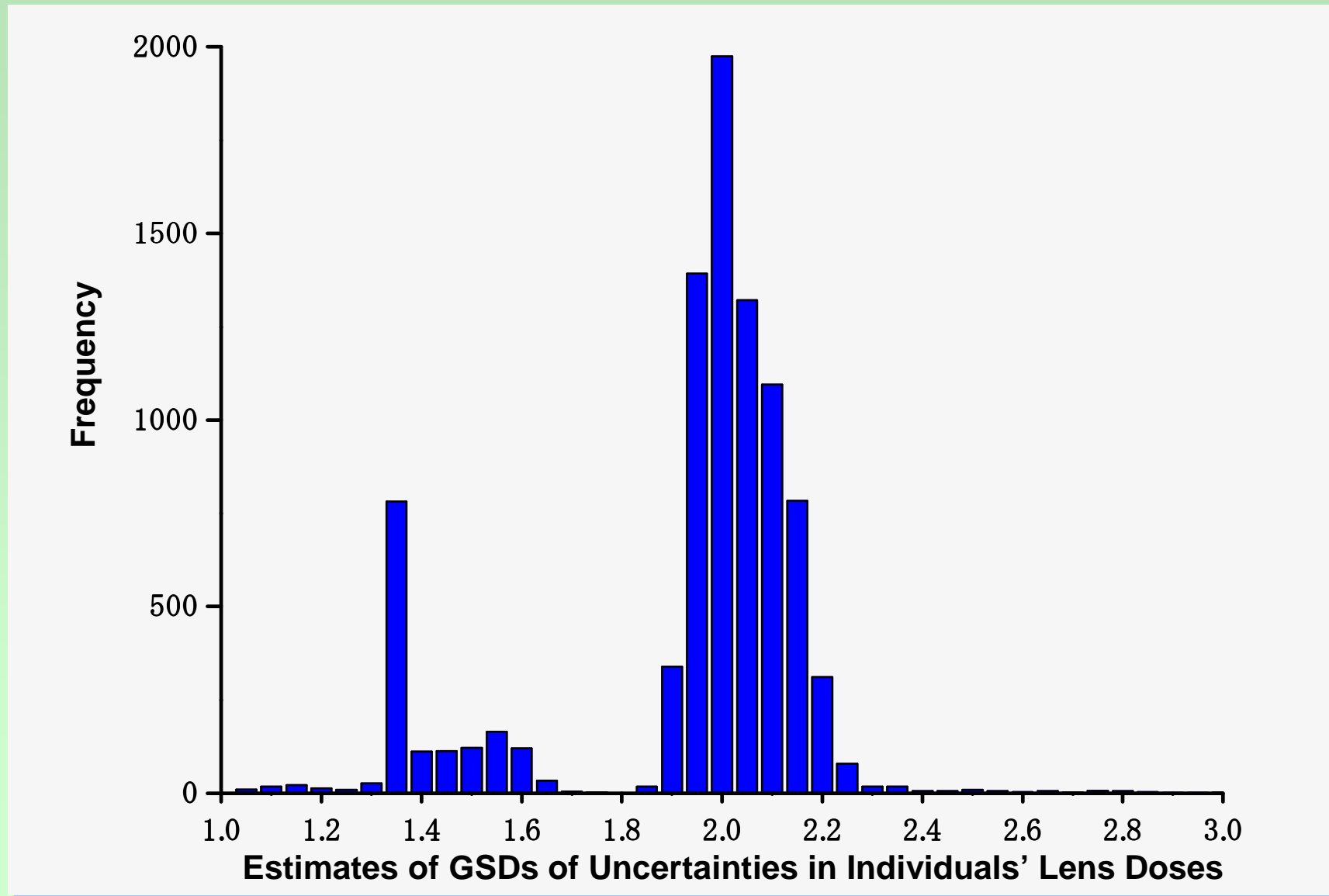


Gamma emitters:  $^{140}\text{Ba}/\text{La}$ ,  $^{132}\text{Te}$ ,  $^{131}\text{I}$ ,  $^{137}\text{Cs}/\text{Ba}$

Beta emitters:  $^{144}\text{Ce}/\text{Pr}$ ,  $^{106}\text{Ru}/\text{Rh}$ ,  $^{90}\text{Sr}/\text{Y}$

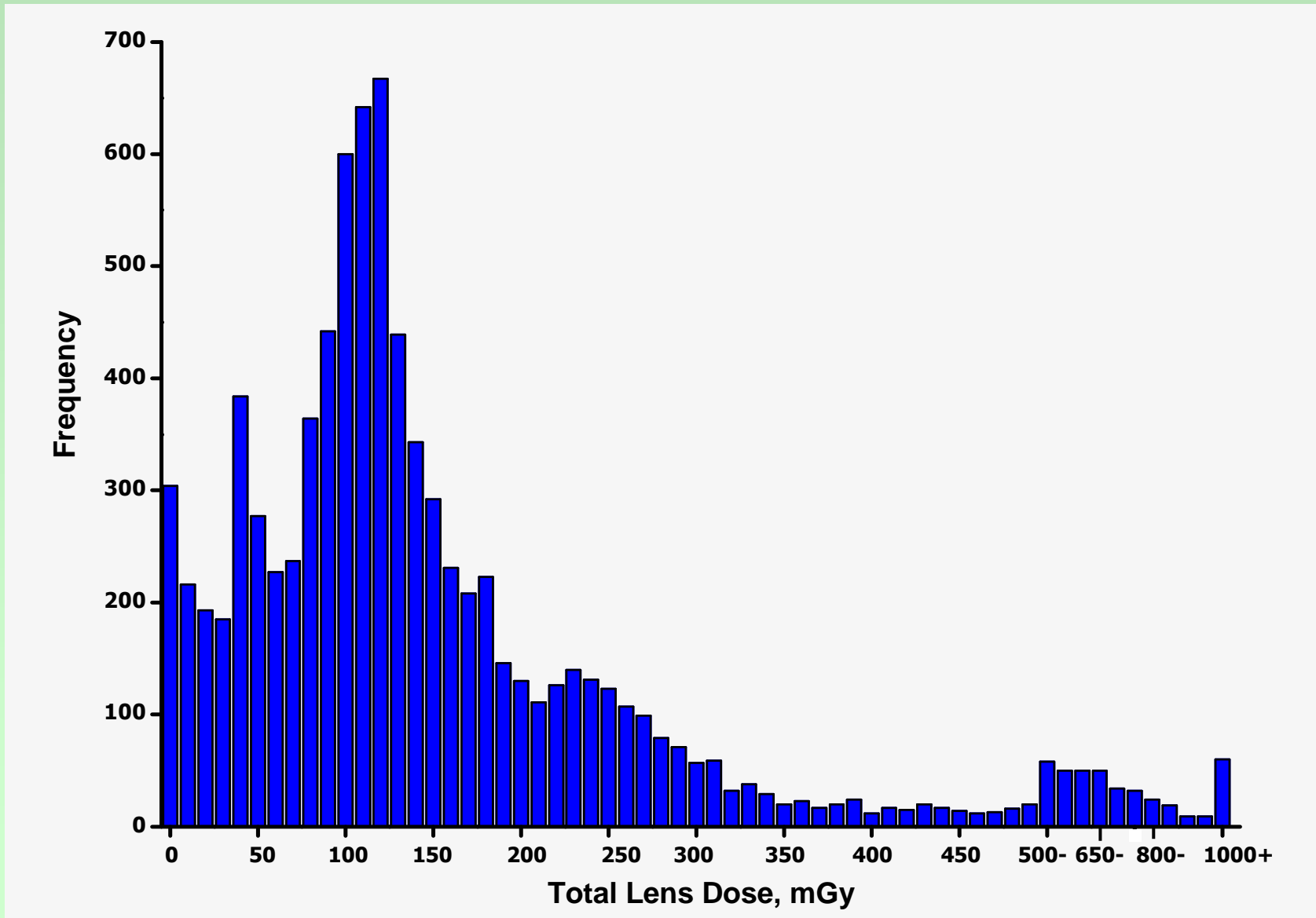
(Chumak, *Radiat Res*, 167:606, 2007)

# Chernobyl Cleanup Workers



(Chumak, *Radiat Res*, 167:606, 2007)

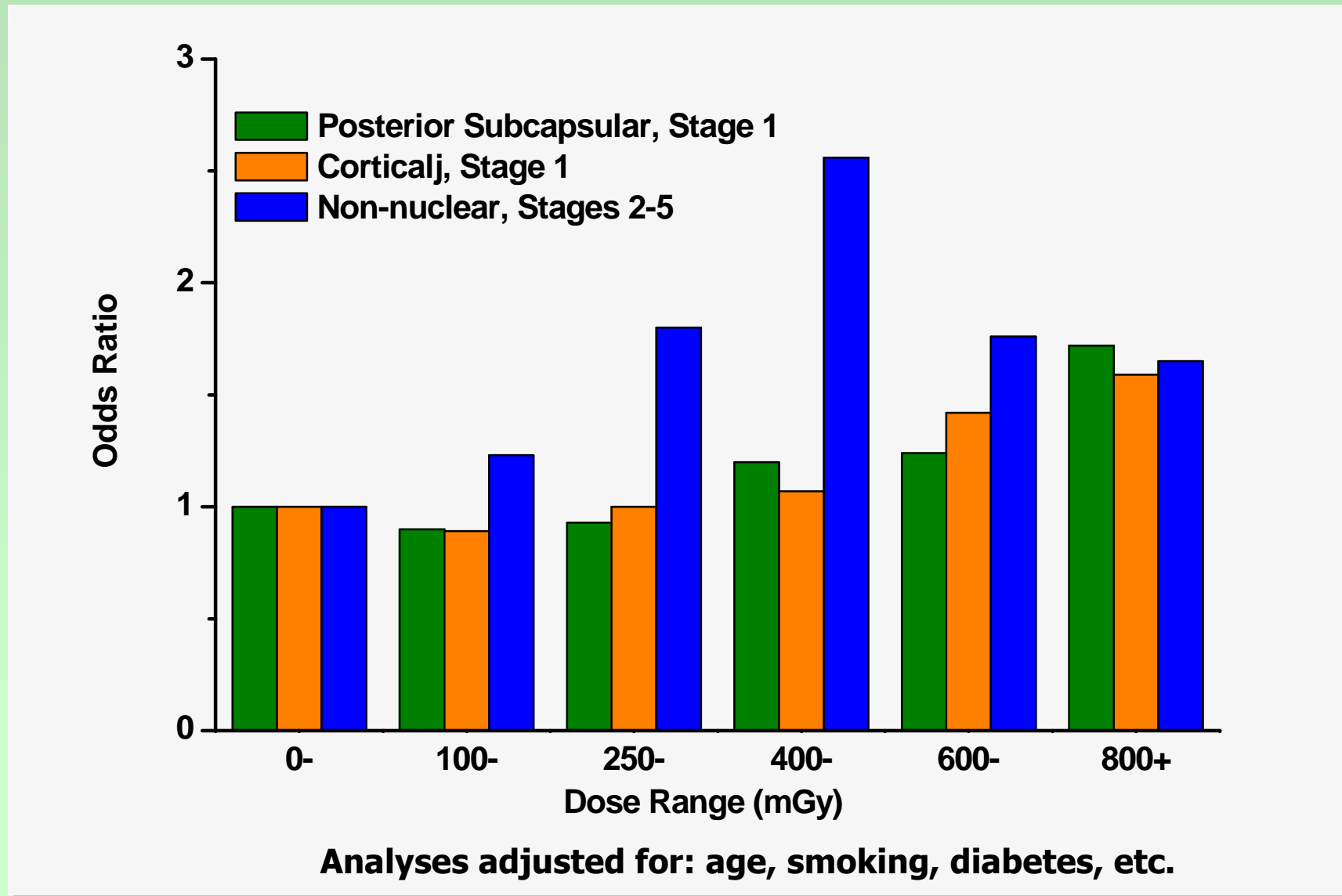
# Frequency Distribution of Workers' Lens Doses



(Chumak, *Radiat Res*, 167:606, 2007)



# Odds Ratios by Dose Response for Types of Opacities



(Worgul, *Radiat Res*, 167:233-43, 2007)



# Chernobyl Cleanup Workers: Cataract Risk and Dose Threshold

Type of Opacity	Odds ratio at 1 Gy (95% CI)	Dose-effect threshold, Gy (95% CI)
Posterior subcapsular, Stage 1	1.42 (1.01-2.00)	0.35 (0.19-0.66)
Cortical, Stage 1	1.51 (1.09-2.10)	0.34 (0.18-0.51)
All non-nuclear, Stage 1	1.52 (1.10-2.12)	0.50 (0.17-0.69)

(Worgul, *Radiat Res*, 167:233-43, 2007)

# **Cohort of U.S. Radiologic Technologists**

**Chodick G, et al. *Am J Epidemiol*, 168:620-, 2008**

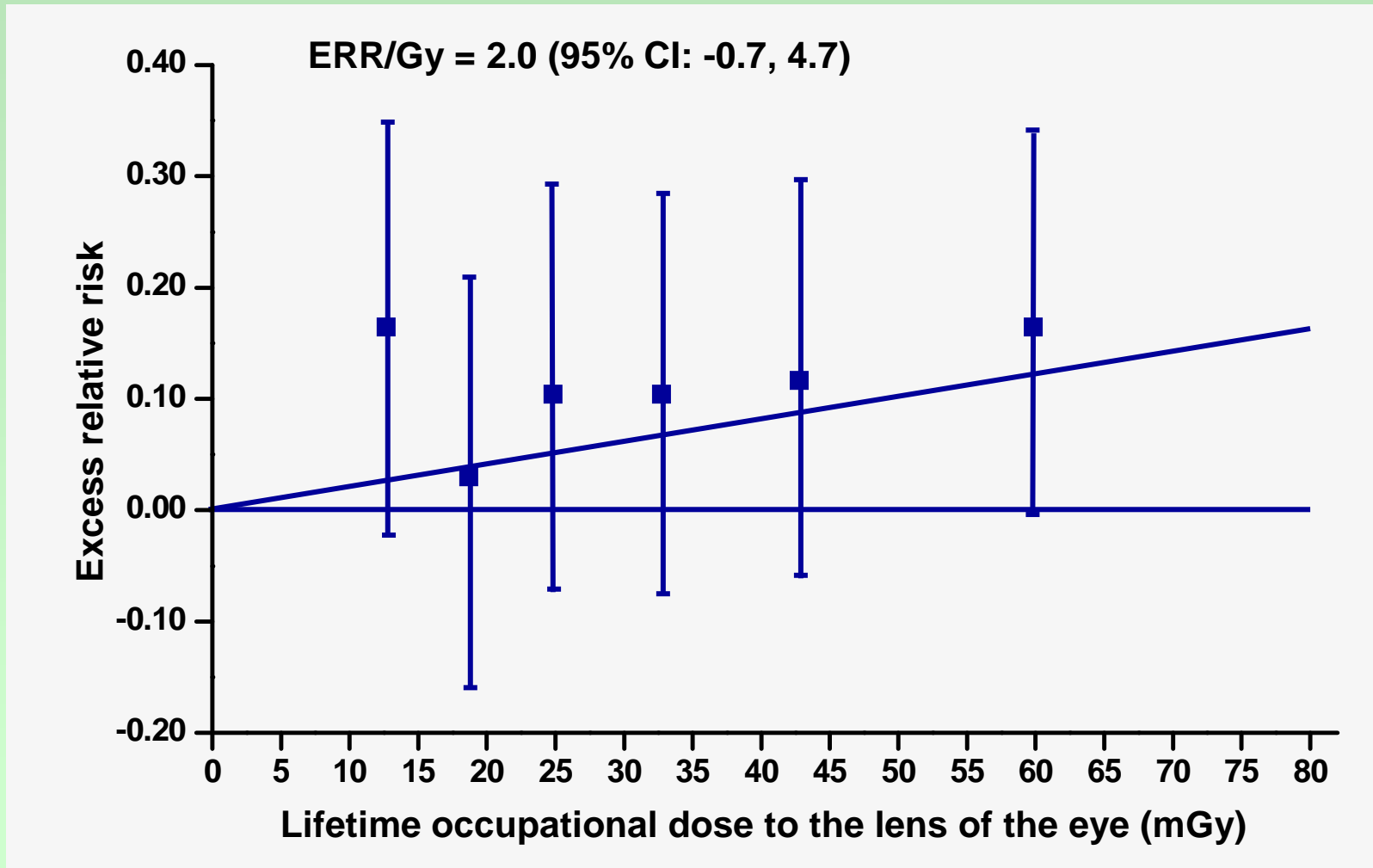


# U.S. Radiologic Tech Study: Characteristics

- N = 35,700 workers, followed up for ~20y.
  - 2,380 cataracts, including 650 cataract extractions
  - Cataract assessment based on self reports
- Median occupational lens dose = 28 mGy  
(highest dose group ~60 mGy)
- Analyses adjusted for other risk factors for cataract.



# Dose-Response for Total-Cataract Risk from Occupational Exposure



Chodick G, et al. *Am J Epidemiol*, 168:620-, 2008



# U.S. Radiologic Techs: Occupational Radiation Exposure and Cataract Findings

- Total-cataract dose-response:  
ERR/Gy = 2.0 (95% CI: -0.7, 4.7)
- Cataract extraction risk:  
ERR/Gy = 1.50 (95% CI: -3.4, 6.4)

# **Japanese Atomic Bomb Survivors: Prevalence of Lens Opacities and Surgically Removed Cataracts**

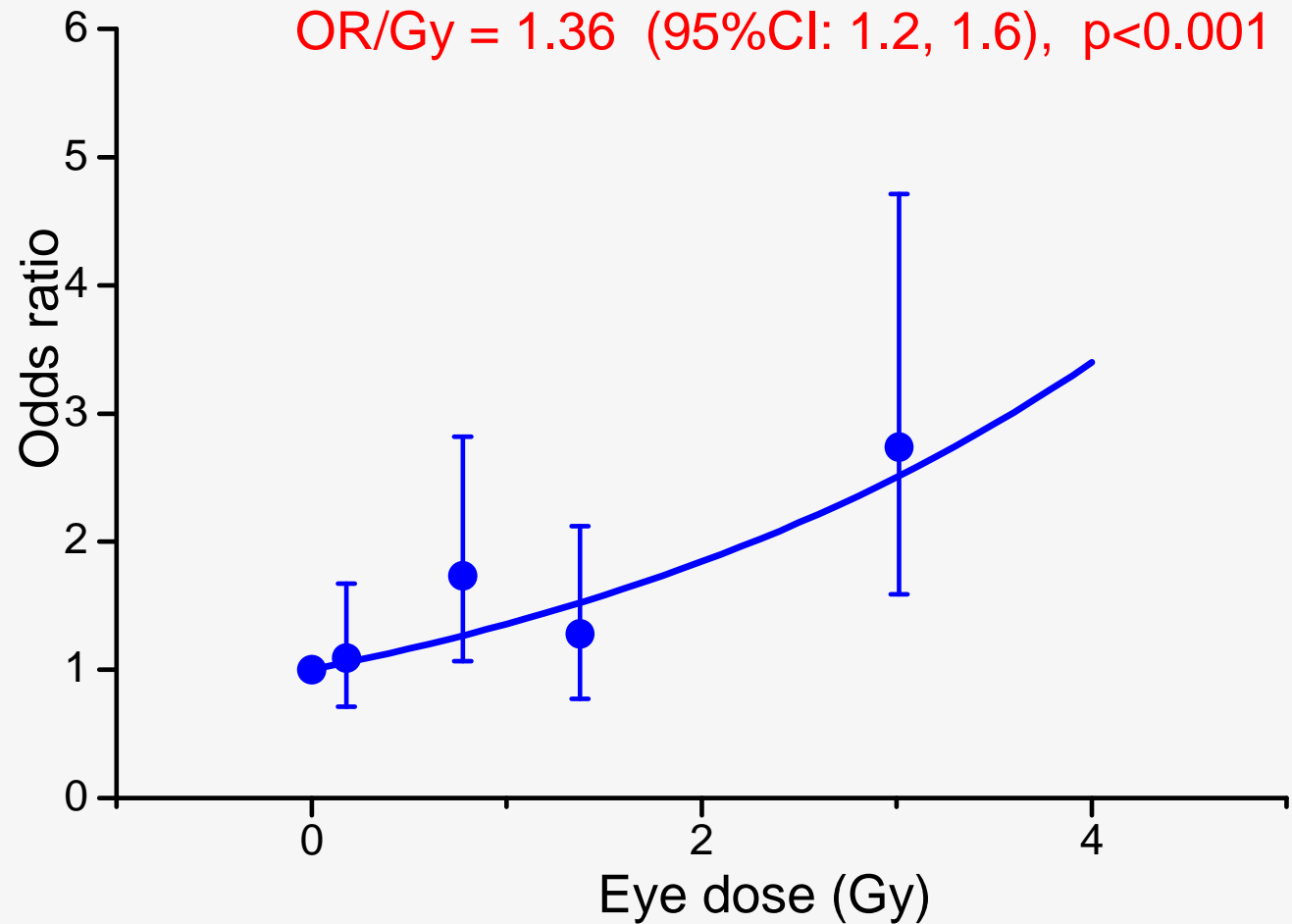
**Minamoto A, et al. *Int J Radiat Biol* 80:339-345; 2004.**

**Nakashima E, et al. *Health Phys* 90:154-160; 2006.**

**Neriishi K, et al. *Radiat Res* 168:404-408; 2007.**



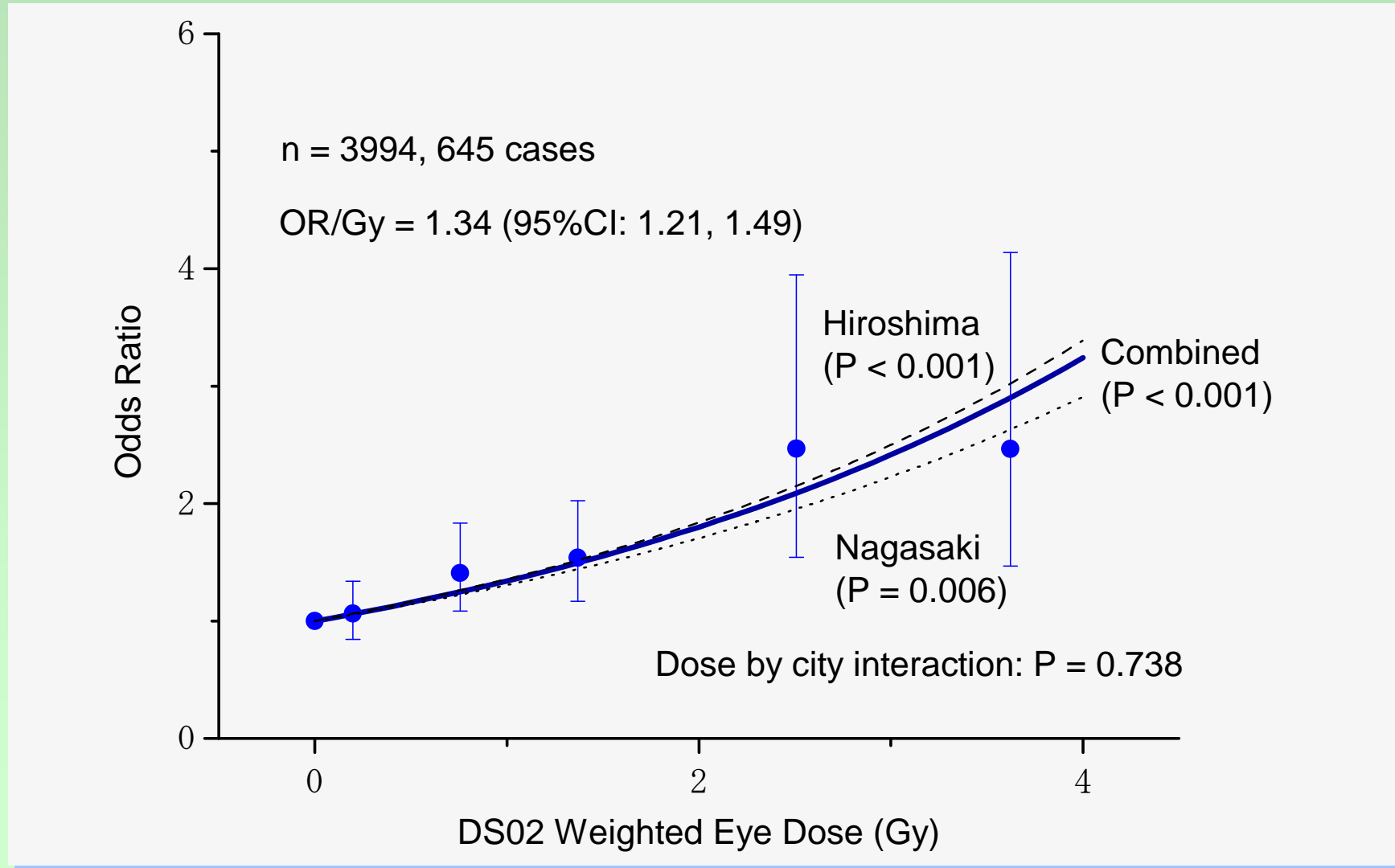
# Clinical Screening: Posterior Subcapsular Opacities



(Minamoto, *Int J Rad Biol*, 80:339, 2004)



# Prevalence of Surgically Removed Cataracts by Dose



(Neriishi, Nakashima et al, 2008, Unpub)



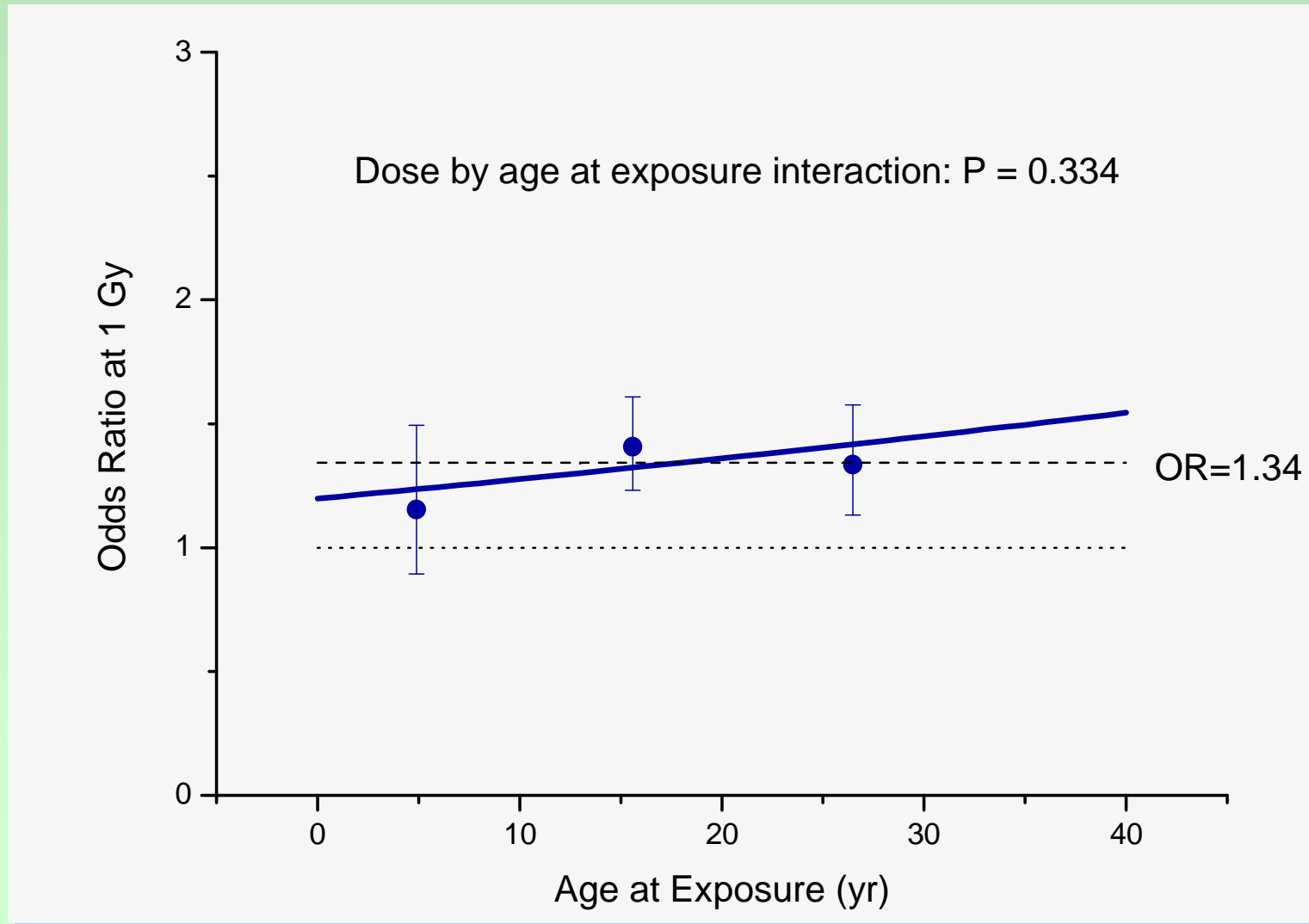
# Cataract Extraction Prevalence: Statistics

- Odds Ratio at 1 Gy: 1.34 (95% CI: 1.21, 1.49),  $p < 0.001$ 
  - Adjusted for city, gender, age at exposure, attained age, diabetes
- Dose-effect threshold, Best estimate:  
0 Gy (95% CI:  $<0$ , 0.7 Gy)

(Neriishi, Nakashima et al, 2008, Unpublished)



# Cataract Extraction Prevalence: Odds Ratio at 1 Gy vs. Age at Exposure



(Neriishi, Nakashima et al, 2008, Unpublished)



# Radiation and Cataract: Unresolved Issues

- What is an appropriate estimate of the dose threshold for induction of vision-impairing cataracts? How does this impact regulations?
- What is the dose threshold and degree of risk for cataracts following highly fractionated or protracted exposure?
- Effect of age at exposure on radiogenic cataract risk
- What biological mechanisms mediate the development of radiation cataracts?

*Thank You.*

*Any Questions?*