RIC 2023 – Navigating the Nuclear Future
Million Person Study - Human Health Radiation Risk Assessment in the Nuclear Power & Industrial Radiographer Worker Cohorts --- March 15, 2023 (W14)

Overview of the Million Person Study and Relevance to NRC

John D Boice Jr

Vanderbilt University, Department of Medicine
National Council on Radiation Protection & Measurements (NCRP)

Vanderbilt-Ingram Cancer Center

John.Boice@ncrponline.org

Good Science = Informed Regulations = Protection of Workers

The study of low dose and low-dose rate exposure is of immeasurable value in understanding the possible range of health effects from prolonged exposures to radiation. The Million Person Study of low-dose health effects was designed to evaluate radiation risks among healthy American workers and veterans who are more representative of today's populations than are the Japanese atomic bomb survivors exposed briefly to high-dose radiation in 1945..

Overview of the Million Person Study and Relevance to NRC

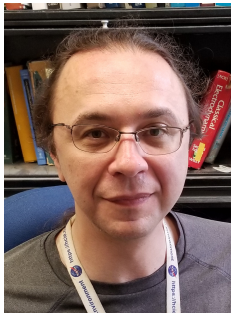
John Boice, Director of Science/Professor of Epidemiology, National Council on Radiation Protection and Measurements/Vanderbilt University Medical Center

Million Person Study—Human Health Radiation Risk Assessment in the Nuclear Power and Industrial Radiographer Cohorts

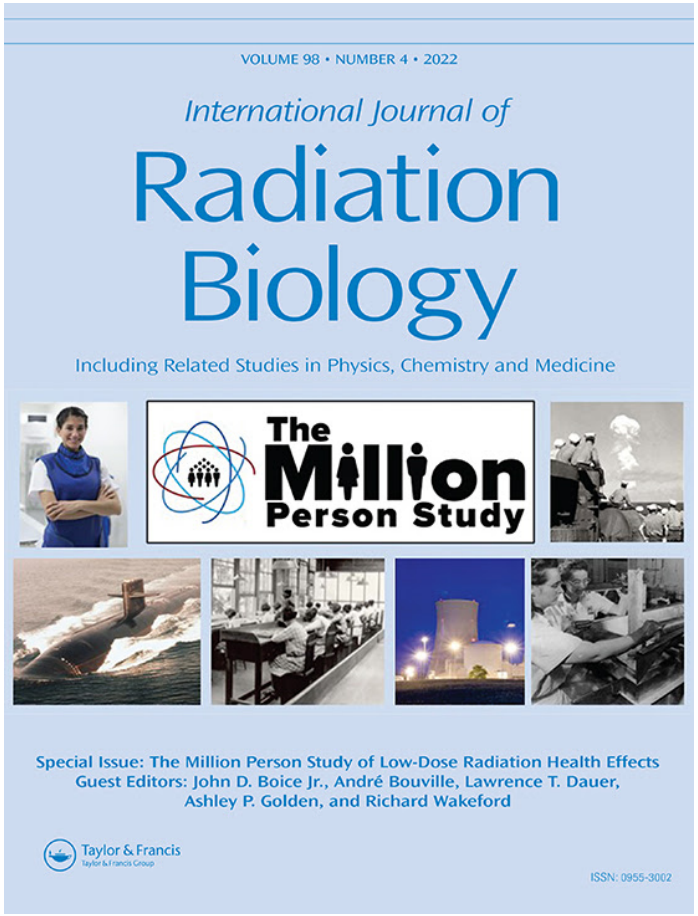
Lawrence Dauer, Attending Physicist, Memorial Sloan Kettering Cancer Center

The Importance of Radiation Epidemiology to Space Exploration

Steve Blattnig, Technical Advisor, National Aeronautics and Space Administration



April 2022 IJRB Special Issue – Million Person Study



24 Peer-Reviewed Articles

The Million Person Study, Whence it Came	Reviews
Relevance to Space Exploration	
A Million Persons, a Million Dreams and Vision for NCREB	
Obtaining Vital Status and Cause of Death	Methods
Statistical Modeling Approaches	
Dosimetry and Uncertainty Approaches	Dosimetry
Dosimetry for Atomic Veterans	
Dosimetry for Medical Radiation Workers	
Dose Reconstruction for Internal Emitters	
Mortality Among Nuclear Power Plant Workers	Original Articles
Mortality Among Medical Workers	
Mortality Among Mallinckrodt Workers	
Mortality Among Los Alamos National Laboratory Workers	
Mortality Among Tennessee Eastman Corporation Workers	
Sex-Specific Lung Cancer Risks among MPS Cohorts	
Radium Dial Painters	

Editors: Andre Bouville, John Boice, Larry Dauer, Ashley Golden, Richard Wakeford

RIC Mar 15, 2023

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2022, VOL. 98, NO. 4, 657–678
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ORIGINAL ARTICLE

Check for updates

Mortality from leukemia, cancer and heart disease among U.S. nuclear power plant workers, 1957–2011

Boice et al. Mortality among Nuclear Power Plant Workers
IJRB 2022; 98(4):657-678)

Vanderbilt Epidemiology Center and Vanderbilt-Ingram Cancer Center, Vanderbilt University, Nashville, TN, USA; [c]EpidStrategies, Cary, NC, USA; [d]International Epidemiology Institute, Rockville, MD, USA; [e]Vanderbilt University Medical Center, Nashville, TN, USA; [f]Oak Ridge Associated Universities, Oak Ridge, TN, USA; [g]Landauer Inc (Retired), Glenwood, IL, USA; [h]Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, NY, USA

ABSTRACT

Background: The aim of the Million Person Study of Low-Dose Health Effects (MPS) is to examine the level of radiation risk for chronic exposures received gradually over time and not acutely as was the case for the Japanese atomic bomb survivors. Nuclear power plant (NPP) workers comprise nearly 15 percent of the MPS. Leukemia, selected cancers, Parkinson's disease, ischemic heart disease (IHD) and other causes of death are evaluated.

Methods and material: The U.S. Nuclear Regulatory Commission's Radiation Exposure Information and Reporting System (REIRS) and the Landauer, Inc. dosimetry databases identified 135,193 NPP workers first monitored 1957–1984. Annual personal dose equivalents [*Hp(10)*] were available for each worker. Radiation records from all places of employment were sought. Vital status was determined through 2011. Mean absorbed doses to red bone marrow (RBM), esophagus, lung, colon, brain and heart were estimated by adjusting the recorded *Hp(10)* for each worker by scaling factors, accounting for exposure geometry and energy of the incident gamma radiation. Standardized mortality ratios (SMR) were calculated. Radiation risks were estimated using Cox proportional hazards models.

Results: Nearly 50% of workers were employed for more than 20 years. The mean duration of follow-up was 30.2 y. Overall, 29,124 total deaths occurred, 296 from leukemia other than chronic lymphocytic leukemia (CLL), 3382 from lung cancer, 140 from Parkinson's disease and 5410 from IHD. The mean dose to RBM was 37.9 mGy (maximum 1.0 Gy; percent >100 mGy was 9.2%), 43.2 mGy to lung, 43.7 mGy to colon, 33.2 mGy to brain, and 43.9 mGy to heart. The SMRs (95% CI) were 1.06 (0.94; 1.19) for leukemia other than CLL, 1.10 (1.07; 1.14) for lung cancer, 0.90 (0.76; 1.06) for Parkinson's disease, and 0.80 (0.78; 0.82) for IHD. The excess relative risk (ERR) per 100 mGy for leukemia other than CLL was 0.15 (90% CI −0.001; 0.31). For all solid cancers the ERR per 100 mGy (95% CI) was 0.01 (–0.03; 0.05), for lung cancer −0.04 (–0.11; 0.02), for Parkinson's disease 0.24 (–0.02; 0.50), and for IHD −0.01 (–0.06; 0.04).

Conclusion: Prolonged exposure to radiation increased the risk of leukemia other than CLL among NPP workers. There was little evidence for a radiation association for all solid cancers, lung cancer or ischemic heart disease. Increased precision will be forthcoming as the different cohorts within the MPS are combined, such as industrial radiographers and medical radiation workers who were assembled and evaluated in like manner.

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KEYWORDS
Epidemiology; Million Person (Worker) Study; nuclear power plant workers; leukemia and cancer; heart disease

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https://doi.org/10.1080/09553002.2021.1988183

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REVIEW

Check for updates

A million persons, a million dreams: a vision for a national center of radiation epidemiology and biology

Boice et al. A Million Persons, A Million Dreams
IJRB 2022;98(4):795-821

[a]National Council on Radiation Protection and Measurements, Bethesda, MD, USA; [b]Vanderbilt University School of Medicine, Nashville, TN, USA; [c]Memorial Sloan Kettering Cancer Center, New York, NY, USA; [d]United States Department of Energy, Gaithersburg, MD, USA; [e]Centers for Disease Control and Prevention, Atlanta, GA, USA; [f]Defense Threat Reduction Agency, VA, USA; [g]National Aeronautics and Space Administration Langley Research Center, Hampton, VA, USA; [h]Radian Scientific, LLC, Huntsville, AL, and Risk Assessment Corporation, Neeses, SC, USA; [i]EpidStrategies, a division of ToxStrategies, Inc, Cary, NC, USA; [j]Oak Ridge Associated Universities, Oak Ridge, TN, USA; [k]Massachusetts General Hospital/Harvard Medical School, Boston, MA, USA; [l]Francis Marion University, Florence, SC, USA; [m]Oak Ridge National Laboratory, Oak Ridge, TN, USA; [n]International Epidemiology Institute, Rockville, MD, USA; [o]Risk Assessment Corporation, Neeses, SC, USA; [p]Washington State University, Richland, WA, USA; [q]Landauer, Inc. (retired), Glenwood, IL, USA

ABSTRACT

Background: Epidemiologic studies of radiation-exposed populations form the basis for human safety standards. They also help shape public health policy and evidence-based health practices by identifying and quantifying health risks of exposure in defined populations. For more than a century, epidemiologists have studied the consequences of radiation exposures, yet the health effects of low levels delivered at a low-dose rate remain equivocal.

Materials and Methods: The Million Person Study (MPS) of U.S. Radiation Workers and Veterans was designed to examine health effects following chronic exposures in contrast with brief exposures as experienced by the Japanese atomic bomb survivors. Radiation associations for rare cancers, intakes of radionuclides, and differences between men and women are being evaluated, as well as noncancers such as cardiovascular disease and conditions such as dementia and cognitive function. The first international symposium, held November 6, 2020, provided a broad overview of the MPS. Representatives from four U.S. government agencies addressed the importance of this research for their respective missions: U.S. Department of Energy (DOE), the Centers for Disease Control and Prevention (CDC), the U.S. Department of Defense (DOD), and the National Aeronautics and Space Administration (NASA). The major components of the MPS were discussed and recent findings summarized. The importance of radiation dosimetry, an essential feature of each MPS investigation, was emphasized.

Results: The seven components of the MPS are DOE workers, nuclear weapons test participants, nuclear power plant workers, industrial radiographers, medical radiation workers, nuclear submariners, other U.S. Navy personnel, and radium dial painters. The MPS cohorts include tens of thousands of workers with elevated intakes of alpha particle emitters for which organ-specific doses are determined. Findings to date for chronic radiation exposure suggest that leukemia risk is lower than after acute exposure; lung cancer risk is much lower and there is little difference in risks between men and women; an increase in ischemic heart disease is yet to be seen; esophageal cancer is frequently elevated but not myelodysplastic syndrome; and Parkinson's disease may be associated with radiation exposure.

Conclusions: The MPS has provided provocative insights into the possible range of health effects following low-level chronic radiation exposure. When the 34 MPS cohorts are completed and combined, a powerful evaluation of radiation-effects will be possible. This final article in the MPS special issue summarizes the findings to date and the possibilities for the future. A National Center for Radiation Epidemiology and Biology is envisioned.

ARTICLE HISTORY
Received 5 August 2021
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KEYWORDS
Million person study; radiation epidemiology; cancer; radiation dosimetry; cognition impairment

Topics

- Background

- DOE Cohorts
- Military Cohorts
- Medical Cohort
- NRC Cohorts
- Recent Findings
- Summary

- Future

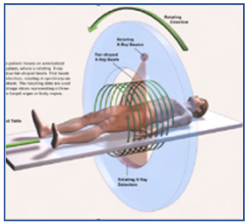
Why another study?

Much is Known about Radiation Health Effects When Exposure is Received All at Once (Briefly)

The Major Gap in Understanding is Health Effects from Exposures Received Gradually Over Time

Needed to accurately access risks related to:

Medicine

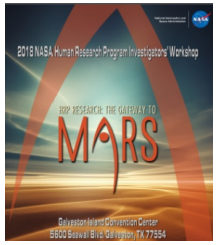


Accidents or Terrorism

Occupation

Environment

Space and High Altitude Travel



Protection Guidelines, Compensation, Risk Assessment/Projection, Representativeness, Specific Relevance, Responsibility to Workers and their Families

Why a Study of a Million Radiation Workers?
To provide the Statistical power (ability) to address:

- low dose effects
- rare cancers
- intakes of radionuclides (and associated high-LET health effects)
- differences between women and men
- other conditions (CVD, CeVD, Dementia, and even Cognition)

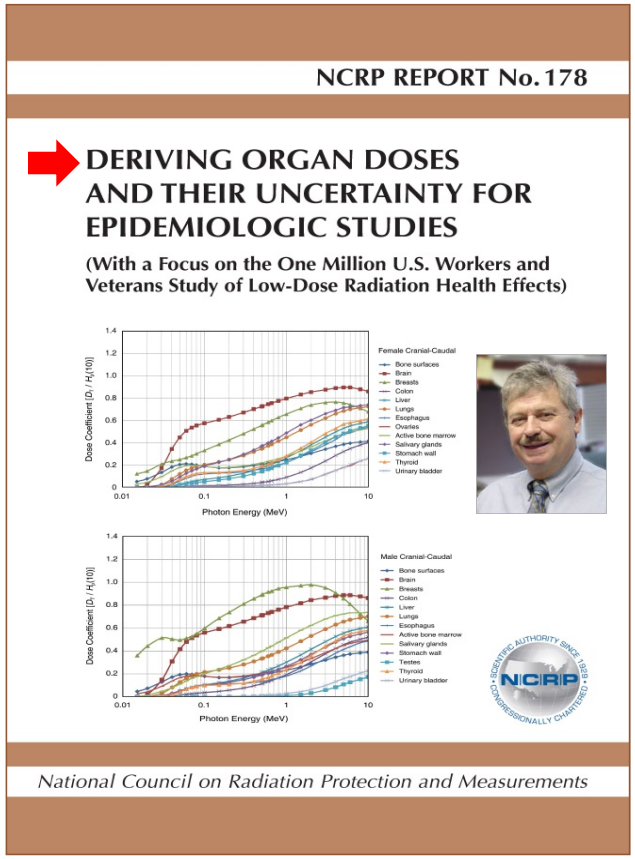
Who is Being Studied?

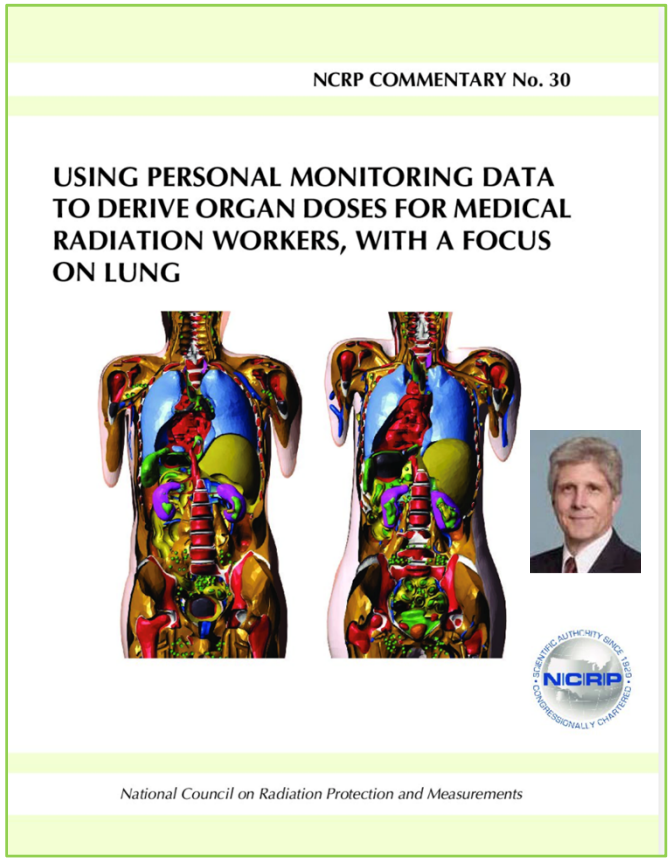
Robert Oppenheimer, General Leslie Groves, Enrico Fermi, Hans Bethe, Theodore Hall

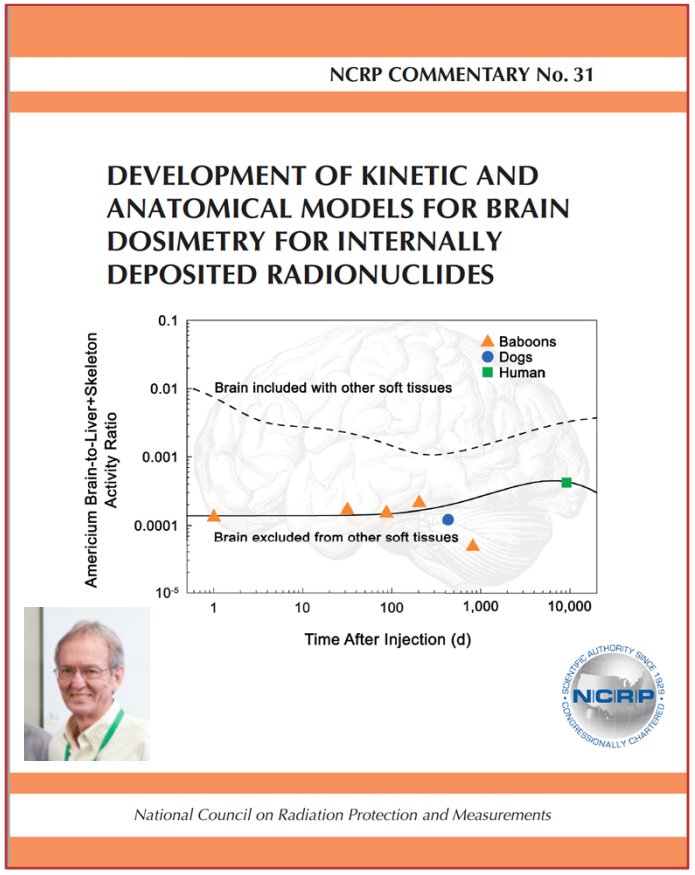
Cohort (Source)	No. Workers
Manhattan Project and other cohorts (DOE)	300,000
Atomic Veterans (DOD)	114,270
Nuclear Power Plant Workers (NRC)	135,193
Industrial Radiographers (NRC)	123,556
Medical Radiation Workers (Landauer)	109,019
Nuclear Submariners & Other (US Navy)	210,000
Radium Dial Workers (DOE)	3,200

Boice et al. *The Million Person Study, Whence it Came and Why*. IJRB April 2022

Dosimetry is the Key to Good Epidemiology



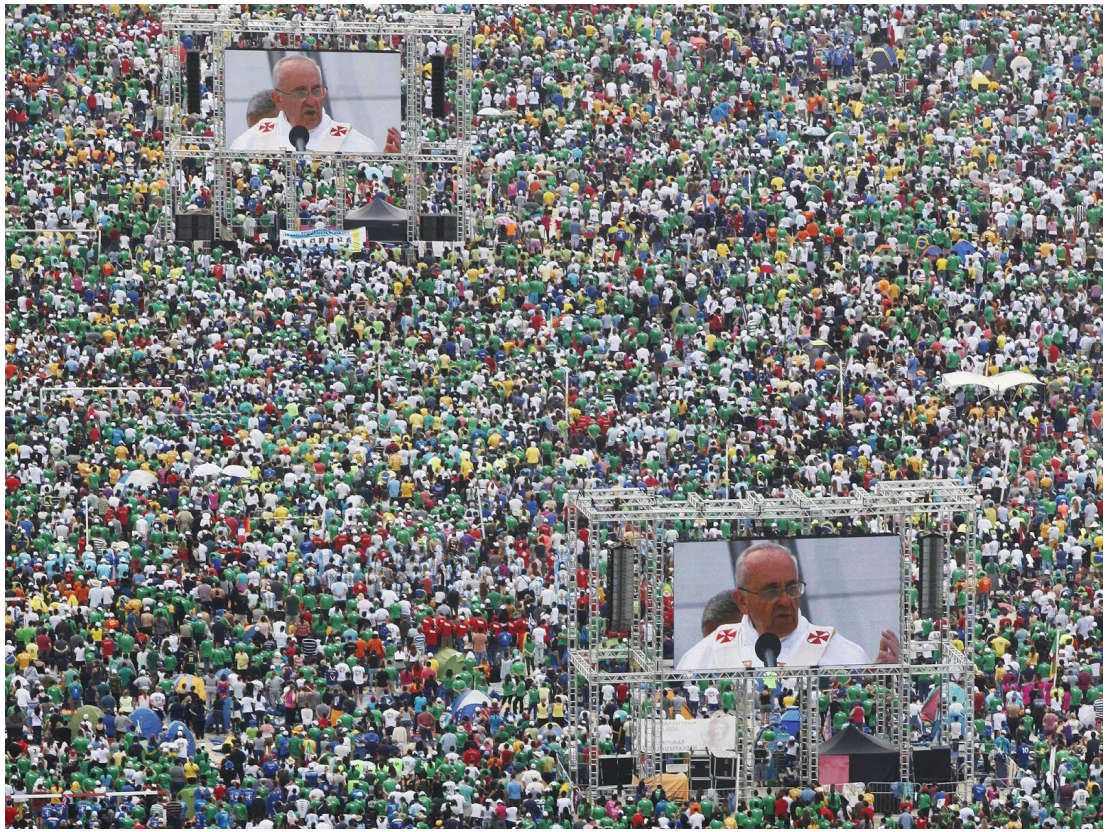




Roadmap for All (Report 178)-2019 Medical Workers (Commentary 30) Internal Emitters – Brain (Commentary 31)-2022

TRACING is Another Key to Good Epidemiology

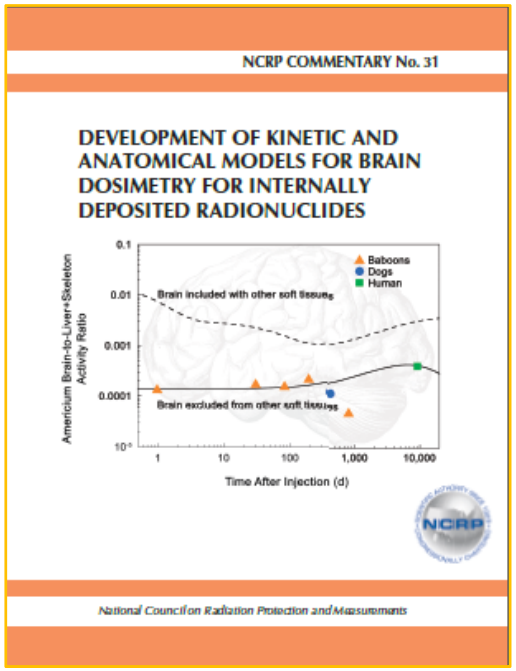
The Pope visits 1 Million People in Philadelphia 2015



Personal Identifiers – <u>30 cohorts</u> - to Trace for Vital Status (Some last known alive 1940s) ; Obtain Cause of Death; Obtain All occupational exposures; Estimate organ doses; Analyze and combine

Topics

- Background
- DOE Cohorts
- Military Cohorts
- Medical Cohort
- NRC Cohorts
- Recent Findings
- Summary
- Future



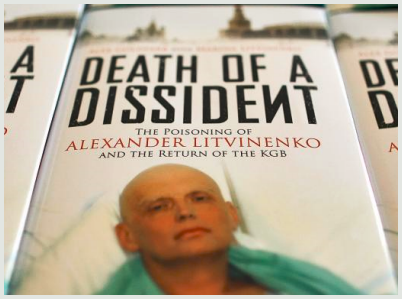
A unique feature of the Million Person Study is incorporating organ-specific doses from intakes of radionuclides in the dose-response analyses.

Relevance: Environmental Risk Assessment

Leggett RW et al. Methods of improving brain dose estimates for internally deposited radionuclides. . *J Radiol Prot 42 (3), 2022*

Manhattan Project and other Workers
Radionuclide Intakes

- Los Alamos National Laboratory, NM (1942) — Pu, H-3
- Rocky Flats (1951), Savannah River (1950) — Pu, H-3
- Hanford, WA (1943) — Pu, Am, U, H-3
- Atomics International / Rocketdyne, CA (1948) — Po, Pu, Am
- Mound Laboratory, OH (1947) — Po, Pu, H-3
- Mallinckrodt, KS (1942), Middlesex, NJ (1943) — Ra, U
- Fernald, OH (1951) — Ra, U

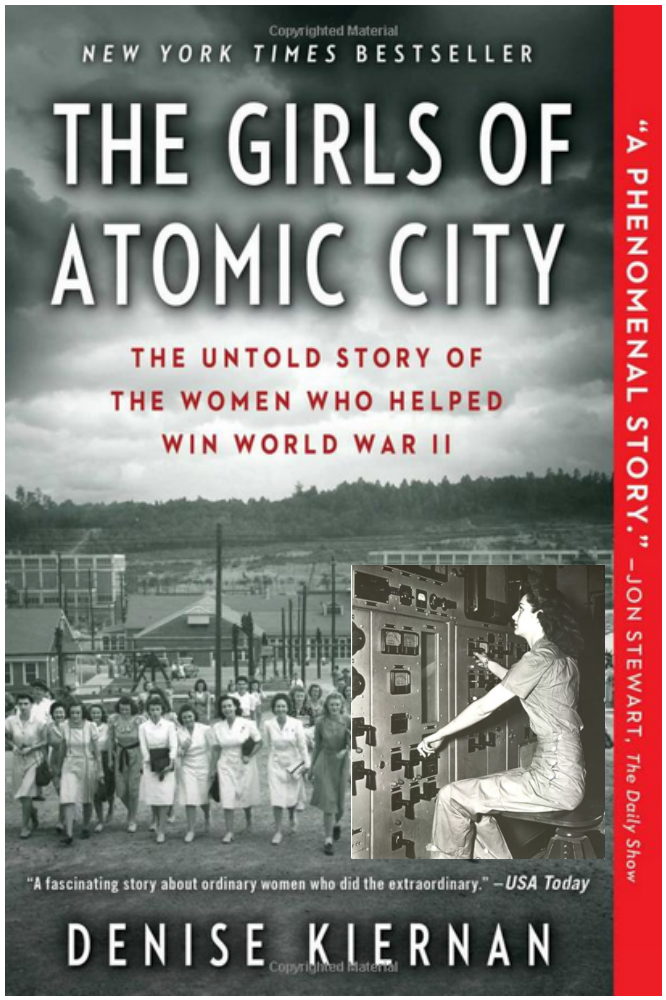


Women in the Million Person Study

☑ Nuclear Power	5,000
☑ Industrial Radiographers	13,000
☑ Mound	2,000
☑ Los Alamos	6,629
☑ Rocky Flats	5,000
☑ Hanford	8,000
K-25 (ORNL)	9,000
Other DOE	40,000
☑ TEC (Oak Ridge)	13,000
☑ Medical	60,000
☑ Radium Dial Painters	3,200

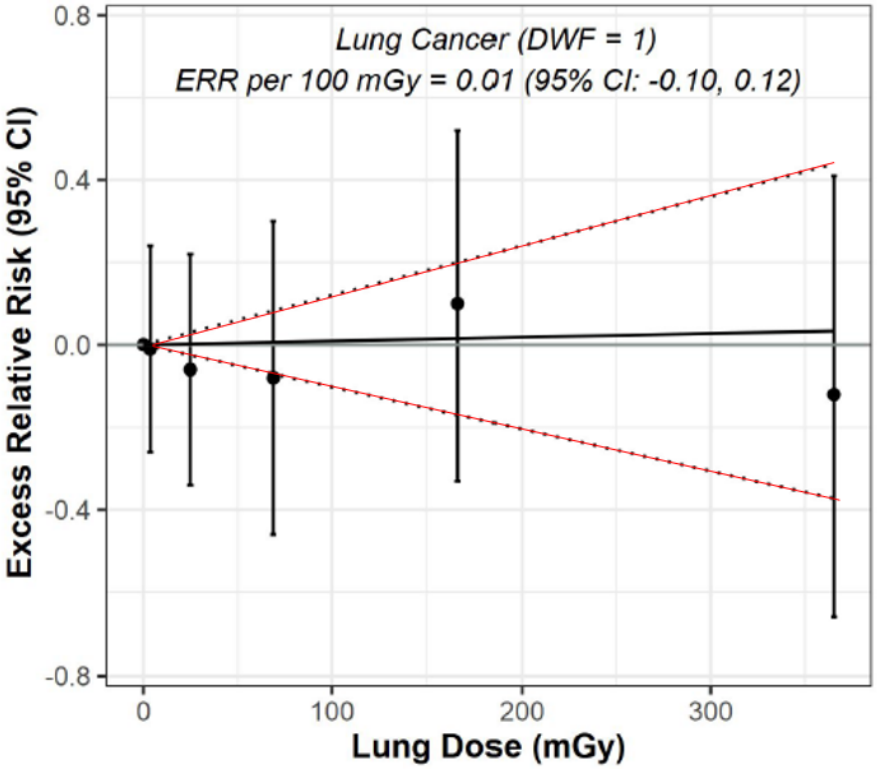
Total already… **>160,000**

Number of adult Japanese female atomic bomb survivors in 1945 ~30,000



Tennessee Eastman Corporation Women

13,951 Women employed 1943-1947 (Uranium dust)
652 cases of lung cancer



Boice *et al*. Mortality among TEC uranium processing workers. *IJRB* 2023

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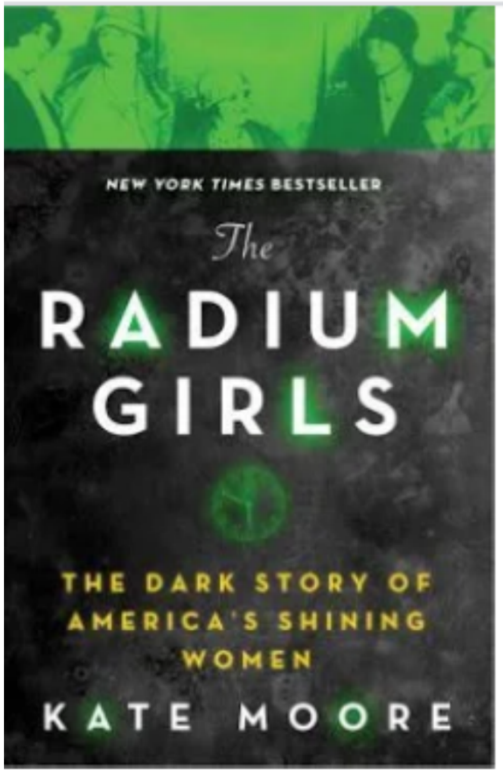
Radium Dial Painters – Reactivated !



Radium Girls (n=3,200)

- Reactivated (Martinez et al. IJRB 2022)
- Lifetime follow-up - 66% alive in 1980
- Improved dosimetry and risk assessment
- Bone cancer, leukemia, breast, nasal sinuses, lung, dementia, cognition
- Lifespan shortening
- Accelerated ageing, DNA methylation
- WARP – training for the future
- Back to the Future - The legacy continues

INTERNATIONAL JOURNAL OF RADIATION BIOLOGY
https://doi.org/10.1080/09553002.2021.1917785

REVIEW

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Check for updates

Radium dial workers: back to the future

Nicole E. Martinez[a,b], Derek W. Jokisch[b,c], Lawrence T. Dauer[d], Keith F. Eckerman[b], Ronald E. Goans[e], John D. Brockman[f], Sergey Y. Tolmachev[g], Maia Avtandilashvili[g], Michael T. Mumma[h,i], John D. Boice, Jr.[i,j], and Richard W. Leggett[b]

[a]Department of Environmental Engineering and Earth Sciences, Clemson University, Clemson, SC, USA; [b]Center for Radiation Protection Knowledge, Oak Ridge National Laboratory, Oak Ridge, TN, USA; [c]Department of Physics and Engineering, Francis Marion University, Florence, SC, USA; [d]Department of Medical Physics and Department of Radiology, Memorial Sloan Kettering Cancer Center, New York, NY, USA; [e]MJW Corporation, Inc., Buffalo, NY, USA; [f]Department of Chemistry, University of Missouri, Columbia, MO, USA; [g]United States Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, WA, USA; [h]International Epidemiology Institute, Rockville, MD, USA; [i]Department of Medicine, Division of Epidemiology, Vanderbilt Epidemiology Center and Vanderbilt-Ingram Cancer Center, Nashville, TN, USA; [j]National Council on Radiation Protection and Measurements, Bethesda, MD, USA

ABSTRACT

Purpose: This paper reviews the history of the radium dial workers in the United States, summarizes the scientific progress made since the last evaluation in the early 1990s, and discusses current progress in updating the epidemiologic cohort and applying new dosimetric models for radiation risk assessment.

Background: The discoveries of radiation and radioactivity led quickly to medical and commercial applications at the turn of the 20th century, including the development of radioluminescent paint, made by combining radium with phosphorescent material and adhesive. Workers involved with the painting of dials and instruments included painters, handlers, ancillary workers, and chemists

ARTICLE HISTORY
Received 14 January 2021
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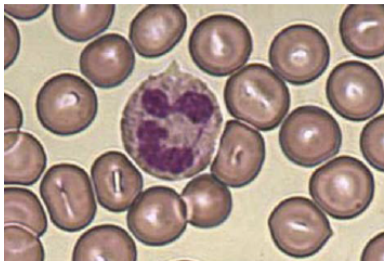
KEYWORDS
Radium; mesothorium; dial painter; Million Person Study



Relevance: Training Radiation Professionals for Future

Martinez et al. IJRB April 2022

Thanks to DOE for financial support

Topics

- Background
- DOE Cohorts
- Military Cohorts
- Medical Cohort
- NRC Cohorts
- Recent Findings
- Summary
- Future

Atomic Veterans, Health and Consequences

Atomic Veterans – Health Studies – 115,000 – From TRINITY 1945 to HARDTACK 1958

Desert Rock VI exercise (TEAPOT), NTS, 1955

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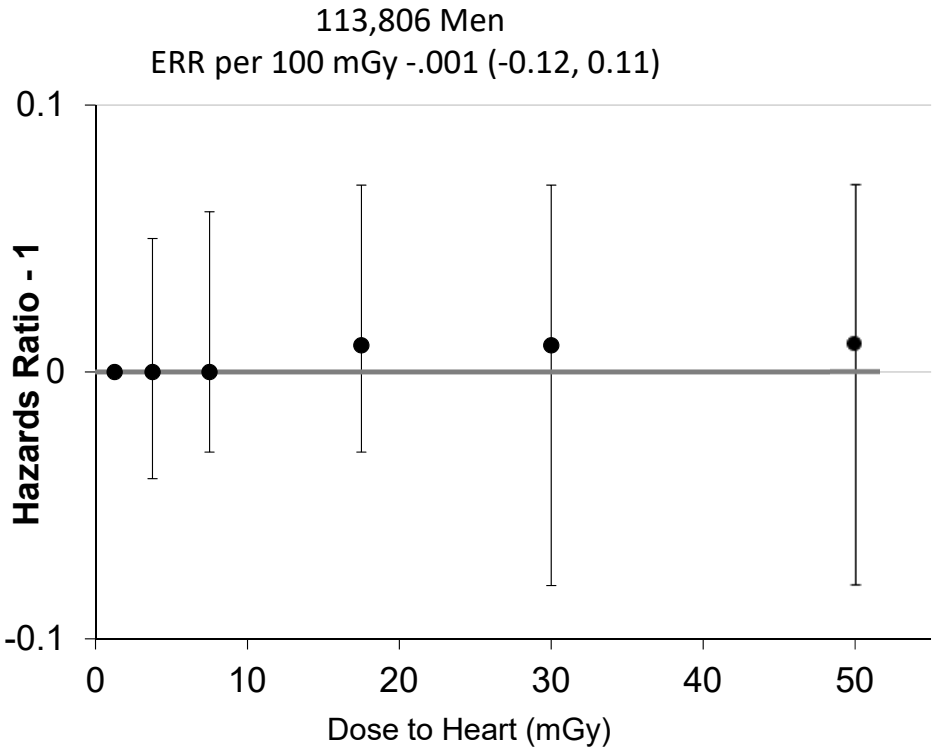
Ischemic Heart Disease (n=16,709) Among Atomic Veterans



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Boice et al. Nuclear Weapons Test Participants. Int J Radiat Biol 2022

Navy Personnel (~300,000) in the Million Person Study

• Nuclear weapons test participants	70,300
• Other Navy Personnel, e.g., shipyard	~60,000
• **Nuclear submariners**	**169,000**
Total	~300,000

SUBMARINER STUDY – NASA COLLABORATION

- To examine: **multiple occupational stressors**: Environmental (radiation, air contaminants); Psychological (confinement, isolation, hostile environnent): Physical (fatigue, high workload, circadian rhythm disruption, sleep deprivation) -- and any interaction with continuous radiation.
  - A *range of neurological, behavioral, and cognitive impairment disorders* will be evaluated, e.g., mortality and incidence for Parkinson's disease
  - Incidence data already have been obtained for *over 67,000 sailors* from Medicare records
  - *Cognitive function scores* are available for all submariners admitted to nursing homes
  - *Other outcomes* include heart disease, sleep disruption, cataracts and many others

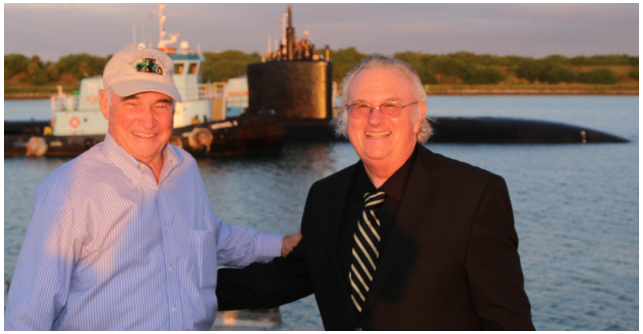
Relevance: Possible Cognition Impairment due to stress and low dose radiation

Slide thanks to Robin Elgart, NASA

Epidemiologists will go to any DEPTH in the Public Interest

USS Montpelier –
Attack Nuclear Sub

At 600 feet



Topics

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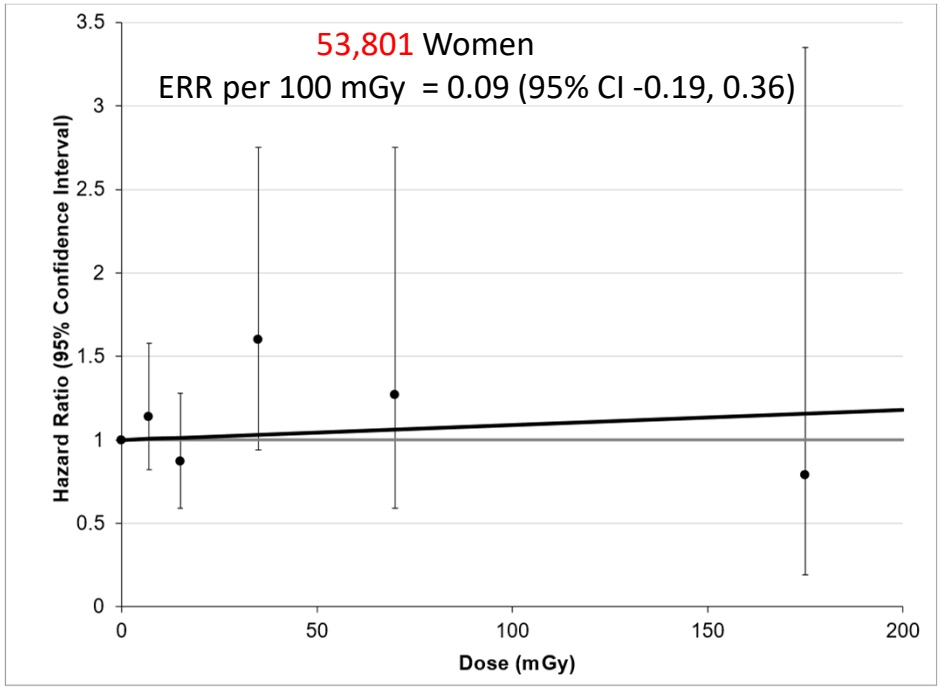
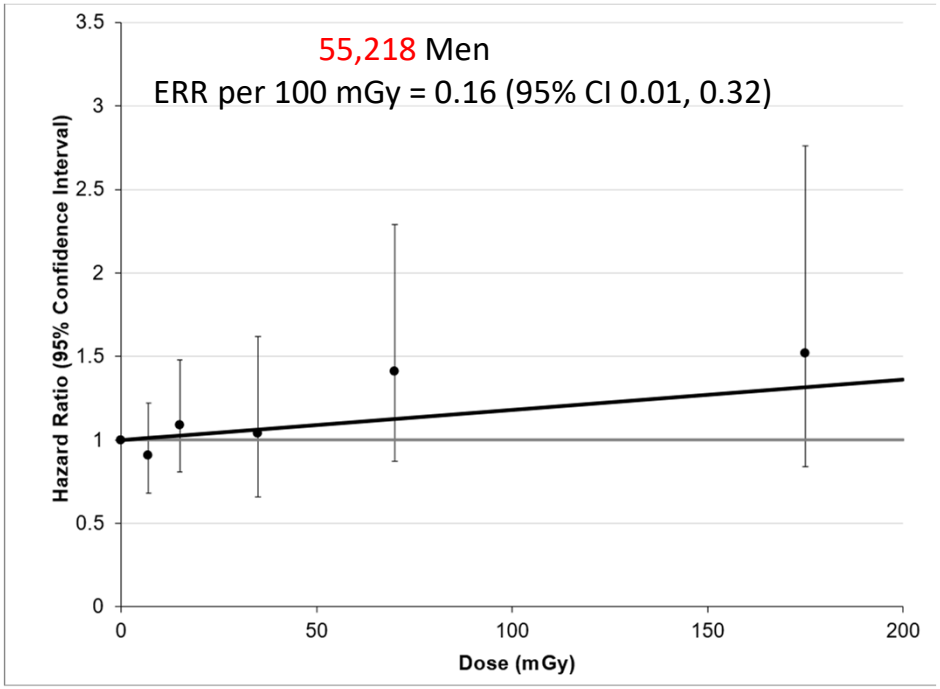
- Medical Cohort
- NRC Cohorts
- Novel Findings - neurobehavioral
- Summary Findings

- Future

Medical Radiation Workers

109,019 Medical Workers employed 1965-1994
General or Interventional Radiography, Nuclear Medicine, Radiation Oncology
370 cases of lung cancer in Women, 480 cases of lung cancer in men

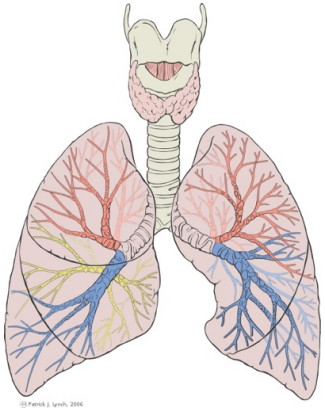




Boice *et al*. Sex-specific lung cancer risk. *IJRB* 2022
Yoder *et al*. Dosimetry medical radiation workers. *IJRB* 2022

Relevance: How important is sex-specific risk differences?

Harmonizing Lung Cancer Risks



Atomic Bomb Survivor Estimates

F: ERR per 100 mGy 0.11 (0.07, 0.16)

M: ERR per 100 mGy 0.04 (0.02, 0.07)

Cohort	No. Workers	ERR at 100 mGy (90% CI)
Nuclear Power Plant	135,193	-0.04 (-0.10, 0.01)
Industrial Radiographers	123,556	0.09 (0.04, 0.19)
Medical Radiation Workers	109,019	0.15 (0.02, 0.27)
NPP + IR + Medical	367,722	0.02 (-0.03, 0.07)
Atomic Veterans	113,806	0.08 (-0.06, 0.22)
Mound	4,954	0.01 (-0.02, 0.04)
Mallinckrodt	2,514	-0.06 (-0.18, 0.06)
Rocketdyne	5,801	0.06 (-0.50, 1.23)
Los Alamos	26,328	0.00 (-0.16; 0.17)
TEC (women)	13,951	0.01 (-0.12, 0.15)

To date, Little evidence for an effect for fractionation exposures and data appear inconsistent with estimates from atomic bomb survivor study

Topics

- Background

- DOE Cohorts
- Military Cohorts
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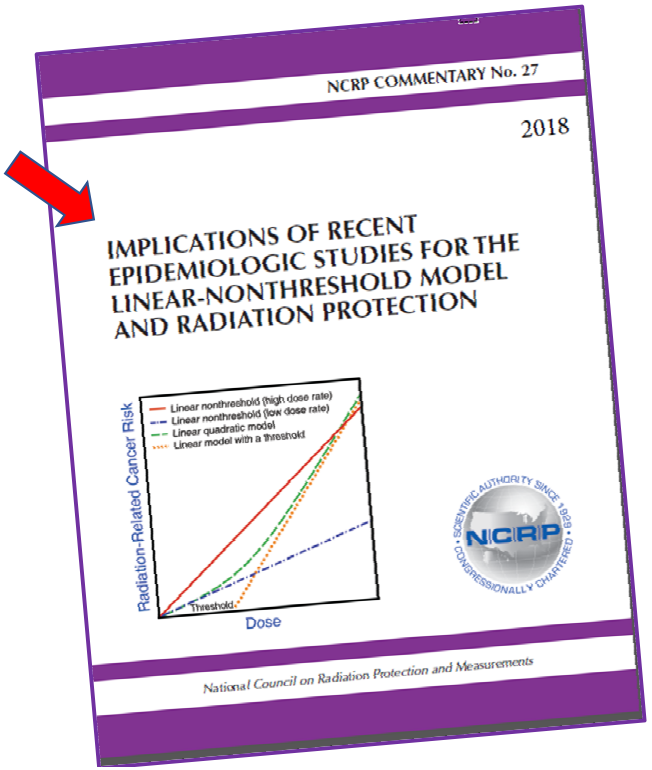
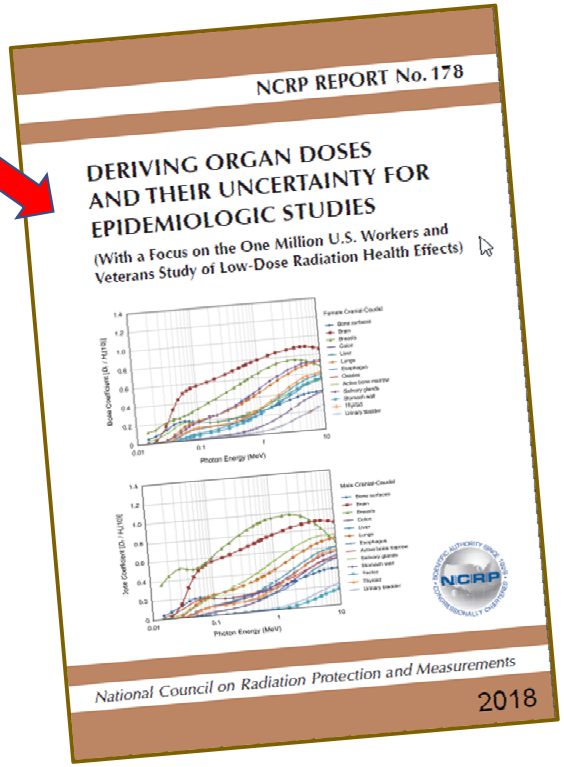
- NRC Cohorts
- Novel Findings - neurobehavioral
- Summary Findings

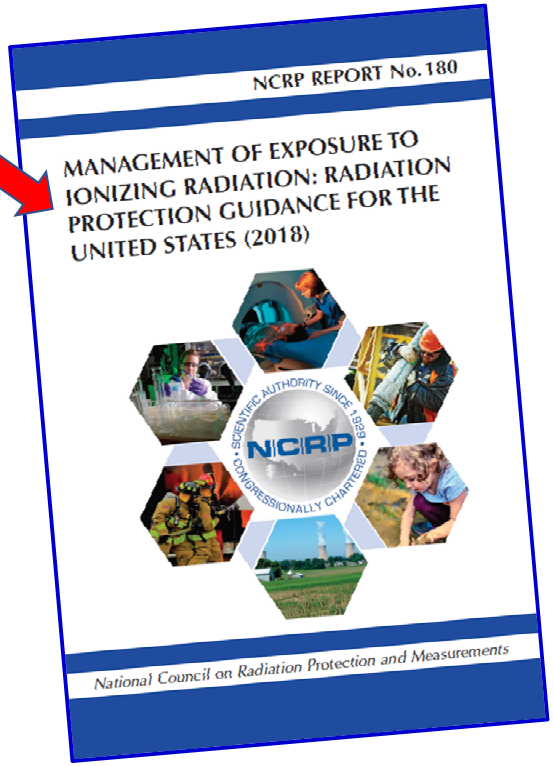
- Future

NCRP – NRC Commentary and Report Collaborations

In a study funded by the NRC, the NCRP reevaluated the LNT model based on new studies completed since the publication of NCRP Report No. 136 in June 2001. In April 2018, the NCRP released Commentary 27, "Implications of Recent Epidemiologic Studies for the Linear-Nonthreshold Model and Radiation Protection," which provides a detailed assessment of currently available epidemiological evidence and concludes that "the LNT model (with the steepness of the dose-response slope perhaps reduced by a DDREF [dose and dose rate effectiveness factor] factor) should continue to be utilized for radiation protection purposes." [40] The Commentary explains that "[w]hile







How are the NRC Cohorts Different from the Other MPS Cohorts?

- The Dosimetry is Exceptional
  - REIRS Personal Dose Equivalents
  - NCRP Report 178 to Convert to Organ Dose
- The Follow-up is Exceptional (>99%) for 258,749
  - Nuclear Power Plant Workers
  - Industrial Radiographers
- Career Doses obtained from DOE REMS, US Navy, Landauer, other

Mumma MT et al. Int J Radiat Biol 2022

1986 - Laying the Groundwork for a Registry of Radiation Workers

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

National Institutes of Health
National Cancer Institute
Bethesda, Maryland 20892

Vincent T. DeVita, Jr., M.D.

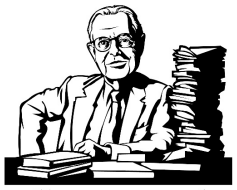
SEP 17 1986

Mr. Landow W. Zech, Jr.
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Zech:

The present risk estimates for low-dose exposure to ionizing radiation, as know, derive from unvalidated interpolations between zero and relatively high-dose, and high dose-rate, exposure. There are few exposure situations can be studied in the expectation that risk estimates directly applicable t low-dose region might be obtainable. One of these is employment in the nuc power industry, but there is at present no practical way of studying the experience of nuclear power plant workers in the U.S.

In revising 10 CFR 20 I hope you will not miss the opportunity to lay the groundwork for a Registry of Radiation Workers containing the annual doses received by individual workers. The need for such a Registry has been



1991 NRC - Radiation Exposure Information and Reporting System (REIRS) - Designed with health studies in mind

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

March 5, 1991

Chairman Kenneth M. Carr

Dr. Samuel Broder, Director
National Cancer Institute
Department of Health and Human Services
9000 Rockville Pike
Building 31, Room 11A48
Bethesda, Maryland 20892

Dear Dr. Broder:

I am writing to inform you of the Nuclear Regulatory Commission's (NRC's) decision to establish new reporting requirements for radiation exposure information and to request the views of the National Cancer Institute (NCI) on the relative merits of conducting additional radioepidemiological studies on radiation workers. As you know, the NCI in 1986 requested that the Commission consider incorporating provisions for a Registry of Radiation Workers into the final revision of 10 CFR Part 20. I am pleased to inform you that the Commission has approved the final revision of 10 CFR Part 20 and that the final rule contains reporting requirements that will allow the collection of information necessary to establish such a registry. A total of seven categories of licensees, including nuclear power reactors, fuel cycle facilities, radiographers, major byproduct materials facilities, high- and low-level waste repositories, and independent spent fuel storage facilities, will be required to provide dose records for each monitored employee for each year. The Commission will retain this information in its currently existing Radiation Exposure Information Reporting System (REIRS) for potential use in epidemiologic studies.

Slide, courtesy of Terry Brock, modified

Generic Letter 1994

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

September 2, 1994

NRC GENERIC LETTER 94-04: VOLUNTARY REPORTING OF ADDITIONAL OCCUPATIONAL RADIATION EXPOSURE DATA

Background

The provisions of § 20.2206 of 10 CFR Part 20 require seven categories of NRC licensees to submit occupational radiation exposure reports. The seven categories are as follows: commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators and reprocessors; manufacturers

regarding exposure histories for required individuals. Finally, REIRS is the largest database of radiation exposures at occupational levels. This makes it a very valuable epidemiological resource in determining the actual risk of exposure at occupational levels.

Federal Register on May 21, 1991 (56 FR 23386). The utility of this information is in conducting such studies and the intention of the National Cancer Institute to conduct these studies was discussed in an April 20, 1994 letter to Bill M. Morris, Director of the Division of Regulatory Applications, Office of Nuclear Regulatory Research from Dr. John Boice, Chief of the Radiation Epidemiology Branch, National Cancer Institute. In the letter,

Carl J. Paperiello, Director
Division of Industrial and Medical Nuclear Safety
Office of Nuclear Material Safety and Safeguards

Roy P. Zimmerman
Associate Director for Projects
Office of Nuclear Reactor Regulation

Technical contact: Charleen T. Raddatz, RES

https://www.nrc.gov/docs/ML1204/ML12047A243.pdf

Topics

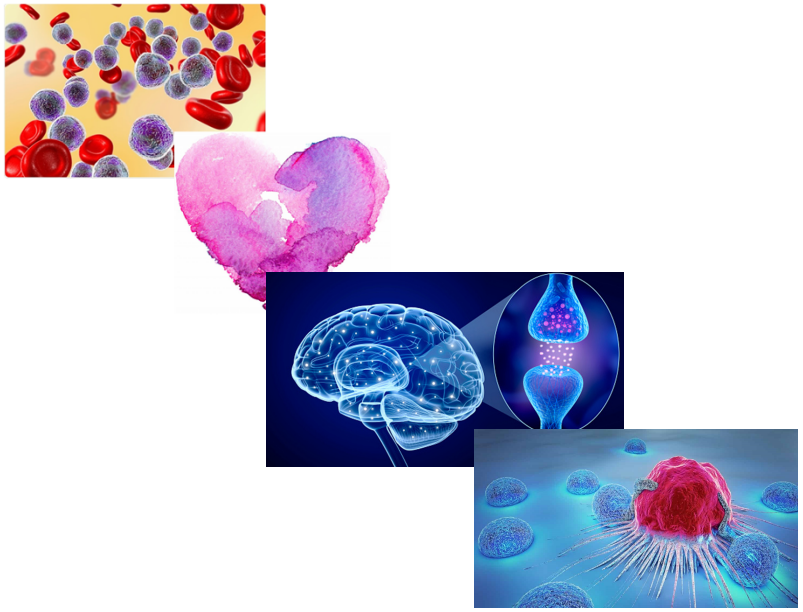
- Background

- DOE Cohorts
- Military Cohorts
- Medical Cohort
- NRC Cohorts
- Recent Findings
- Summary

- Future

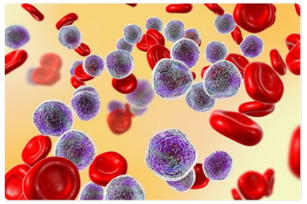
MPS – Selected Results

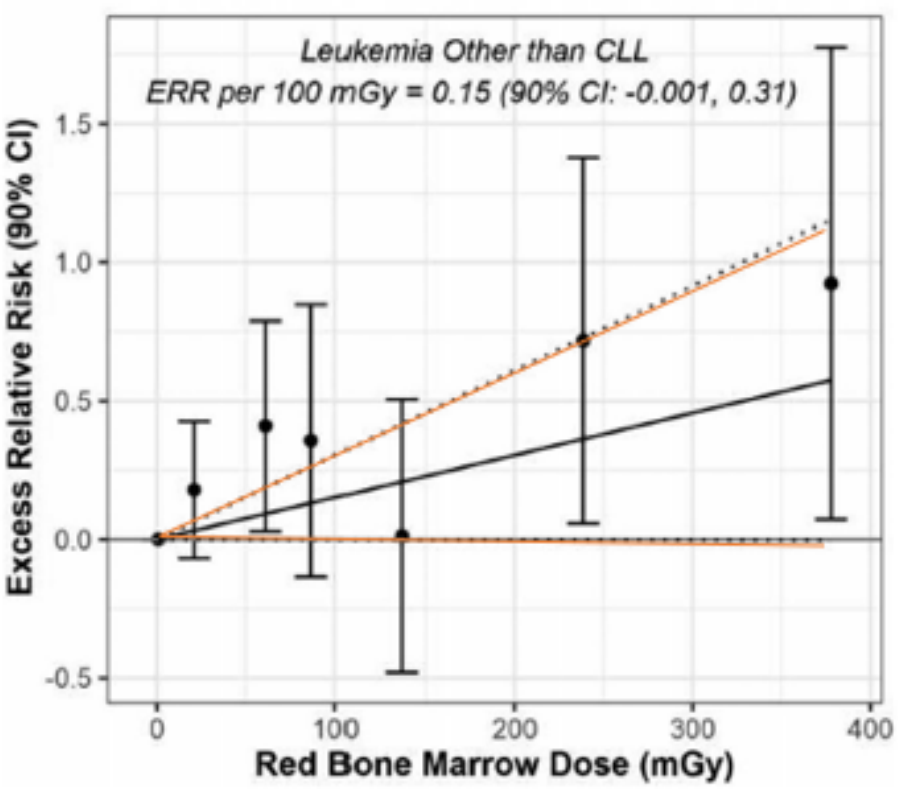
- Leukemia
- Ischemic Heart Disease
- Parkinson's Disease



Leukemia (non-CLL) – Dose Response

Nuclear Power Plant Workers





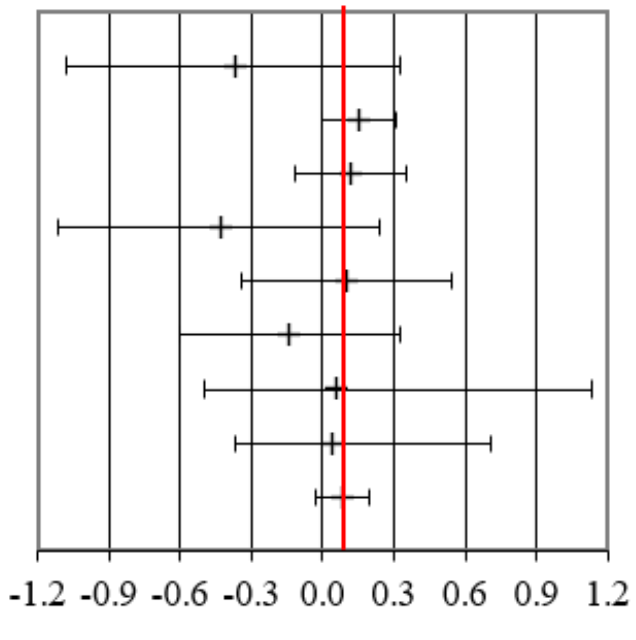
ERR = Excess Relative Risk; i.e., RR -1

Boice *et al*. Mortality among nuclear power plant workers. *IJRB* 2022

Leukemia Radiation Risks – Meta-analysis – 8 Studies

Cohort (n)	n	ERR at 100 mGy (95% CIs)
Atomic Vets (114,270)	710	-0.37 (-1.08, 0.33)
NPP (135,193)	303	0.15 (-0.001, 0.31)
Ind Rad (123,556)	167	0.12 (-0.12, 0.35)
LANL (26,328)	160	-0.43 (-1.11, 0.24)
Medical (109,019)	139	0.10 (-0.34, 0.54)
Mallinckrodt (2,514)	93	-0.14 (-0.60, 0.33)
Rocketdyne (5,801)	25	0.06 (-0.5, 1.13)
Mound (4,977)	21	0.04 (-0.37, 0.71)
*META ESTIMATE**	*1,618*	*0.087 (-0.03, 0.20)*

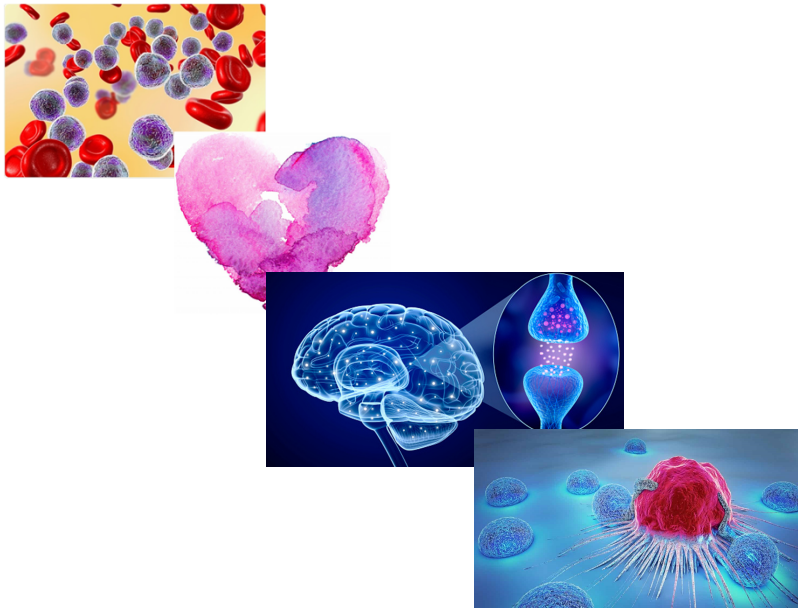
* Sum = 521,658



Boice *et al.* A Million Persons, A Million Dreams. *IJRB* 2022

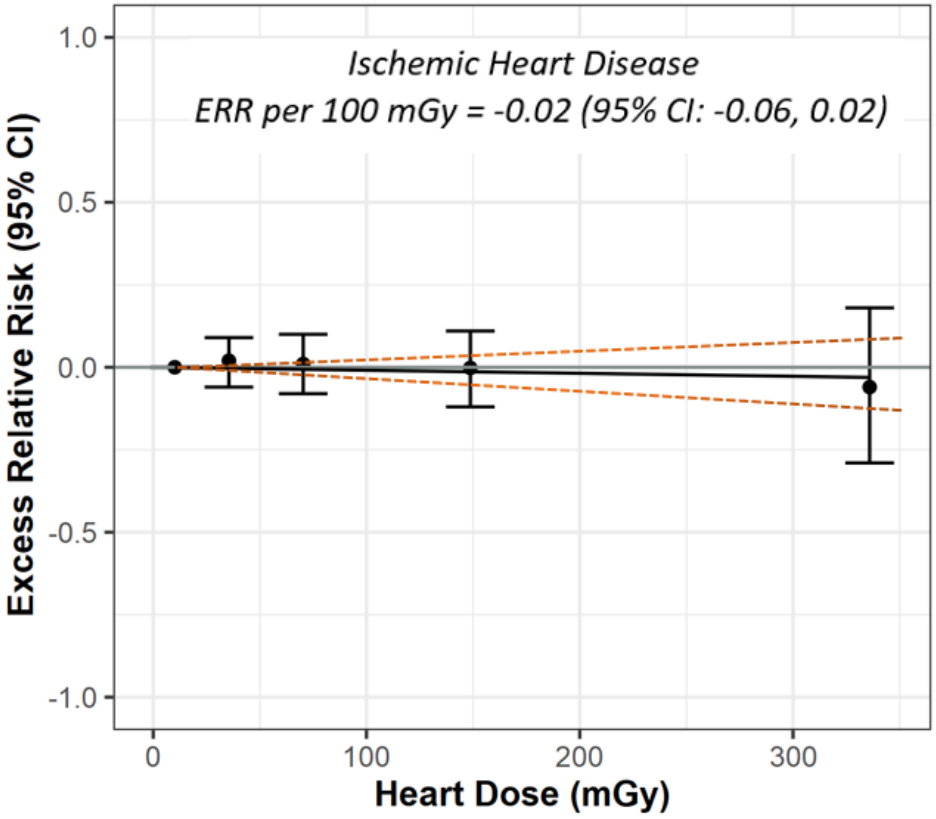
MPS – Selected Results

- Leukemia
- Ischemic Heart Disease
- Parkinson's Disease

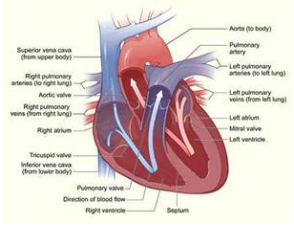


Ischemic Heart Disease (n=9,888)

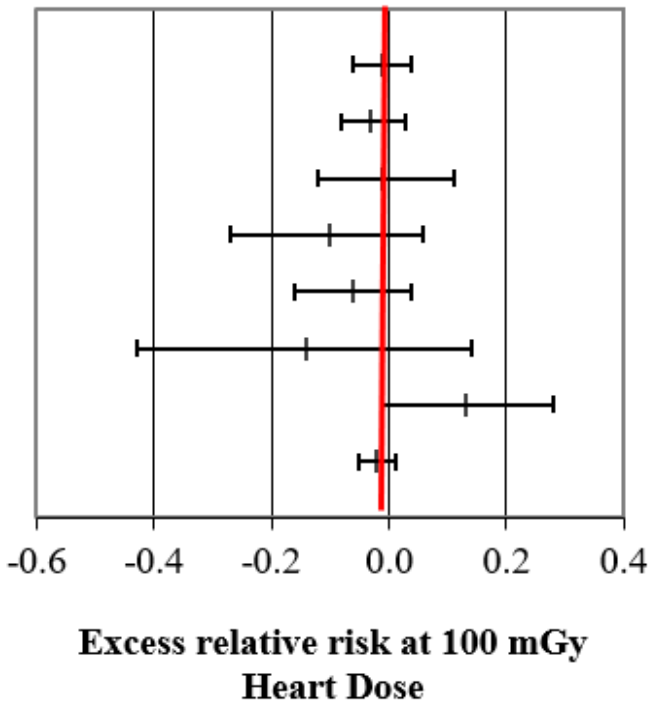
Nuclear Power Plant + Industrial Radiographers (n=258,703)



Ischemic Heart Disease Risk Estimates



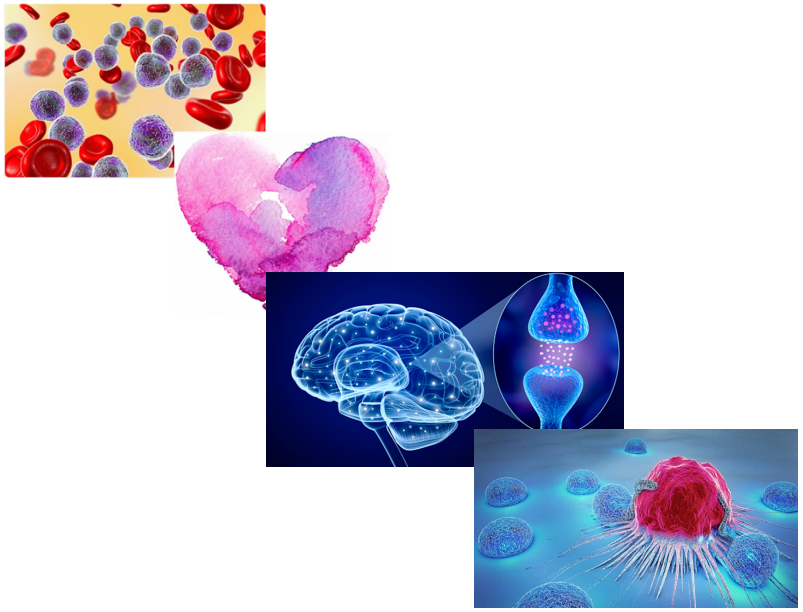
Cohort (n)	n	ERR at 100 mGy (95% CIs)
NPP (135,193)	5,410	-0.01 (-0.06; 0.04)
IR (123,556)	4,478	-0.03 (-0.08; 0.03)
Atomic Vets (114,270)	16,625	-0.01 (-0.12; 0.11)
Medical (109,019)	1,655	-0.10 (-0.27; 0.06)
LANL (26,328)	3,054	-0.06 (-0.16; 0.04)
Mound (4,977)	548	-0.14 (-0.43; 0.14)
Mallinckrodt (2,514)	521	0.13 (-0.01; 0.28)
*META ESTIMATE**	*32,291*	*-0.020 (-0.051; 0.012)*
Total n = 515,860		



Relevance: Based on MPS to date, heart disease should Not be included in a system of radiation protection

MPS – Selected Results

- Leukemia
- Ischemic Heart Disease
- Parkinson's Disease



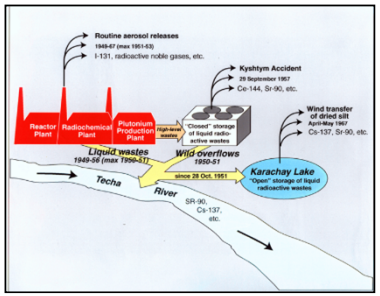
“It’s not going to do any good to land
on Mars if we’re stupid.” –
Ray Bradbury

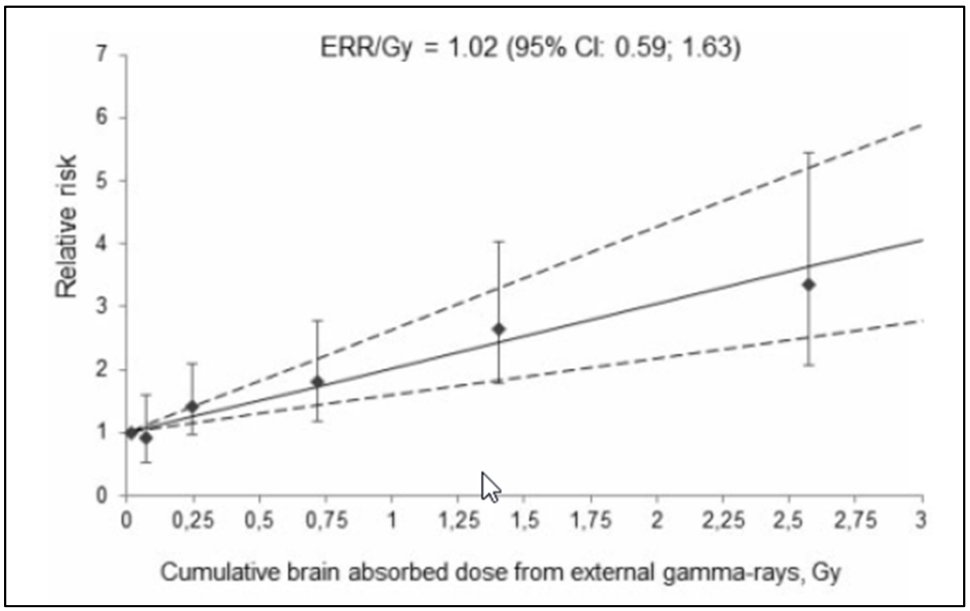
OPEN ACCESS Freely available online PLOS ONE

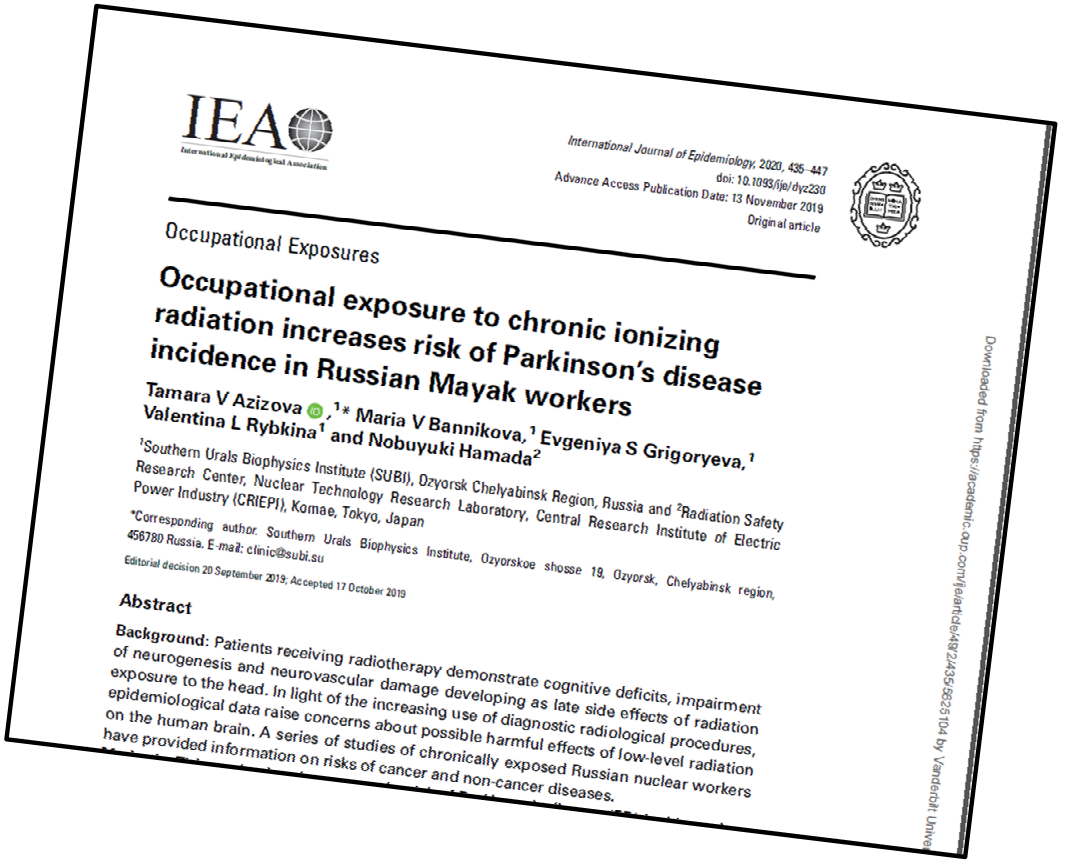
Galactic Cosmic Radiation Leads to Cognitive Impairment and Increased Aβ Plaque Accumulation in a Mouse Model of Alzheimer’s Disease

Jonathan D. Cherry[1], Bin Liu[2], Jeffrey L. Frost[2], Cynthia A. Lemere[2], Jacqueline P. Williams[3], John A. Olschowka[4], M. Kerry O’Banion[4]*

Parkinson's Disease
Mayak Workers







IEA International Epidemiological Association

International Journal of Epidemiology, 2020, 435–447
doi: 10.1093/ije/dyz230
Advance Access Publication Date: 13 November 2019
Original article

Occupational Exposures

Occupational exposure to chronic ionizing radiation increases risk of Parkinson's disease incidence in Russian Mayak workers

Tamara V Azizova [1]*, Maria V Bannikova, [1] Evgeniya S Grigoryeva, [1] Valentina L Rybkina [1] and Nobuyuki Hamada [2]

[1]Southern Urals Biophysics Institute (SUBI), Ozyorsk Chelyabinsk Region, Russia and [2]Radiation Safety Research Center, Nuclear Technology Research Laboratory, Central Research Institute of Electric Power Industry (CRIEPI), Komae, Tokyo, Japan

*Corresponding author. Southern Urals Biophysics Institute, Ozyorskoe shosse 19, Ozyorsk, Chelyabinsk region, 456780 Russia. E-mail: clinic@subi.su

Editorial decision 20 September 2019; Accepted 17 October 2019

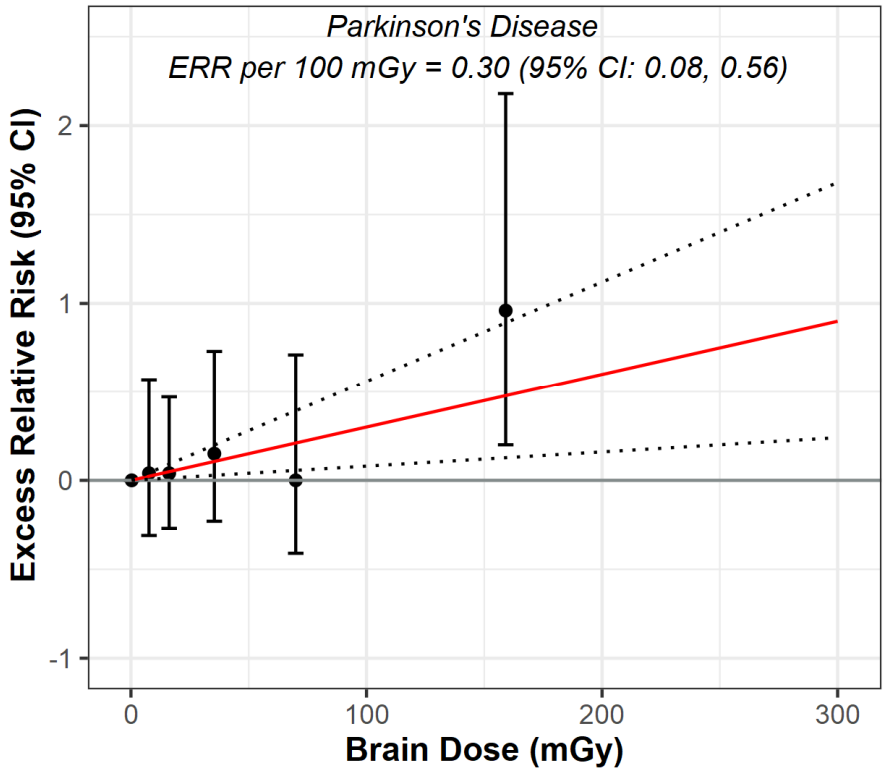
Abstract

Background: Patients receiving radiotherapy demonstrate cognitive deficits, impairment of neurogenesis and neurovascular damage developing as late side effects of radiation exposure to the head. In light of the increasing use of diagnostic radiological procedures, epidemiological data raise concerns about possible harmful effects of low-level radiation on the human brain. A series of studies of chronically exposed Russian nuclear workers have provided information on risks of cancer and non-cancer diseases.

Azizova T et al. Occupational exposure to chronic radiation. Int J Epidemiol 2020

Parkinson's Disease (n=367,722)

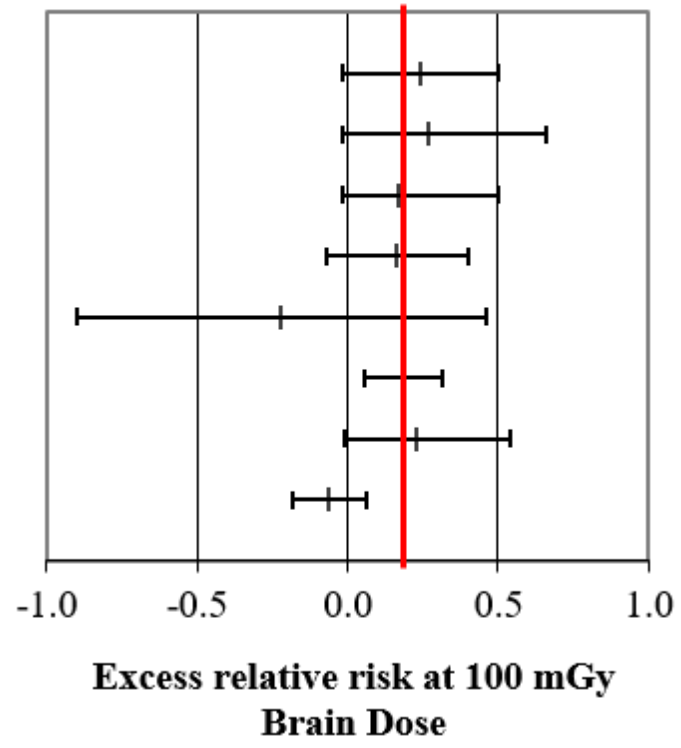
Nuclear Power Plant + Industrial Radiographers + Medical Workers (n=354)



Boice et al. A Million Persons, A Million Dreams. IJRB 2022

Parkinson's Disease Risk Estimates

Cohort (No.)	Cases n	ERR at 100 mGy (95% CIs)
NPP (135,193)	140	0.24 (-0.02; 0.50)
IR (123,556)	128	0.27 (-0.02; 0.66)
Medical (109,019)	87	0.17 (-0.02; 0.50)
LANL (26,328)	193	0.16 (-0.07; 0.40)
Atomic Vets (114,270)	874	-0.22 (-0.90; 0.46)
*META ESTIMATE**	*1422*	*0.185 (0.054; 0.316)*
Mound (4,977)**	135	0.23 (-0.01; 0.54)
Mallinckrodt (2,514)**	93	-0.06 (-0.18; 0.06)



*Total = 508,276

**Dementia, ALZ, PD, MND

Relevance: Is Parkinson's a radiation effect? Surprising if so and needs to be confirmed.

Topics

- Background
- DOE Cohorts
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- Recent Findings
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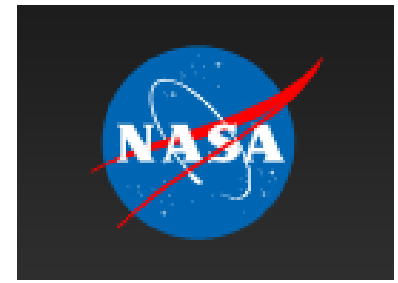
Conclusions – Findings to Date

- Chronic exposures cause leukemia (not surprising)
- Chronic exposures below 0.5 Gy do not cause IHD
- Chronic exposures are associated with Parkinson's disease – a new finding with complex implications if confirmed
- Chronic exposures may be associated with lung cancer but at a lower level than acute exposures
- Further follow-up & combination with other MPS cohort studies will provide more definitive conclusions

U.S. National Effort
Past and Present – Funding



Memorial Sloan Kettering
Cancer Center™

Current: DOE, NASA, US Navy. CDC, and in kind from others

Acknowledgments

- Laurence Dauer, Michael Bellamy, **Memorial Sloan Kettering**
- Sarah Cohen, EpidStrategies Linda Walsh, **University of Zurich**
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- **ORNL** (Rich Leggett, Keith Eckerman, Caleigh Samuels, Derek Jokisch, Nicole Martinez, Nolan Hertel)
- **ORAU** (Betsy Ellis, Ashley Golden, Dave Girardi, Sara Howard)
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- **Landauer** (Craig Yoder)
- National Council on Radiation Protection and Measurements (**NCRP**) (Kathy Held)

Funding from NASA, DOE, US Navy, NRC, NCI

(NNX15AU88G) (80NSSC17M0016) (NNX16AG04G) (80NSSC19M0161)

Topics

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- Summary Findings

- Future

Future

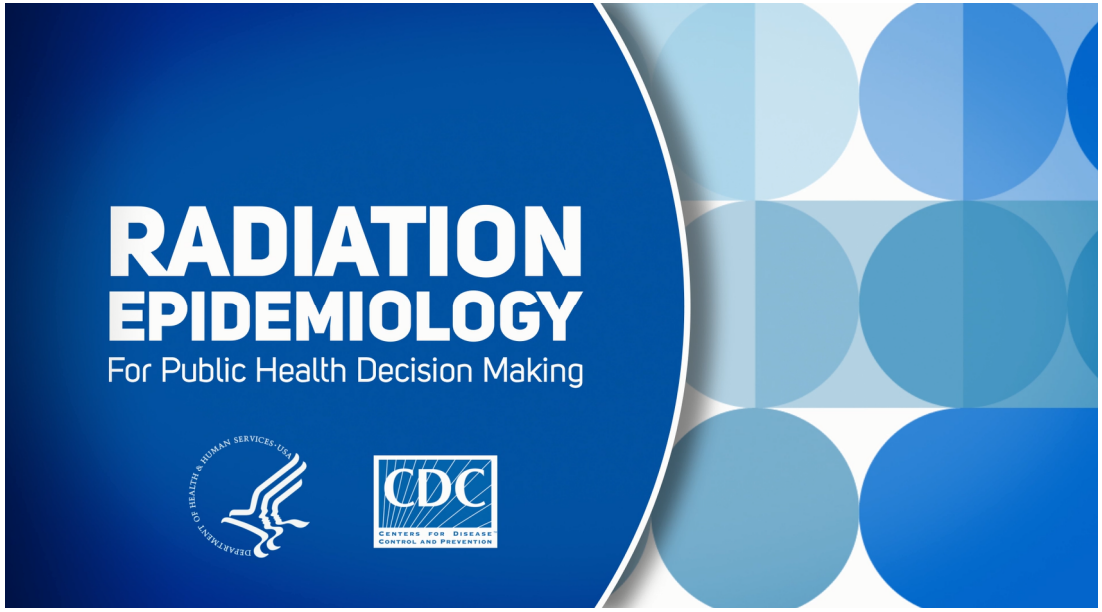
- Complete Studies DOE Worker, Radium Dial and Submariner Studies
- Complete Studies on Dementia, Depression, Cognition – Brave New World
- **Harmonize** (combine) ensemble/biologically-based models beyond meta-analyses
- **Medicare Claims Files** for Incidence and Smoking Hx
- Extend Follow-up 10 years for Nuclear Power, Industrial Radiographers
- Consider Workers exposed to Neutrons, Tritium – LANL, Rocky Flats, Hanford
- Consider AI, Machine Learning – BIG DATA – handling ~billions of data points
- Provide evidence on appropriateness of **LNT**-model for radiation protection
- Seek collaborators - radiation professionals needed for future
- **Vision**: The National Center for Radiation Epidemiology and *Biology*

CMS
CENTERS for MEDICARE & MEDICAID SERVICES

"A Million Dreams are Keeping me Awake" (and not retired)
- The Greatest Showman

Educational Videos -- Radiation Epidemiology for Public Health Decision Making

URL: https://www.cdc.gov/nceh/radiation/emergencies/radiation-epidemiology-videos.htm



Boice JD, Held KD, Shore RE. Radiation epidemiology and health effects following low-level radiation exposure. *J Radiol Prot. 2019 Jul 4;39(4):S14-S27*.

2023 NCRP Annual Meeting:
March 27 - 28, 2023

Integration of Physics, Biology and Epidemiology in Radiation Risk Assessment

Eric J. Grant, *Chair*
Emily A. Caffrey, *Vice Chair*