CURRENT DIRECTIONS AND THE FUTURE OF LOW-DOSE RADIATION RESEARCH

OCCUPATIONAL STUDIES

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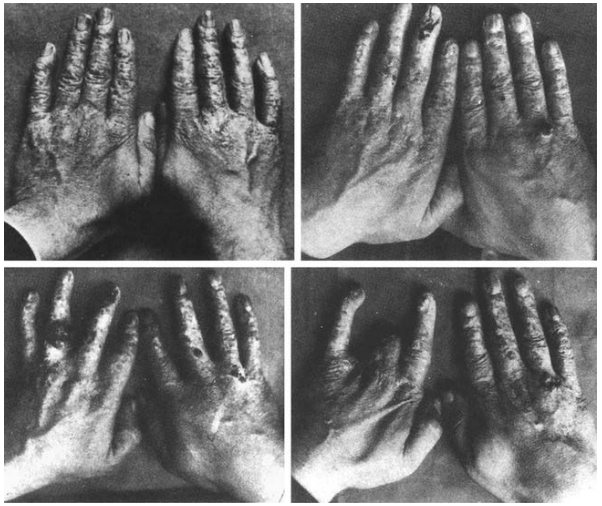
Recognition of occupational carcinogens: Case reports



Demonstration of a cancroid of the right hand, which developed after exposure to roentgen rays. *Fortschr Roentgenst* **1902**; 6:106–11

Recognition of occupational carcinogens: Comparative mortality studies

Two early studies on relative mortality in occupationally-exposed cohorts

Cohort	Size	Years first worked	Follow-up
U.K. Radiologists (Court-Brown and Doll, 1956)	1377	1897-1954	1897-1957 (subsequently through 1997)
U.S. Radiologists, (Seltzer and Sartwell, 1964)	16339	1915-1954	1915-1958

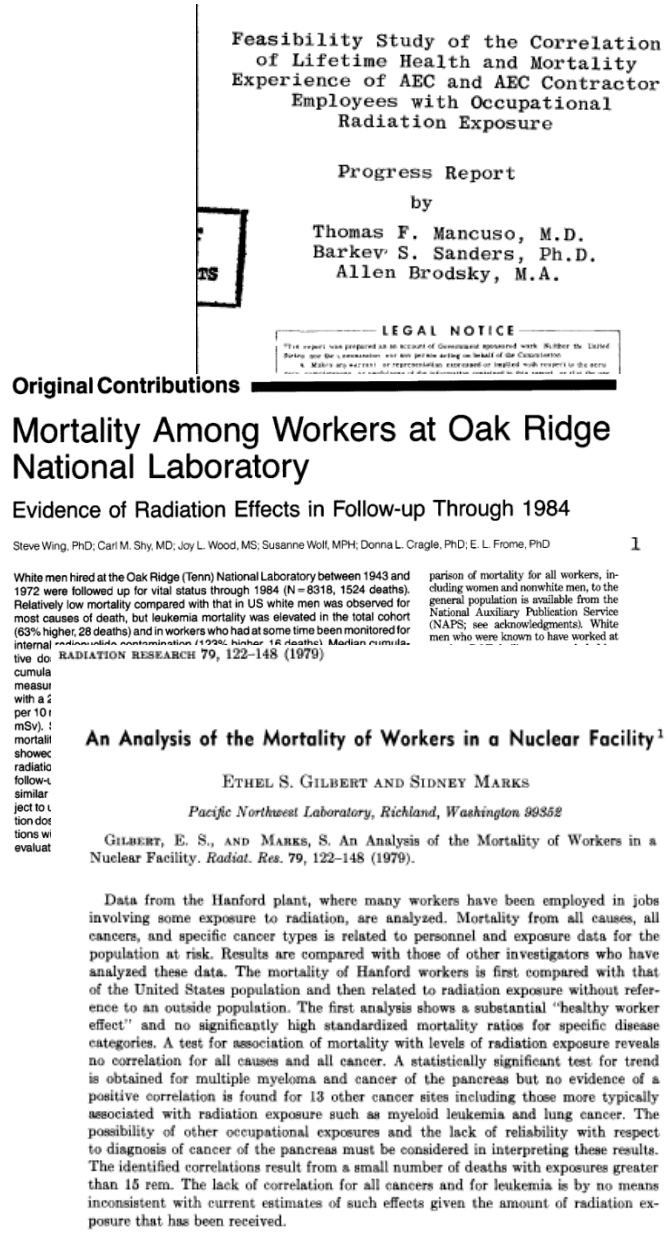
Recognition of occupational carcinogens: Analytical studies of industrial cohorts

Oak Ridge National Laboratory

Hanford B Plant Reprocessing Canyon

Reports on nuclear workers: 1970s and 1980s

Cohort	Country	Publication date(s)
Hanford	US	1977, 1978, 1979, 1981
Oak Ridge Natl Lab	US	1985
Atomic Energy Auth.	UK	1985
Sellafield	UK	1986
Rocky Flats	US	1987
Atomic Energy Canada	CAN	1987
AWE	UK	1988
SRS	US	1988



Feasibility Study of the Correlation of Lifetime Health and Mortality Experience of AEC and AEC Contractor Employees with Occupational Radiation Exposure

Progress Report

by

Thomas F. Mancuso, M.D.
Barkev S. Sanders, Ph.D.
Allen Brodsky, M.A.

LEGAL NOTICE

Original Contributions

Mortality Among Workers at Oak Ridge National Laboratory

Evidence of Radiation Effects in Follow-up Through 1984

Steve Wing, PhD; Carl M. Shy, MD; Joy L. Wood, MS; Susanne Wolf, MPH; Donna L. Cragle, PhD; E. L. Frome, PhD

1

White men hired at the Oak Ridge (Tenn) National Laboratory between 1943 and 1972 were followed up for vital status through 1984 (N = 8318, 1524 deaths). Relatively low mortality compared with that in US white men was observed for most causes of death, but leukemia mortality was elevated in the total cohort (63% higher, 28 deaths) and in workers who had at some time been monitored for internal

parison of mortality for all workers, including women and nonwhite men, to the general population is available from the National Auxiliary Publication Service (NAPS; see acknowledgments). White men who were known to have worked at

RADIATION RESEARCH 79, 122–148 (1979)

An Analysis of the Mortality of Workers in a Nuclear Facility[1]

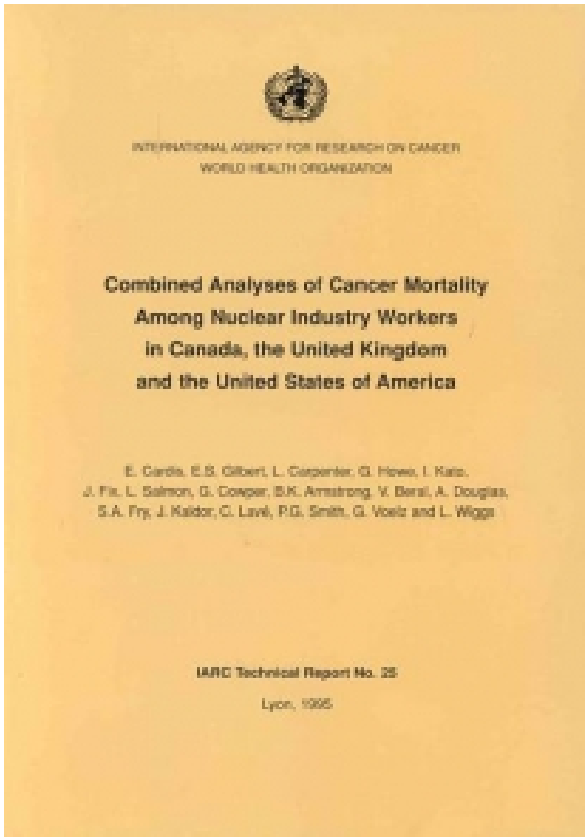
ETHEL S. GILBERT AND SIDNEY MARKS

Pacific Northwest Laboratory, Richland, Washington 99352

GILBERT, E. S., AND MARKS, S. An Analysis of the Mortality of Workers in a Nuclear Facility. *Radiat. Res.* 79, 122–148 (1979).

Data from the Hanford plant, where many workers have been employed in jobs involving some exposure to radiation, are analyzed. Mortality from all causes, all cancers, and specific cancer types is related to personnel and exposure data for the population at risk. Results are compared with those of other investigators who have analyzed these data. The mortality of Hanford workers is first compared with that of the United States population and then related to radiation exposure without reference to an outside population. The first analysis shows a substantial "healthy worker effect" and no significantly high standardized mortality ratios for specific disease categories. A test for association of mortality with levels of radiation exposure reveals no correlation for all causes and all cancer. A statistically significant test for trend is obtained for multiple myeloma and cancer of the pancreas but no evidence of a positive correlation is found for 13 other cancer sites including those more typically associated with radiation exposure such as myeloid leukemia and lung cancer. The possibility of other occupational exposures and the lack of reliability with respect to diagnosis of cancer of the pancreas must be considered in interpreting these results. The identified correlations result from a small number of deaths with exposures greater than 15 rem. The lack of correlation for all cancers and for leukemia is by no means inconsistent with current estimates of such effects given the amount of radiation exposure that has been received.

Reports on nuclear workers 1990s: Collaborative studies



INTERNATIONAL AGENCY FOR RESEARCH ON CANCER
WORLD HEALTH ORGANIZATION

Combined Analyses of Cancer Mortality Among Nuclear Industry Workers in Canada, the United Kingdom and the United States of America

E. Cardis, E.S. Gilbert, L. Carpenter, G. Howe, I. Kato, J. Fix, L. Salmon, G. Cowper, B.K. Armstrong, V. Beral, A. Douglas, S.A. Fry, J. Kaldor, C. Lavé, P.G. Smith, G. Voelz and L. Wiggs

IARC Technical Report No. 28

Lyon, 1995

Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries

E Cardis, M Vrijheid, M Blettner, E Gilbert, M Hakama, C Hill, G Howe, J Kaldor, C R Muirhead, M Schubauer-Berigan, T Yoshimura, F Bermann, G Cowper, J Fix, C Hacker, B Heinmiller, M Marshall, I Thierry-Chef, D Utterback, Y-O Ahn, E Amoros, P Ashmore, A Auvinen, J-M Bae, J Bernar Solano, A Biau, E Combalot, P Deboodt, A Diez Sacristan, M Eklof, H Engels, G Engholm, G Gulis, R Habib, K Holan, H Hyvonen, A Kerekes, J Kurtinaitis, H Malker, M Martuzzi, A Mastauskas, A Monnet, M Moser, M S Pearce, D B Richardson, F Rodriguez-Artalejo, A Rogel, H Tardy, M Telle-Lamberton, I Turai, M Usel, K Veress

Abstract

Objectives To provide direct estimates of risk of cancer after protracted low doses of ionising radiation and to strengthen the scientific basis of radiation protection standards for environmental, occupational, and medical diagnostic exposures.
Design Multinational retrospective cohort study of cancer mortality.
Setting Cohorts of workers in the nuclear industry in 15 countries.
Participants 407 391 workers individually monitored for external radiation with a total follow-up of 5.2 million person years.
Main outcome measurements Estimates of excess relative risks per sievert (Sv) of radiation dose for mortality from cancers other than leukaemia and from leukaemia excluding chronic lymphocytic leukaemia, the main causes of death considered by radiation protection authorities.
Results The excess relative risk for cancers other than leukaemia was 0.97 per Sv, 95% confidence interval 0.14 to 1.97. Analyses of causes of death related or unrelated to

by the public in the general environment, by patients through repeated diagnostic procedures,[1] and by radiation workers.

The effects of low dose chronic exposure to external radiation have been directly estimated in several cohorts of workers in the nuclear industry,[3] but the sample size has limited the precision of these estimates. Analyses of combined cohorts have improved precision.[4-7] Estimates from these analyses, however, are compatible with a range of possibilities, from a reduction of risk at low doses to risks higher than those underlying current radiation protection recommendations.

The 15 country study, an international collaborative study of cancer risk among radiation workers in the nuclear industry, was carried out to further improve the precision of direct estimates of risk after protracted low dose exposures and to strengthen the scientific basis of radiation protection.[1] We present risk estimates for mortality from all cancers, excluding leukaemia, and from leukaemia excluding chronic lymphocytic leukaemia and compare them with estimates derived from data on survivors of the A bomb. We have used the term nuclear industry to refer to facilities engaged in production of nuclear power, manufacture of nuclear weapons, enrichment and processing of nuclear fuel,

Reports on nuclear workers
1990s: Russian nuclear workers

Obninsk Nuclear Power Plant

Mayak

Reports on nuclear workers: The last decade

Summary of some recent occupational cohort studies

Study	Year	Outcome	Sample size	Cases	Mean dose	ERR per 100mGy	95% CI (90% CI*)
Korean workers	2008	Cancer mortality	79,679	134	6mSv	0.72	-0.5 to 2.1
Korean nuclear workers	2010	Cancer incidence	16,236	203	20mSv	0.21	-0.19 to 0.9
Rocketdyne	2011	Cancer mortality	46,970	647	14mSv	0.02	- 0.18 to 0.17
Japanese workers	2012	Cancer mortality	200,583	2,636	12mSv	0.13	-0.03 to 0.30
Canadian workers	2013	Cancer mortality	45,316	437	22mSv	0.18	-0.04 to 0.53
German nuclear workers	2014	Cancer mortality	8,972	115	20mSv	-0.1	-0.4 to 0.1
USRT	2016	Breast cancer	66,915	1,922	37mGy	0.07	-0.005 to 0.19
US nuclear workers**	2015	Cancer mortality	119,195	10,877	20mSv	0.01	-0.02 to 0.05
UKNRRW**	2009	Cancer incidence	174,451	11,133	25mSv	0.03	0.004 to 0.05
French nuclear workers**	2017	Cancer mortality	59,004	2,536	26mSv	0.04	-0.04 to 0.13*
INWORKS	2015	Cancer mortality	308,297	17,957	21mGy	0.05	0.018 to 0.079*

Path to recognition of occupational carcinogens

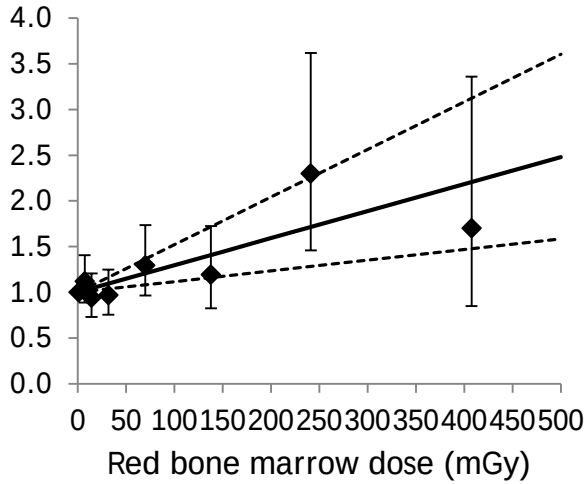
Analytical studies

Comparative mortality

Case reports

Deaths from major causes and leukemia in RSNA, 1955–1958, with expected deaths based on the age- and time-specific mortality rates of the AAOO

Cause of death	Age group (years)	Observed deaths in RSNA	Expected no of deaths at AAOO rates	Excess of observed over expected	Mortality ratio
All causes	35–49	79	61.5	17.5	1.3
	50–64	339	271 5	67.5	1 2
	65–79	438	295.0	143.0	1.5
	35–79	856	628.0	228.0	1.4
Leukemia	35–49	2	1.9	0.1	1 0
	50–64	8	1.1	6.9	7 3
	65–79	9	4.7	4.3	1.9
	35–79	19	7 7	11.3	2.5



Occupational radiation studies: Future directions - 1

New pooling efforts and updating of existing cohorts

Evolution of study cohorts

- Encompass increasing numbers of female nuclear workers
- Older workers on the job
- Lower exposures
- Improved exposure assessments for more recent periods
- Improved outcome information for more recent periods

Analytical methods to handle uncertainties in dose estimates

Attention to temporal factors: older age distributions at end of follow-up

Counterfactual frameworks for analysis

Nested studies to improve exposure, covariate, and outcome information

Occupational radiation studies: Future directions - 2

- Research programs within public health and disease prevention agencies
  - Part of broad research programs on occupational hazards
  - Normal NIH/NSFgrant mechanisms
  - Unconstrained grants
  - Peer review
  - Not coordinated research
- Research programs within agencies missions involving energy-related research
  - Narrow health research programs focused on radiation exposure
  - Lack external competition
  - Constraints
  - Domain-specific
  - Centralized
  - Established links government/industry