National Cancer Institute

Radiation Workers

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Why Study Radiation Workers?

- Risk estimates for health effects primarily based on atomic bomb survivors
- For workers and the general public, most exposures are to low doses and low dose rates
- Uncertainty in extrapolating from high doses and high dose rate to low dose and low dose rate radiation exposures

Medical Radiation Worker Studies

Medical Radiation Workers: Populations

Population	Number of workers
UK radiologists	2,700
U.S. radiologists	6,500
U.S. Army technologists	6,600
U.S. radiologic technologists	146,000
Chinese x-ray workers	27,000
Japanese technologists	12,200
Danish radiotherapy workers	4,200
Canadian radiation workers	67,500

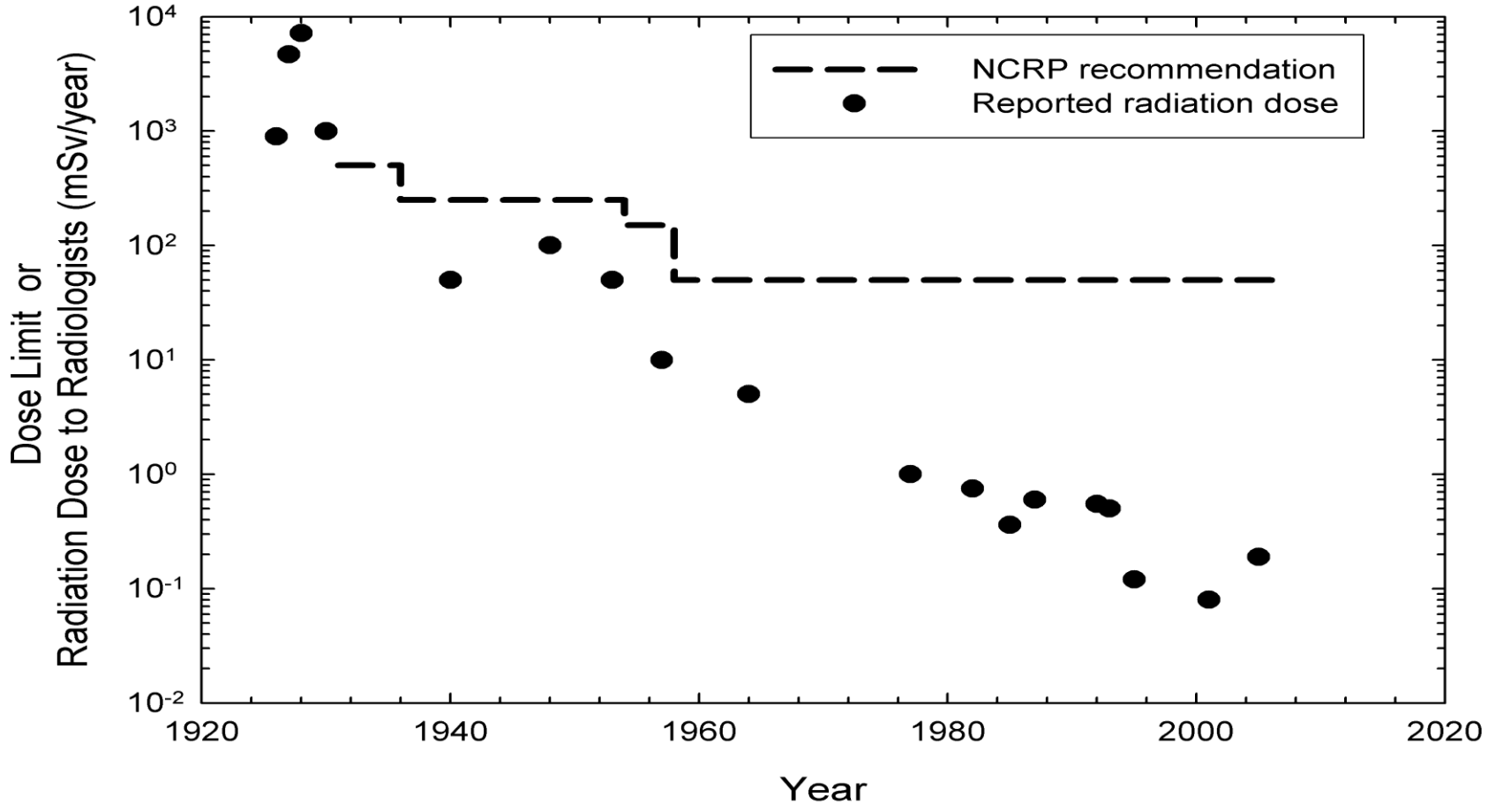
Linet et al. Radiat Res 2010

Medical Radiation Workers: Findings

- Increased leukemia risks in medical radiation workers who first worked before/during 1920s in UK and US, or before 1970 in China
- Elevated mortality from skin cancer in early UK and US radiologists
- Later Danish and Chinese medical radiation workers had elevated incident skin cancer risks
- Other solid cancer findings less consistent
- **None of the results before 2002 based on dose data**

Yoshinaga et al. Radiology 2004
Linet et al. Radiat Res 2010

Trends in Literature-Reported Average Annual Occupational Effective Doses to Radiologists



Source: Reports summarized in Table 5 in Linet et al. Radiat Res 2010

Medical Radiation Worker Studies with Doses

Population Features	Canadian	Chinese	U.S. Radiologic Technologists
Size	67,500	27,000	146,000
Percent female	65%	20%	73%
!st worked	1951-87	1950-80	1926-80
Cum average estimated dose , exposure period	3.78 mSv, 1951-87	356 mGy, <1949-94	76 mSv, 1916-87
Organ doses available	No	No	Yes
Confounders	No	No	Yes

Zielinski et al. Int J Med Environ Health 2009; Zhang et al. Radiat Prot Dosim 1998; Simon et al. Radiat Res 2014

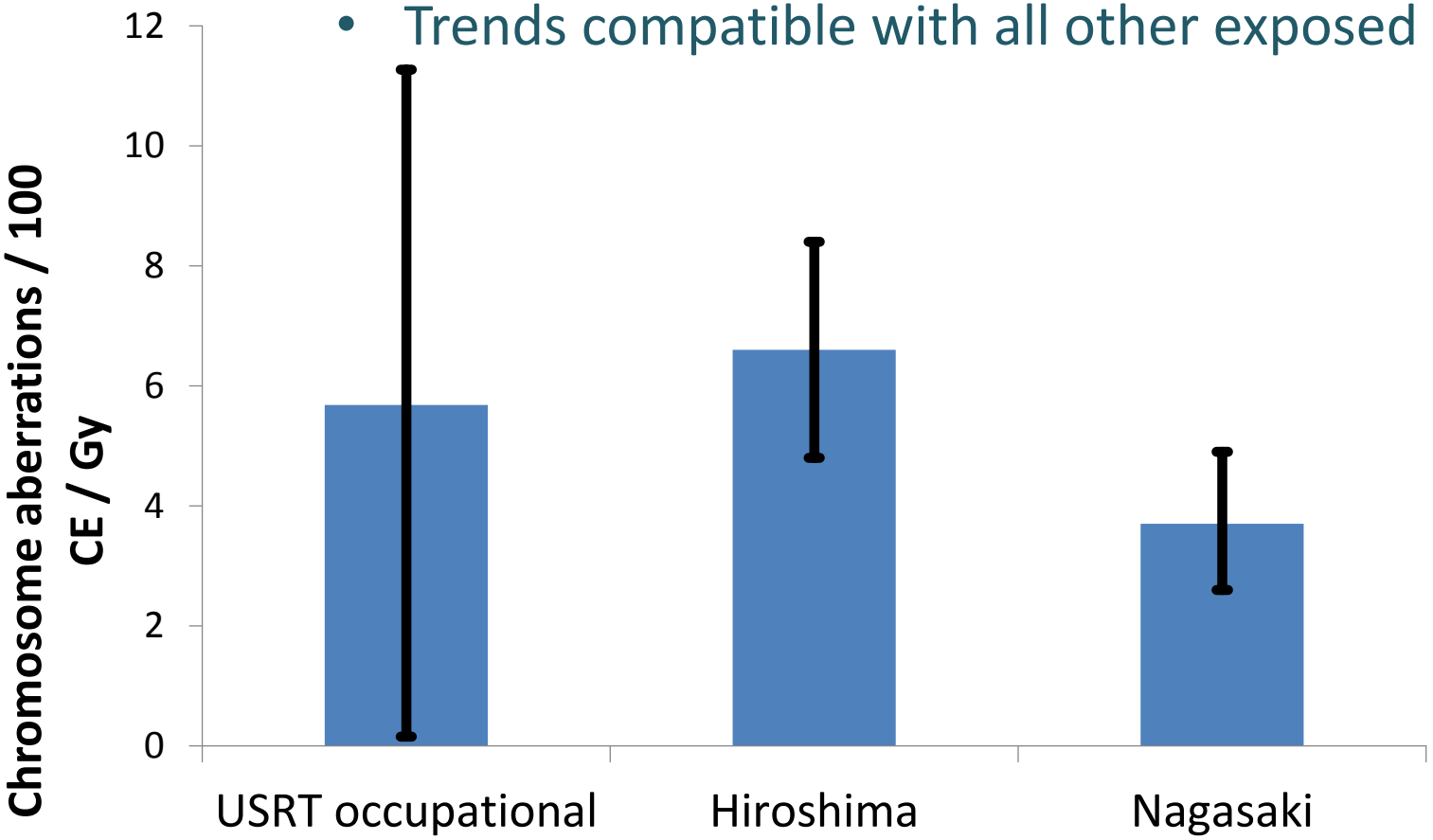
USRT Dose Reconstruction: 2014 Update

- 90,305 → 110,374 technologists with doses
- 350,000 → 921,134 badge doses
- Incorporated individual work history: 1 survey → 3 surveys
- Period-specific apron usage: literature and 3rd survey
- Doses to 12 organs using time period-specific conversion coefficients

Simon SL et al. Radiat Res 2006; Simon SL et al. Radiat Res 2014

Chromosome aberration dose trend (95% CI) in USRT Versus A-bomb

- Aberration trends similar to Japanese A-bomb
- Trends compatible with all other exposed groups



Little et al. Radiat Res 2014

Risk Assessment in USRT

- 30-year cohort follow-up
  - Ongoing exposure-response 2015-16
    - Breast cancer incidence & mortality
    - Basal cell carcinoma of the skin incidence
    - Circulatory diseases mortality
  - Future exposure-response 2016-17
    - Hematopoietic malignancies
    - Other specific solid tumors
    - Cataracts

Occupational Exposures – FGIP/NM* in USRT

- Importance
  - Rapidly growing use internationally of
    - Fluoroscopically-guided interventional procedures
    - Radionuclides in nuclear medicine procedures
  - Limited or no previous epidemiologic investigations

*FGIP — fluoroscopically-guided interventional procedures
NM — nuclear medicine procedures

Risk Assessment for FGIP/NM in USRT

- Ever vs never FGIP and NM: 2015

- Combine work history, badge dose readings, literature,* and focus group information to refine estimated doses of technologists performing fluoroscopically-guided (FGIP) and nuclear medicine (NM) procedures: 2015-2016

- Exposure-response risk assessment: 2016-17

*Kim KP et al. Health Phys 2008; Kim KP et al. Health Phys 2012; Drozdovitch V et al. Health Phys 2014 and in preparation

Nuclear Workers Studies

Large Nuclear Worker Studies

- Many individual studies, most involving low doses, low dose rates, & limited power

- National Registry of Radiation Workers (UK), 3rd follow-up, 2009

- Combined populations
  - IARC* 3-country study, 1995
  - IARC 15-country study, 2005, 2007

* International Agency for Research on Cancer

Large Nuclear Workers Studies: Features

Characteristics of Population	IARC 3-Country	IARC 15-Country	NRRW
Size	96,000	407,391	174,541
Percent female	14.6%	10%	<10%
Countries	US/UK/ Canada	US/UK/Japan Canada, etc.	UK
Cum average recorded dose	40 mSv	19 mSv	25 mSv
No. deaths	15,825	24,158	26,731
No. cancers	3,976	6,715	8,107

Cardis et al. Radiat Res 2005; Cardis et al. BMJ 2005, Cardis et al. Radiat Res 2007; Muirhead et al. Br J Cancer 2009

IARC* 15-Country Study: Dosimetry

- Objective: convert recorded doses to organ doses
- Approach
  - Dosimetry subcommittee
  - Questionnaires on dosimetry practices & radiation environments
  - Special studies of representative facilities
  - Testing of representative dosimeters

* International Agency for Research on Cancer

Large Nuclear Workers Studies: Cancer Mortality

Study	All cancer excluding leukemia (linear) ERR/Gy (90% CI)	Leukemia excluding CLL (linear-quadratic) ERR/Gy (90% CI)
3-country	– 0.07 (–0.39, 0.30)	2.18 (0.13, 5.7)
15-country excl Canada	0.97 (0.27, 1.8) 0.58 (–0.2, 1.6)	1.9 (<0, 7.1)
NRRW	0.28 (0.02, 0.6)	1.7 (0.1, 4.3)
Atomic bomb survivors	0.26 (0.14, 0.41)	1.4 (0.1, 3.4)

Cardis et al. Radiat Res 2005; Cardis et al. BMJ 2005, Cardis et al. Radiat Res 2007; Muirhead et al. Br J Cancer 2009

IARC* 15-Country Study: Mortality for Solid Cancers Related Versus Not Related to Smoking

Smoking-Related Vs. Not Related	ERR/Gy (90% CI)
All Solid Cancers	0.87 (0.02, 1.9)
Smoking-Related Lung cancer Other smoking-related	0.91 (–0.1, 2.2) 1.85 (0.26, 4.0) 0.21 (<0, 2.0)
Unrelated	0.62 (–0.5, 2.2)

Cardis et al. BMJ 2005

Large Nuclear Worker Studies: Non-Cancer Mortality

- IARC* 15-country study
  - Little evidence of dose-response relationship
  - Suggested dose-response for attained age <50
- NRRW
  - Dose-response for circulatory disease mortality
  - Possible confounding by smoking

* International Agency for Research on Cancer

Radiation Worker Studies: Assessment

- Strengths:
  - Provide risk estimates of cancer and other health effects associated with low dose, low dose rate radiation exposures
  - Exposure-response based on annual dose estimates derived from monitoring data (and other sources for some studies)

Radiation Worker Studies: Assessment

- Weaknesses:
  - Subject to limitations of low dose epidemiologic studies
  - Lack of badge measurement data in early periods for medical radiation workers
  - Uncertainties, errors, & missing measurements
  - Potential biases due to confounding, questionnaire-derived recall
  - Lack of data on confounding factors