Risk of ionising radiation – an introduction

Basics, facts, recent research

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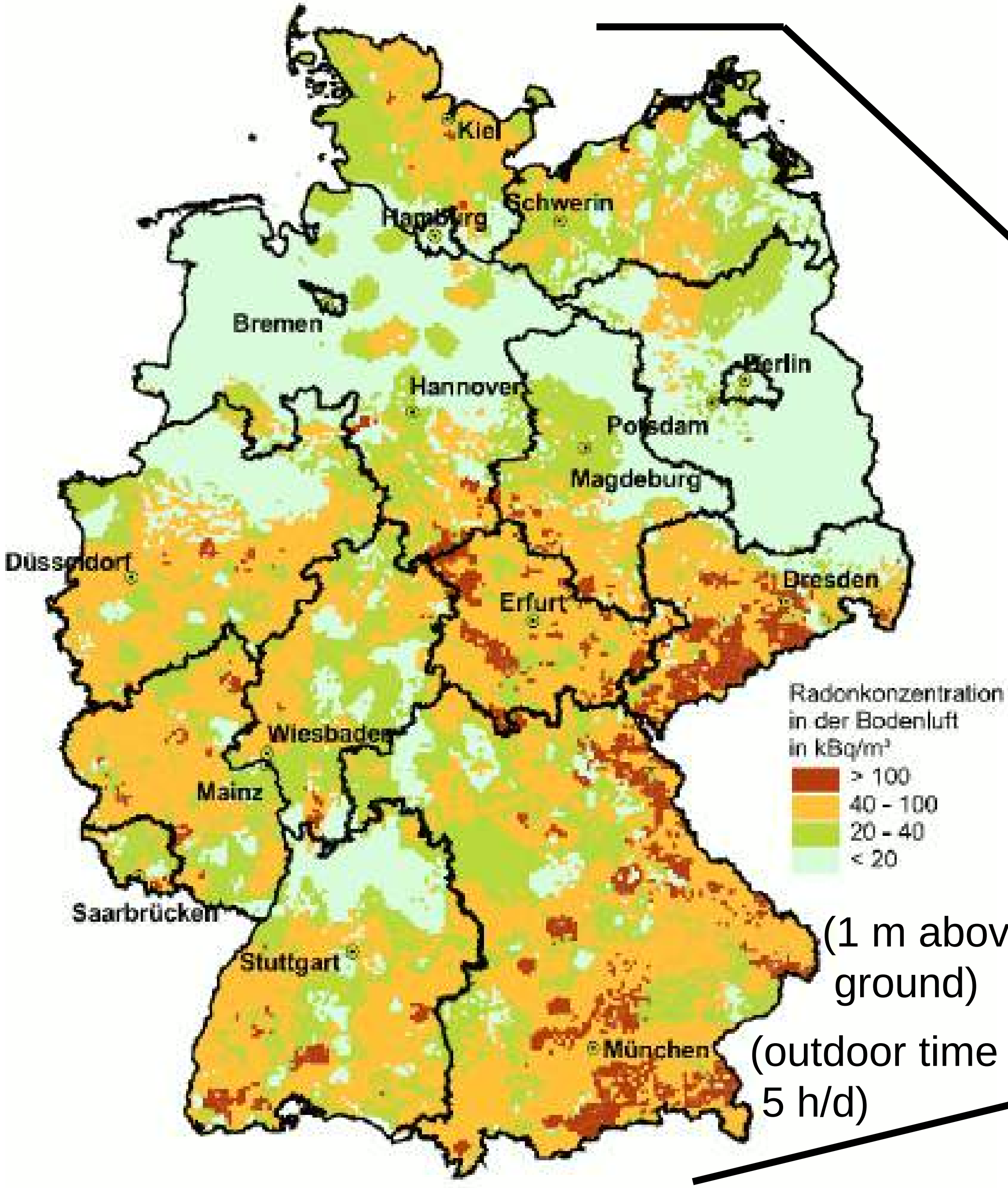
(IPPNW Feb. 27th, 2016)

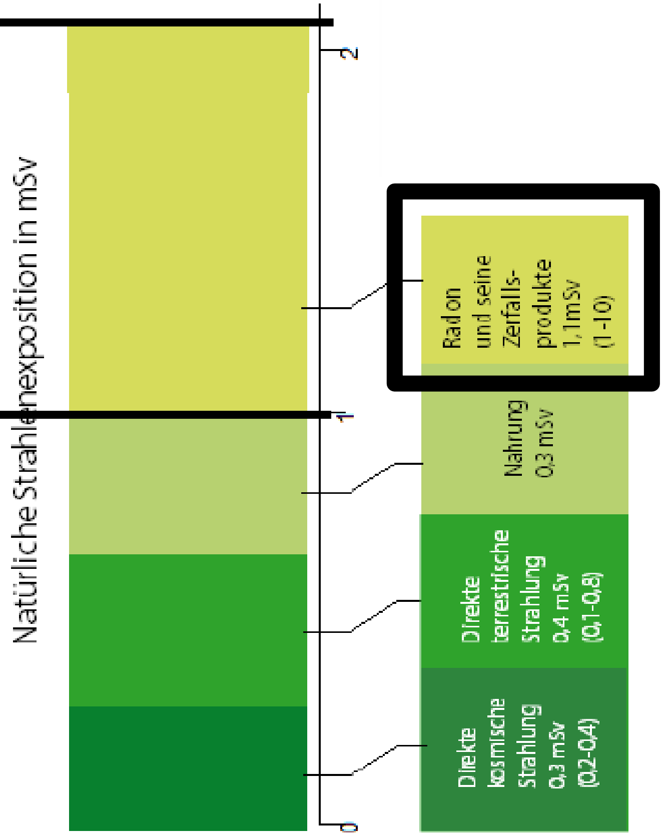
① Natural radiation – no risk ?!

Average effective dose: Radon (2013)



(1 m above ground)

(outdoor time 5 h/d)



Karte: Umweltradioaktivität und Strahlenbelastung im Jahr 2011 (Unterrichtung durch die Bundesregierung), Bundestagsdrucksache 17/14395 (2013); rm17297
Grafik rechts: Umweltradioaktivität und Strahlenbelastung im Jahr 2013, Bundestagsdrucksache 18/5565 v. 13.07.2015

Indoor radon - status

Pooled analysis of 7 US-studies (New Jersey, Winnipeg, Missouri, Iowa, Connecticut, Utah, Idaho)

N=3662 cases (of these 2556 women), N=4966 controls (3596 women)
nuclear track dosimeter, 12 months measurement, living room, bedroom; address with longest duration

Conditional logistic regression (cum. exposure 5-30 years prior to 1st D_x)

- *Age at 1st Dx (<60, 60-64, 65.69, 70-74, 75+ years)*
- *Cigarette smoking*
  - *cigarettes/d: Never-smokers, 1-9, 10-19, 20-29, 30+ /d*
  - *duration of smoking: Never-smokers, 1-24, 25-34, 35-44, 45+ years)*
- *total number of livelong addresses (<3, 3+)*

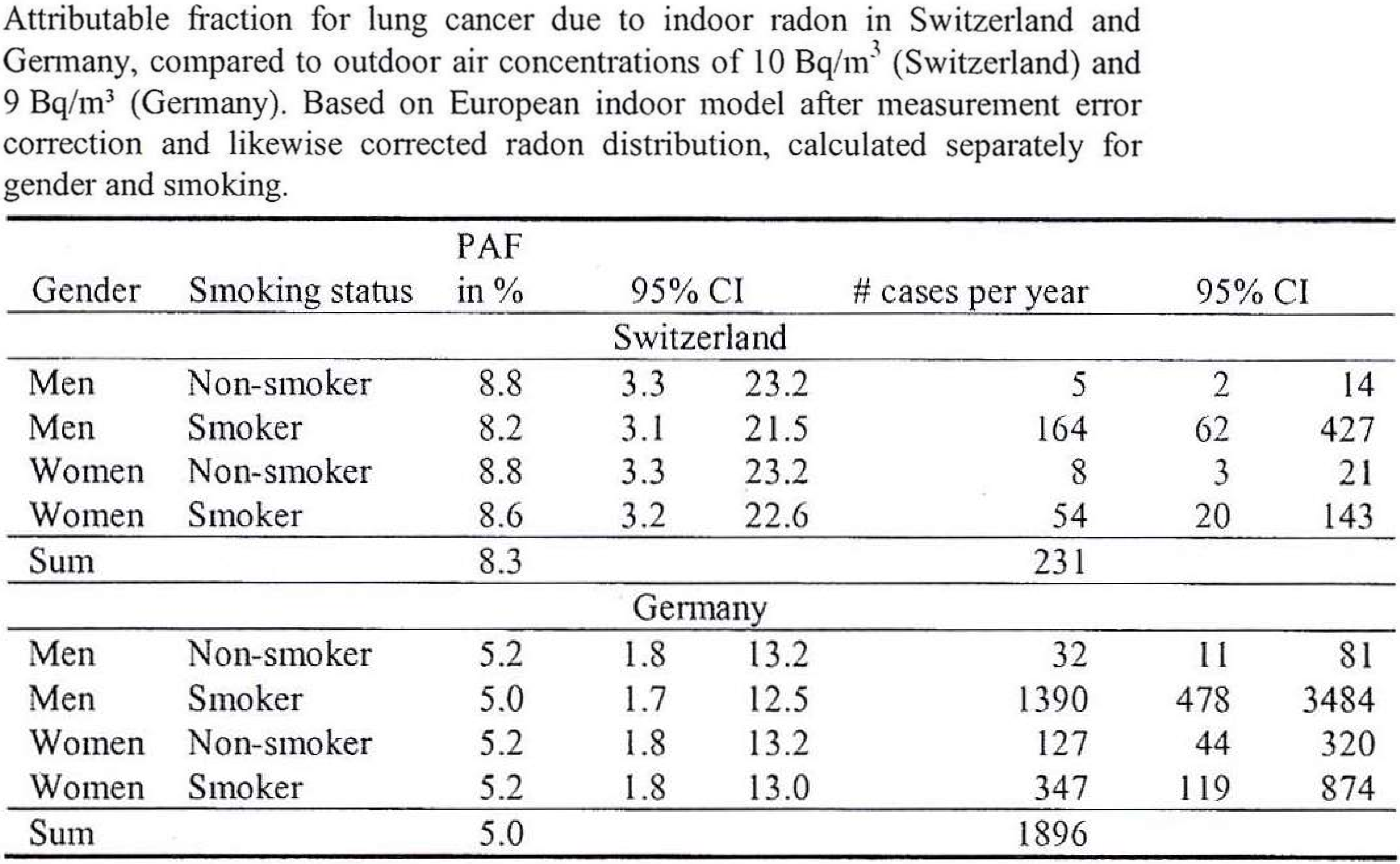
BEIR VI: 10-15% of all lung cancers (US: 15,000-23,000 of a total of 157,400/J)

[Extrapolation from results for miners: 1.12 (1.02-1.25)]
(n.s. tendency toward higher risks for SCLC, lower risks for older ages;
no difference: gender, years of education, smoking status, specific studies)

Increased risks in subgroups with better exposure assessment
(e.g. time in residence >25 J: 0.21 (0.03-0.52))

Kre Epidemiology 16.2(2005), 137-145 rM9784
Da 6/2005 (online version)

Radon cancers: Lung cancer



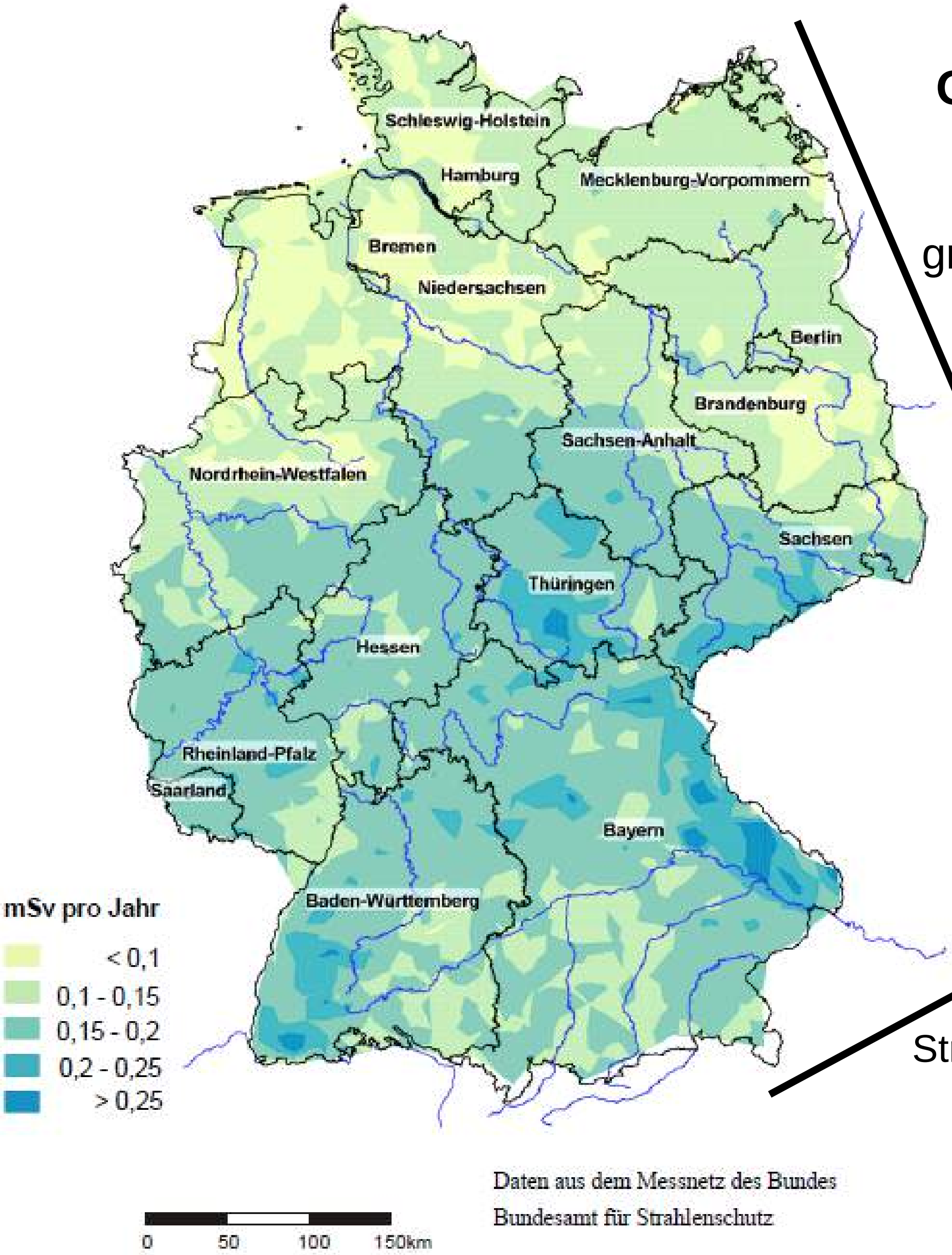
Attributable fraction for lung cancer due to indoor radon in Switzerland and Germany, compared to outdoor air concentrations of 10 Bq/m^3 (Switzerland) and 9 Bq/m^3 (Germany). Based on European indoor model after measurement error correction and likewise corrected radon distribution, calculated separately for gender and smoking.

Gender	Smoking status	PAF in %	95% CI		# cases per year	95% CI	
			Switzerland				
Men	Non-smoker	8.8	3.3	23.2	5	2	14
Men	Smoker	8.2	3.1	21.5	164	62	427
Women	Non-smoker	8.8	3.3	23.2	8	3	21
Women	Smoker	8.6	3.2	22.6	54	20	143
Sum		8.3			231		
			Germany				
Men	Non-smoker	5.2	1.8	13.2	32	11	81
Men	Smoker	5.0	1.7	12.5	1390	478	3484
Women	Non-smoker	5.2	1.8	13.2	127	44	320
Women	Smoker	5.2	1.8	13.0	347	119	874
Sum		5.0			1896		

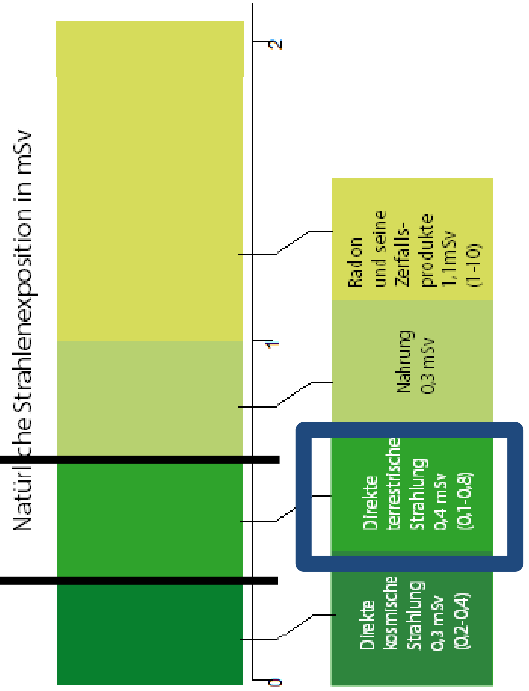
aus: Menzler S, Piller G, Gruson M, Schaffrath Rosario A, Wichmann HE, Kreienbrock L. Population Attributable for Lung Cancer Due to Residential Radon in Switzerland and Germany. Health Phys 2008, 95 2: 179-189 (modif.)

Outdoor environmental radiation exposure 2013 in Germany

(assumption: 5 hours/d, based on ground level γ-dose rate measurements)



Daten aus dem Messnetz des Bundes
Bundesamt für Strahlenschutz



Quell

Strahlenbelastung im Jahr 2013, Unterrichtung durch die Bundesregierung, Bundestagsdrucksache 18/5565 v. 13.07.2015, S. 9.

Updated estimates of the proportion of childhood leukaemia incidence in Great Britain that may be caused by natural background ionising radiation

Mark P Little[1,4], Richard Wakeford[2] and Gerald M Kendall[3]

Abstract

The aetiology of childhood leukaemia remains generally unknown, although

Using the newer dosimetry we calculate that the best estimate of the proportion of cases of childhood leukaemia in Great Britain predicted to be attributable to this source of exposure is 15–20%,

previously, but use recently published revised estimates of natural background radiation doses received by the red bone marrow of British children to update the previous results. Using the newer dosimetry we calculate that the best estimate of the proportion of cases of childhood leukaemia in Great Britain predicted to be attributable to this source of exposure is 15–20%, although the uncertainty associated with certain stages in the calculation (e.g. the nature of the transfer of risk between populations and the pertinent dose received from naturally occurring alpha-particle-emitting radionuclides) is significant. The slightly lower attributable proportions compared with those previously derived by Wakeford *et al* (*Leukaemia* 2009 **23** 770–6) are largely due to the lower doses (and in particular lower high LET doses) for the first year of life.

J. Radiol. Prot. **29** (2009) 467–482

ehp ENVIRONMENTAL HEALTH PERSPECTIVES
http://www.ehponline.org

Background Ionizing Radiation and the Risk Childhood Cancer: A Census-Based Nationwide Cohort Study

Ben D. Spycher, Judith E. Lupatsch, Marcel Zwahlei
Martin Röösli, Felix Niggli, Michael A. Grotzer,
Johannes Rischewski, Matthias Egger,
and Claudia E. Kuehni for the Swiss Pediatric Oncology
and the Swiss National Cohort Study Group

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Received: 11 April 2014
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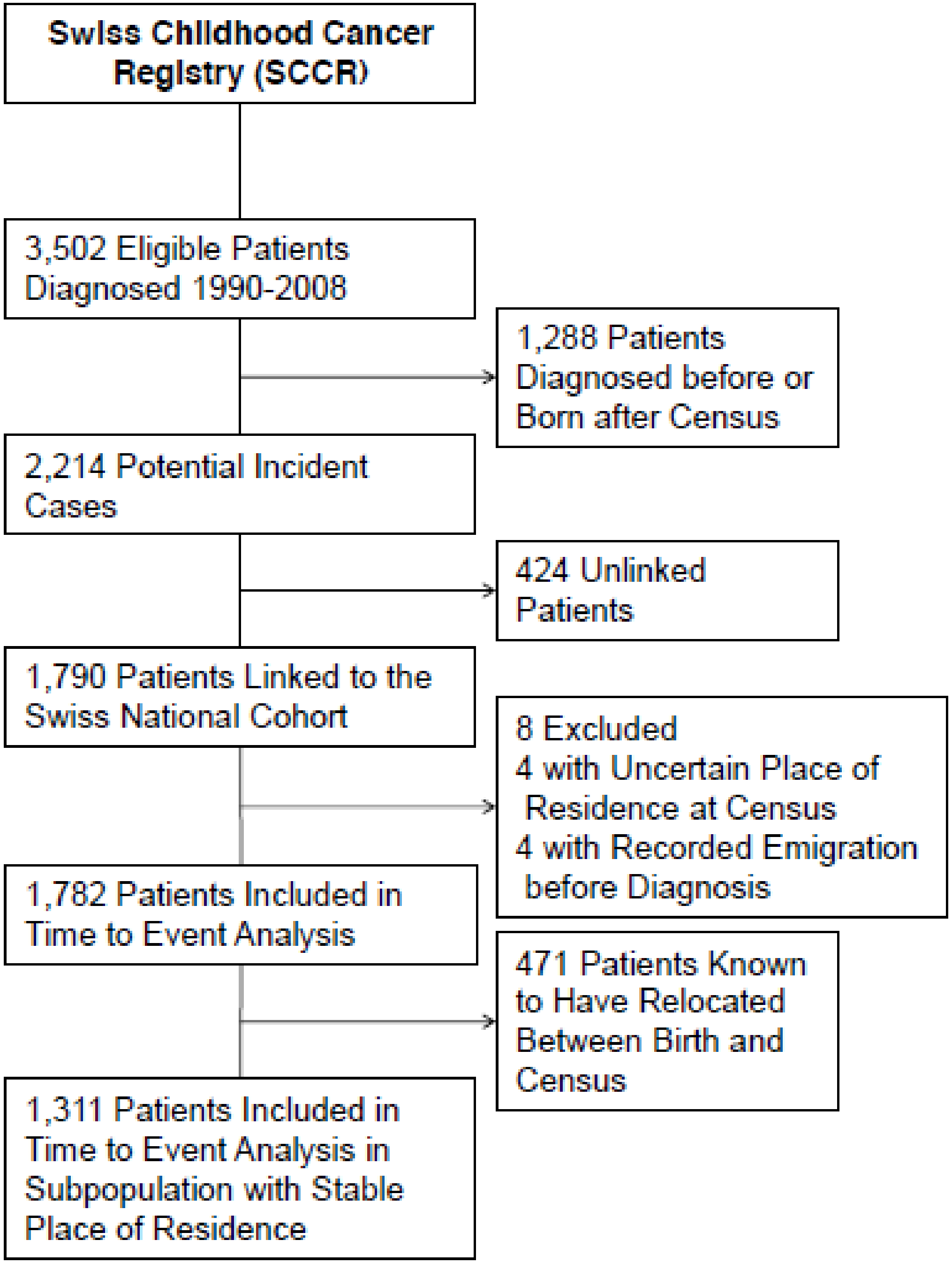


Swiss Childhood Cancer Registry (SCCR)

3,502 Eligible Patients Diagnosed 1990-2008

1,288 Patients Diagnosed before or Born after Census

2,214 Potential Incident Cases

424 Unlinked Patients

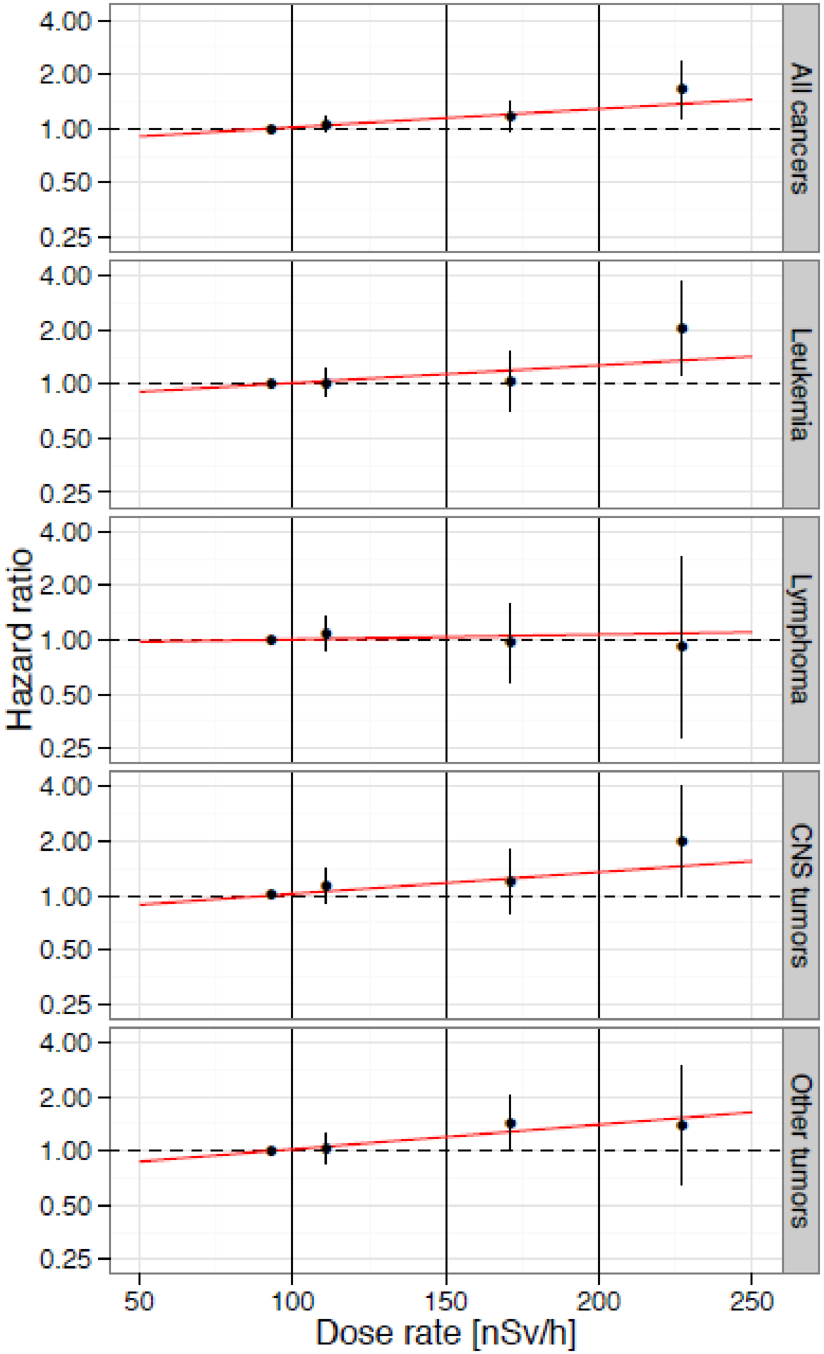
1,790 Patients Linked to the Swiss National Cohort

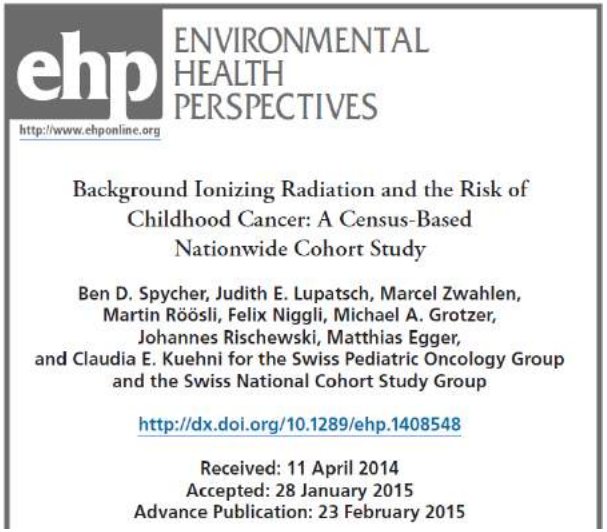
8 Excluded
4 with Uncertain Place of Residence at Census
4 with Recorded Emigration before Diagnosis

1,782 Patients Included in Time to Event Analysis

471 Patients Known to Have Relocated Between Birth and Census

1,311 Patients Included in Time to Event Analysis in Subpopulation with Stable Place of Residence





ENVIRONMENTAL
HEALTH
PERSPECTIVES

Background Ionizing Radiation and the Risk of
Childhood Cancer: A Census-Based
Nationwide Cohort Study

Ben D. Spycher, Judith E. Lupatsch, Marcel Zwahlen,
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Figure 2. Hazard ratios for cancer by dose rate of external ionizing radiation among children aged <16 years in the Swiss National Cohort. Results from Cox proportional hazards models adjusting for sex and birth year using a categorized exposure (points and bars (95% CIs) placed along the x-axis at mean dose rates within categories; categories delineated by vertical lines) and a linear exposure term (red line). Dose rates <100 nSv/h are the reference category. CNS central nervous system.

0,95 mSv/J

2,19 mSv/J

② Radiation from nuclear disasters

Nuclear accidents

Health detriment of Chernobyl:

→ 16,000 (3,400-72,000) Incident thyroid cancers

.

→ 25,000 (11,000-59,000) incident other cancers

→ 15,000 excess cancer deaths

IJC International Journal of Cancer

Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident

Elisabeth Cardis[1*], Daniel Krewski[2], Mathieu Boniol[1], Vladimir Drozdovitch[1], Sarah C. Darby[3], Ethel S. Gilbert[4], Suminori Akiba[5], Jacques Benichou[6], Jacques Ferlay[1], Sara Gandini[7], Catherine Hill[8], Geoffrey Howe[9], Ausrele Kesminiene[1], Mirjana Moser[10], Marie Sanchez[1], Hans Storm[11], Laurent Voisin[1] and Peter Boyle[1]

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[2]*McLaughlin Centre for Population Health Risk Assessment, Institute of Population Health, University of Ottawa, Ottawa, Ontario, Canada*
[3]*Clinical Trial Service Unit, University of Oxford, United Kingdom*
[4]*Radiation Epidemiology Branch, Division of Epidemiology and Genetics, National Cancer Institute, Bethesda, MD, USA*
[5]*Kagoshima University, Graduate School of Medical and Dental Sciences, Kagoshima, Japan*
[6]*Biostatistics Unit, University of Rouen Medical School and Rouen University Hospital, Rouen, France*
[7]*European Institute of Oncology, Milano, Italy*
[8]*Institut Gustave-Roussy, Villejuif, France*
[9]*Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, NY, USA*
[10]*Federal Office of Public Health, Bern, Switzerland*
[11]*Danish Cancer Society, Copenhagen, Denmark*

The Chernobyl accident, which occurred April 26, 1986, resulted in a large release of radionuclides, which were deposited over a very wide area, particularly in Europe. Although an increased risk of thyroid cancer in exposed children has been clearly demonstrated in the most contaminated regions, the impact of the accident on the risk of other cancers as well as elsewhere in Europe is less clear. The objective of the present study was to evaluate the human cancer burden in Europe as a whole from radioactive fallout from the accident. Average country- and region-specific whole-body and thyroid doses from Chernobyl were estimated using new dosimetric models and radiological data. Numbers of cancer cases and deaths possibly attributable to radiation from Chernobyl were estimated, applying state-of-the-art risk models derived from studies of other irradiated populations. Simultaneously, trends in cancer incidence and mortality were examined over time and by dose level. The risk projections suggest that by now Chernobyl may have caused about 1,000 cases of thyroid cancer and 4,000 cases of other cancers in Europe, representing about 0.01% of all incident cancers since the accident. Models predict that by 2065 about 16,000 (95% UI 3,400–72,000) cases of thyroid cancer and 25,000 (95% UI 11,000–59,000) cases of other cancers may be expected due to radiation from the accident, whereas

Epidemiological studies focusing on the most contaminated regions of the 3 most affected countries have confirmed a causal relationship between the observed increased risk of thyroid cancer and exposure to radioactive iodines from the Chernobyl fallout among those who were children or adolescents when the accident happened.[3–5] Other types of cancer, including leukemia, have also been investigated,[1,6–17] but as yet no association with radiation exposure has been clearly demonstrated. Recent studies suggest a possible doubling of the risk of leukemia among Chernobyl cleanup workers[18] and a small increase in the incidence of premenopausal breast cancer[19] in the most contaminated districts (with average whole-body doses above 40 mSv), both of which appear to be related to radiation dose. These findings need confirmation in further epidemiological studies with careful individual dose reconstruction.

The full extent of the health impact of Chernobyl on the population is difficult to gauge. Ten years ago, Cardis and collaborators[20] estimated that about 9,000 deaths from cancers and leukemia might be expected over the course of a lifetime in the most exposed populations in Belarus, the Russian Federation and

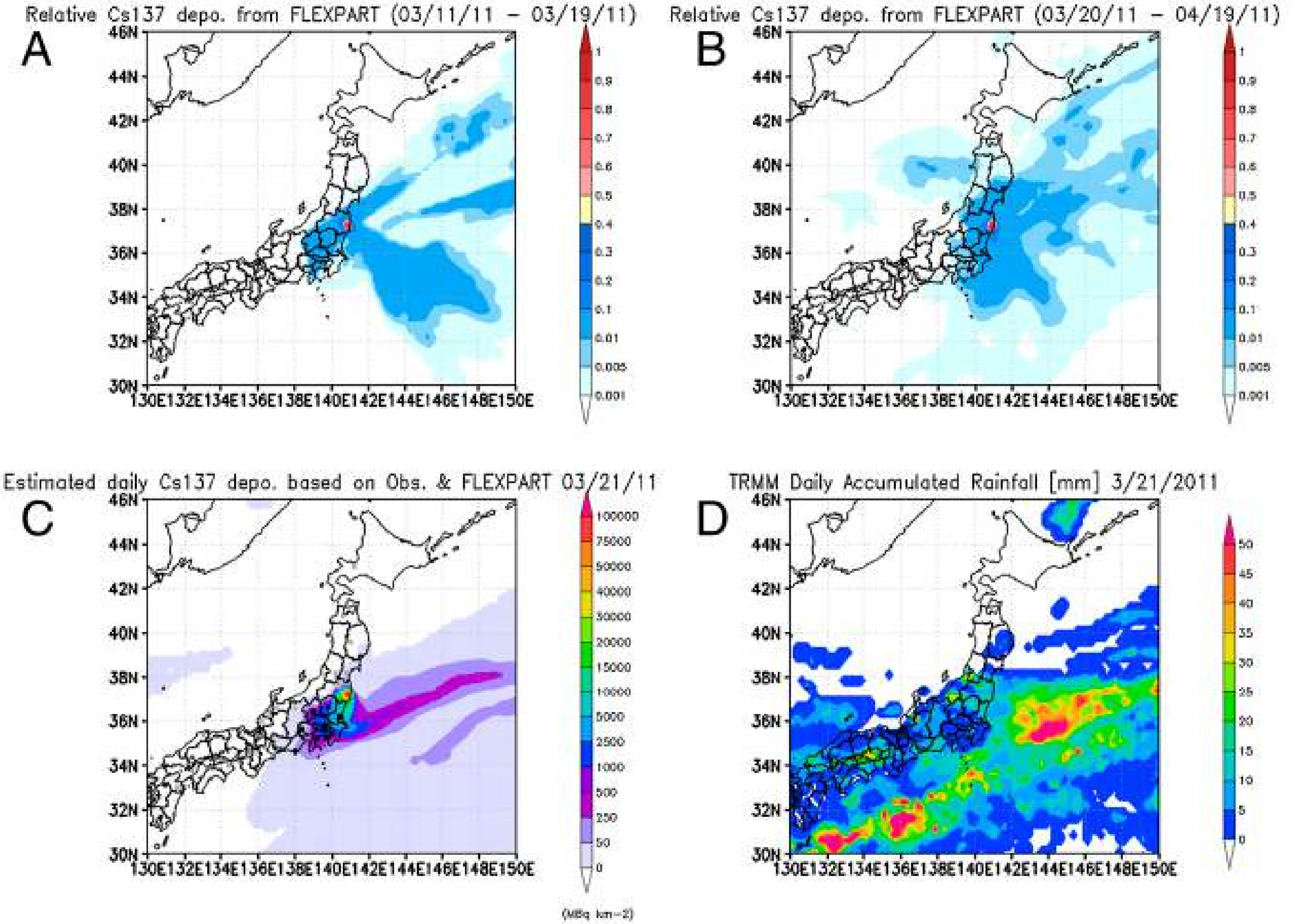


Fig. 1. Cesium-137 deposition maps. (*A*) Relative deposition contributions between March 11 and 19, showing the areas potentially effected by ^{137}Cs before the start of measurements. The sums of the depositions during the period were divided by the maximum deposition in the accumulated field. (*B*) The same as in *A*, but for March 20–April 19. (*C*) An example of estimated daily deposition of ^{137}Cs on March 21. Squares in black denote the observation locations in each prefecture (Table S2). (*D*) Daily accumulated rainfall on March 21 by TRMM.

Quelle: Teppei, JY et al.: Cesium-137 deposition and contamination of Japanese soils due to the Fukushima nuclear accident, PNAS, 108 (49), 2011, 19530-4.

施設名　2-E-29赤城耕司様宅
作業工種　除染前 モニタリング
測定点　玄関前
測定日　H25・5・11
立会者　菊池(県)・赤井・渡部
清水地区1
コリメーター有

シンチレーション
1cm　0.31　μSv/h
50cm　0.46　μSv/h
100cm　0.48　μSv/h
（GM管）
1cm　731　cpm


0.386 μSv/h
2012.11.24


2013.09.16

2011.11.12

Der erste Fukushima-Krebs

AKW-Mitarbeiter hat Leukämie – Regierung erkennt Verstrahlung als Ursache an

The first Fukushima-cancer case

Government recognizes causation by occupational radiation exposure

[redacted]

hat die japanische Regierung erstmals offiziell bestätigt, dass ein früherer Angestellter des Kraftwerks aufgrund der radioaktiven Strahlung nach der Kernschmelze an Krebs erkrankt ist. Andere Krankheitsursachen könnten ausgeschlossen werden. Bei dem Mann, der nach der Havarie 2011 in dem Atomkraftwerk gearbeitet habe, sei Leukämie diagnostiziert worden. Der Ex-Angestellte, der laut Medien 41 Jahre alt ist, wird finanziell entschädigt.

Nach dem Unglück erkrankten mehrere in der Anlage im Nordosten Japans tätige Arbeiter an Krebs. Bislang wurde ein direkter

bens und eines Tsunamis am 11. März 2011 das Kühlsystem ausgefallen, woraufhin es in mehreren Reaktoren zur Kernschmelze kam. Drei der sechs Reaktoren wurden bei der Katastrophe zerstört und

sollen noch vier Jahrzehnte dauern. Zehntausende Menschen mussten die verstrahlte Gegend in und um Fukushima verlassen.

Trotz Protesten in der Bevölkerung hat die japanische Regierung eine Wende in der Atompolitik eingeleitet. Im August und im Oktober dieses Jahres sind im Atomkraftwerk Sendai zwei Reaktoren wieder hochgefahren worden. Das AKW Sendai liegt nur 50 Kilometer vom Vulkan Sakurajima entfernt, einem der aktivsten Vulkane des fernöstlichen Landes. Die Regierung strebt an, dass der Anteil der Atomenergie an der Stromversorgung bis zum Jahr 2030 bei 20 bis

Quelle: Ostsee-Zeitung vom 21.10.2015;

Int. J. Epidemiol. Advance Access published January 27, 2012

International Journal of Epidemiology 2012;1–1

CANUPIS study strengthens evidence of increased leukaemia rates near nuclear power plants

From ALFRED KOERBLEIN

Table 1 SIR and RR near Swiss, British and German nuclear power stations

Data set	O	E	SIR	*P*-value*	RR	*P*-value**
Switzerland (CH)						
0–5 km	11	7.87	1.40	0.3431	1.46	0.3334
5–15 km	54	56.40	0.96			
Great Britain (GB)						
<5 km	20	14.74	1.36	0.2216	1.41	0.1715
>5 km	1579	1640.44	0.96			
Germany (D)						
<5 km	34	24.09	1.41	0.0656	1.45	0.0549
>5 km	585	599.58	0.98			
CH + GB + D						
<5 km	65	46.70	1.39	0.0130	1.44	0.0069
>5 km	2218	2296.42	0.97			

**P*-value (Poisson distribution).

***P*-value (Binomial distribution).

Epidemiology: „Classical“ cohorts

Atomic bomb survivors in Hiroshima and Nagasaki
Cohort: Life Span Study (LSS) of the RERF (establ. 1950-’52)
N ≈ 100.000 participants (all ages)

Average dose of the exposed: 270 mSv

Problems:

- up to 200.000 casualties – survivors are selection of healthy/resilient
- initiation of assessment 5-7 years after the nuclear bomb
- „unexposed“ control group sampled from fallout-area

Shimizu, JAMA 1990 (pap 4174)

Selection Bias in Cancer Risk Estimation from A-Bomb Survivors

Donald A. Pierce,[a,1] Michael Vaeth[b] and Yukiko Shimizu[c,2]

[a] *Department of Statistics, Radiation Effects Research Foundation, Hiroshima, Japan;* [b] *Department of Biostatistics, Aarhus University, Aarhus, Denmark; and* [c] *Department of Epidemiology, Radiation Effects Research Foundation, Hiroshima, Japan*

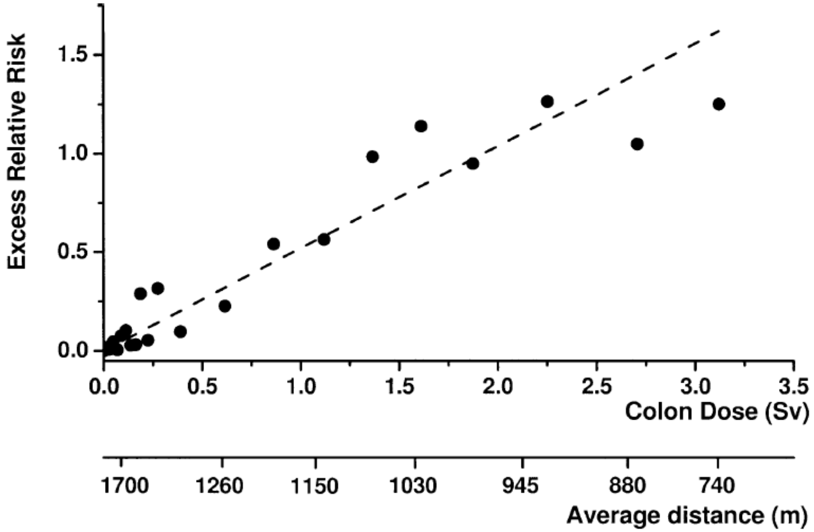


FIG. 1. Solid cancer apparent radiation risk in terms of both dose and distance from the bombs.

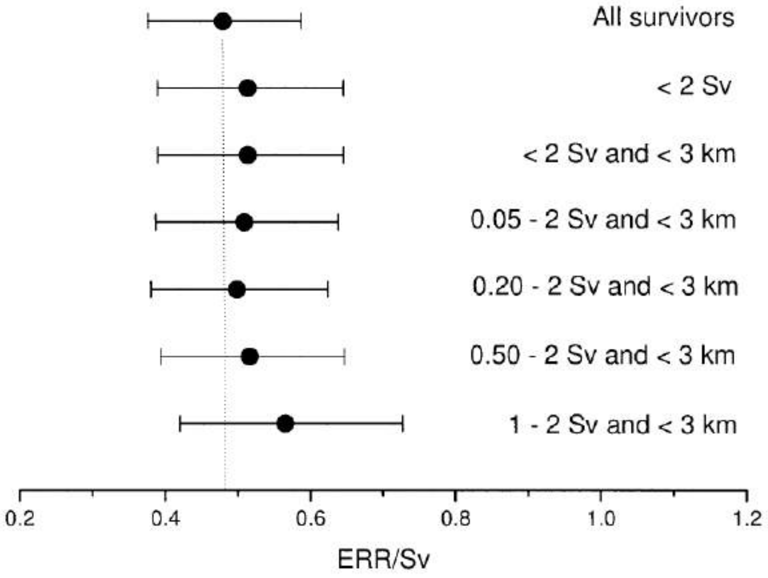


FIG. 2. Solid cancer risk estimation based on restricted dose–distance ranges to reduce differential selection. Error bars are 90% confidence limits.

We consider the possible bias in cancer risk estimation from A-bomb survivors due to selection of the cohort by survival.

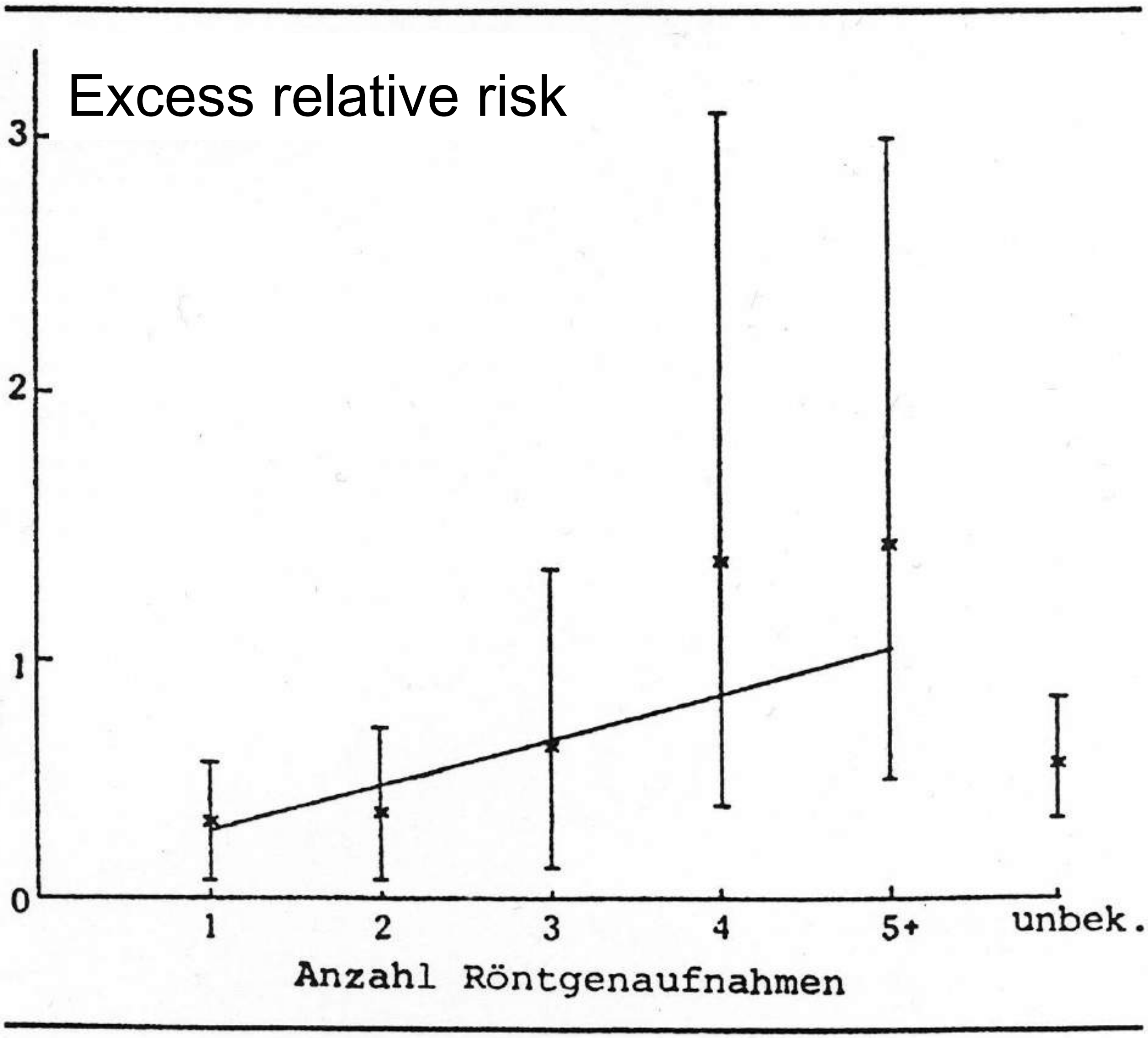
. . . For solid cancer this would correspond to bias in the excess relative risk at 1 Sv of at most about 15–20%.

RADIATION RESEARCH 167, 735–741 (2007)

③ Radiation epidemiology: quantifying risk

A. cancer

Childhood cancer (<15 years) following prenatal exposure



Quelle: *Bithell, J. F., A. M. Stewart*, Pre-natal irradiation and childhood malignancy, in: British Journal of Cancer 31, 1975, S. 271 ff.

CHILDHOOD LEUKAEMIA FOLLOWING MEDICAL DIAGNOSTIC EXPOSURE TO IONISING RADIATION *IN UTERO* OR AFTER BIRTH

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Sackville Street, Manchester M60 1QD, UK

Radiation Protection Dosimetry (2008), pp. 1–9

Table 1. Details of the case–control studies that have investigated the influence upon the risk of leukaemia in childhood of antenatal diagnostic exposure to ionising radiation, and the unadjusted relative risk of childhood leukaemia associated with such exposure that may be derived from each study.

Case–control study	Study Précis	Number of cases (exposed/total)	Amount of statistical information[a]	Relative risk[b] (unadjusted)	95% confidence interval[c]
Bithell and Stewart, 1975(10)	GB (OSCC); deaths, 1953–1967	569/4052	297	1.49	(1.33, 1.67)
Hirayama, 1979(14)[d]	Japan; incident cases, 1969–1977	738/4628	296	1.60	(1.42, 1.79)
Monson and MacMahon, 1984(15)	NE USA; deaths, 1947–1960	94/704	76	1.48	(1.18, 1.85)
Robinette and Jablon, 1976(16)[e]	USA (military hospitals); deaths, 1960–1969	64/429	44	1.08	(0.80, 1.46)
Naumburg *et al.*, 2001(17)	Sweden; incident cases, 1973–1989	68/624	29	1.13	(0.78, 1.63)
Roman *et al.*, 2005(18)	England & Wales (UKCCS); incident cases, 1992–1996	37/1196	28	1.05	(0.73, 1.52)
Shu *et al.*, 2002(19)	North America (CCG); ALL incident cases, 1989–1993	55/1809	26	1.16	(0.79, 1.71)
Polhemus and Koch, 1959(20)	Los Angeles; incident cases, 1950–1957	66/251	23	1.23	(0.82, 1.85)
Infante-Rivard, 2003(21)	Quebec; ALL incident cases, 1980–1998	42/701	21	0.85	(0.56, 1.30)
Hopton *et al.*, 1985(22)	N England; leukaemia and lymphoma, incident cases, 1980–1983	37/245	19	1.35	(0.86, 2.11)
Kaplan, 1958(23)	California; acute leukaemia deaths, 1955–1956	40/150	17	1.60	(1.00, 2.57)
Graham *et al.*, 1966(24)	USA ‘tri-state’; incident cases, 1959–1962	27/313	17	1.40	(0.87, 2.27)
van Steensel-Moll *et al.*, 1985(25)	Netherlands; ALL incident cases, 1973–1979	41/517	12	2.22	(1.27, 3.88)
Ford *et al.*, 1959(26)	Louisiana; deaths, 1951–1955	21/78	11	1.71	(0.96, 3.06)
Stewart, 1973(27); Mole, 1974(28)	GB (OSCC) **twins**; deaths, 1953–1964	51/70	11	2.17	(1.19, 3.95)
Salonen, 1976(29)	Finland; incident cases, 1959–1968	15/300	10	1.01	(0.54, 1.90)
Ager *et al.*, 1965(30)	Minnesota; deaths, 1953–1957	20/107	10	1.27	(0.68, 2.37)
Roman *et al.*, 1997(31)	S England; incident cases, 1962–1992	16/143	10	0.72	(0.39, 1.34)
Golding *et al.*, 1992(32)	SW England; incident cases, 1971–1991	14/63	9	2.03	(1.06, 3.88)
Fajardo-Gutiérrez *et al.*, 1993(33)	Mexico City; incident cases	16/80	7	1.89	(0.91, 3.95)
Magnani *et al.*, 1990(34)	Turin; AL incident cases, 1981–1984	10/164	6	1.09	(0.49, 2.44)
Rodvall *et al.*, 1990(35)	Swedish **twins**; incident cases, 1952–1983	10/27	5	1.83	(0.77, 1.47)
Gunz and Atkinson, 1964(36)	New Zealand; incident cases, 1958–1961	14/102	5	1.11	(0.47, 2.61)
Shu *et al.*, 1988(37)	Shanghai; incident cases, 1974–1986	8/309	4	1.86	(0.71, 4.87)
Roman *et al.*, 1993(38)	S England; leukaemia plus NHL incident cases, 1972–1989	5/37	4	1.12	(0.40, 3.15)
Shu *et al.*, 1994(39)	North America (CCG); infant AL incident cases, 1983–1988	7/291	4	1.10	(0.43, 2.83)
Harvey *et al.*, 1985(40)	Connecticut **twins**; incident cases, 1935–1981	5/13	3	1.81	(0.55, 5.99)
Wells and Steer, 1961(41)	New York; incident cases	4/77	3	0.72	(0.22, 2.34)
Kjeldsberg, 1957(42)	Norway; incident cases, 1946–1956	5/55	3	0.59	(0.18, 1.93)
McKinney *et al.*, 1999(43)	Scotland (UKCCS), incident cases, 1991–1994	6/144	3	2.31	(0.69, 7.70)
van Duijn *et al.*, 1994(44)	Netherlands; ANLL incident cases, 1973–1979	6/80	3	2.35	(0.78, 6.99)
Murray *et al.*, 1959(45)	New York; deaths, 1940–1957	3/65	2	0.92	(0.25, 3.36)
Gardner *et al.*, 1990(46)	NW England; incident cases, 1950–1985	3/20	2	1.19	(0.31, 4.55)
Meinert *et al.*, 1999(47)	Germany; incident cases, 1980–1994	3/1184	2	0.93	(0.24, 3.60)
Shu *et al.*, 1994(48)	Shanghai; AL incident cases, 1986–1991	7/166	2	2.39	(0.61, 9.41)

The studies are ranked by the amount of statistical information used in the derivation of the relative risk (after Bithell(13)). UKCCS, United Kingdom Childhood Cancer Study; CCG, Childrens Cancer Group; AL, acute leukaemia; ALL, acute lymphoblastic leukaemia; ANLL, acute non-lymphoblastic leukaemia; NHL, non-Hodgkin's lymphoma.

[a] The reciprocal of the sum of the reciprocals of the number of exposed cases, the number of unexposed cases, the number of exposed controls and the number of unexposed controls.

[b] The crude odds ratio derived from the reported case–control study data, which is approximately the unadjusted relative risk.

[c] Woolf approximate 95% confidence interval for the crude odds ratio.

[d] Reported in conference proceedings only.

[e] Reported in an abstract only.

BMJ, Volume 331, 9 July 2005, 77-80

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 and the international study group

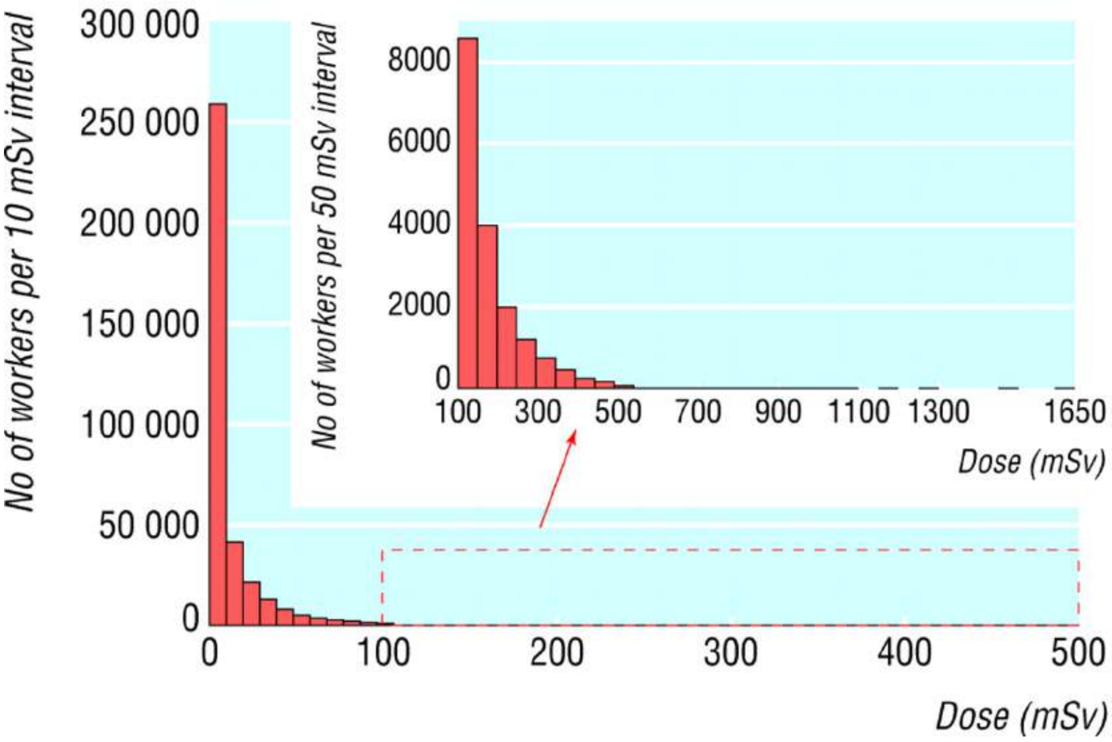
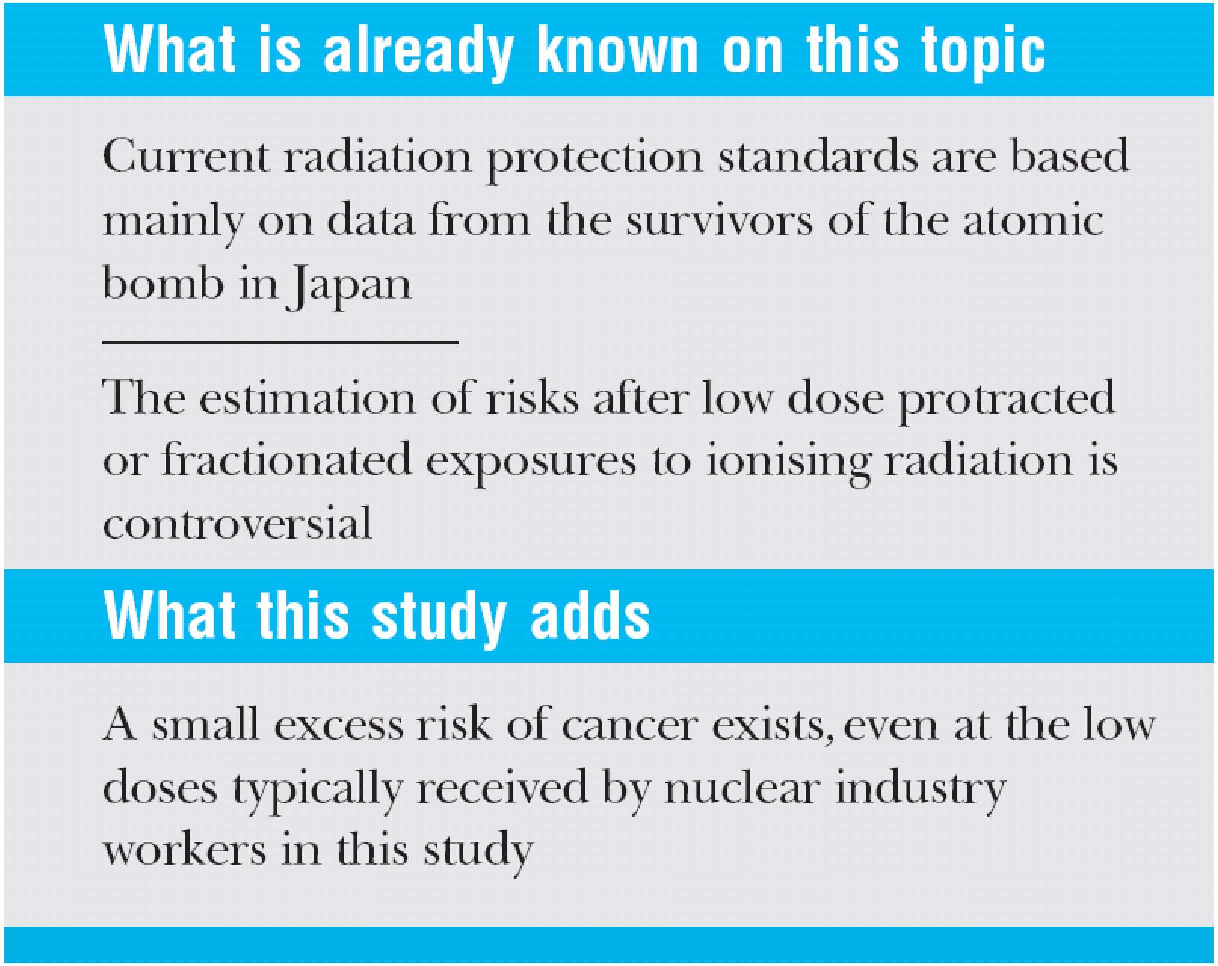


Fig 1 Distribution of cumulative radiation doses among workers included in the analyses

(N= 407,591; 5.2 mio. person years)

>90 % < 50 mSv

< 0.1% >500 mSv



What is already known on this topic

Current radiation protection standards are based mainly on data from the survivors of the atomic bomb in Japan

The estimation of risks after low dose protracted or fractionated exposures to ionising radiation is controversial

What this study adds

A small excess risk of cancer exists, even at the low doses typically received by nuclear industry workers in this study

Abstract: 1-2% of all cancer deaths in the cohort caused by occupational radiation exposure *(appr. 1000-2000)*

(roughly 110,000 cancer deaths for other reasons

BMJ, Vol. 331, 9 July 2005, 77-80

EDITOR'S CHOICE

Is cancer risk
expected?

P Jacob,[1] W Rühm,[1] L

See Editorial, p 785

[1] Hemholtz Zentrum München, Institute of Radiation Protection, Neuherberg, Germany; [2] Federal Office for Radiation Protection, Department of Radiation Protection and Health, Oberschleißheim, Germany; [3] Johannes Gutenberg – University Mainz, Institute of Medical Biostatistics, Epidemiology and Informatics, Mainz, Germany

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Accepted 13 May 2009
Published Online First
30 June 2009

ABSTRACT

Occupational exposures to ionisi
at low-dose rates and may accu
up to several hundred milligray.
The objective of the present stu
evidence of cancer risks from su
moderate-dose (LDRMD) exposu
Our literature search for primary
on cancer incidence and mortali
exposures included publications
an update of the UK National Re
Workers study. For each (LDRM
the risk for the same types of c
bomb survivors with the same g
matched quantities for dose, me
mean age at exposure. A combi
of the excess relative risk per dos
to the corresponding value for th
was 1.21 (90% CI 0.51 to 1.90)
The present analysis does not co
per dose for LDRMD exposures
atomic bomb survivors. This resu
risk values currently assumed for

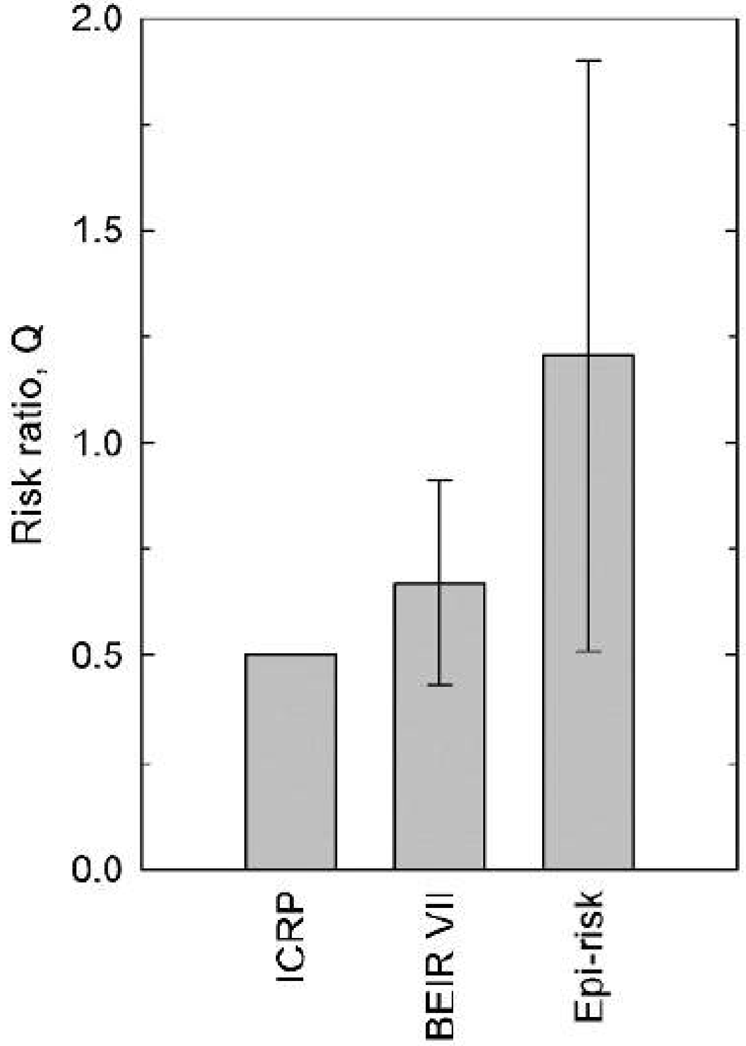


Figure 3 Ratio *Q* of excess relative risk-per-dose values for cancer after low-dose-rate, moderate-dose exposures and after acute, high-dose exposures as recommended by the International Commission on Radiological Protection (ICRP),[2] used by BEIR VII (95% CI),[3] and derived in the present analysis from epidemiological studies (epi-risk, 90% CI).

Occup Environ Med 2009;**66**:789–796. doi:10.1136/oem.2008.043265

Is cancer risk of radiation workers larger than expected?

P Jacob,[1] W Rühm,[1] L Walsh,[2] M Blettner,[3] G Hammer,[3] H Zeeb[3]

Occup Environ Med 2009;**66**:789–796. doi:10.1136/oem.2008.043265

What this paper adds

- Occupational exposures to ionising radiation occur normally at low-dose rate and may sum up to moderate doses in the order of 100 mGy.
- Limits of occupational exposures are based on the assumption that cancer risk factors are lower than for the atomic bomb survivors by a factor of two.
- Twelve recent epidemiological studies on cancer after low-dose-rate, moderate-dose exposures were included in this analysis of cancer risks related to such exposures.
- The studies provide evidence that cancer risk factors for occupational exposures are not lower than for atomic bomb survivors.
- The new evidence for cancer risks should be taken into account in optimisation procedures for the use of radionuclides and ionising radiation at the work place and in medicine.

Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study

Klervi Leuraud, David B Richardson, Elisabeth Cardis, Robert D Daniels, Michael Gillies, Jacqueline A O'Hagan, Ghassan B Hamra, Richard Haylock, Dominique Laurier, Monika Moissonnier, Mary K Schubauer-Berigan, Isabelle Thierry-Chef, Ausrele Kesminiene

Methods We assembled a cohort of 308 297 radiation-monitored workers employed for at least 1 year by the Atomic Energy Commission, AREVA Nuclear Cycle, or the National Electricity Company in France, the Departments of Energy and Defence in the USA, and nuclear industry employers included in the National Registry for Radiation Workers in the UK. The cohort was followed up for a total of 8·22 million person-years. We ascertained deaths caused by leukaemia, lymphoma, and multiple myeloma. We used Poisson regression to quantify associations between estimated red bone marrow absorbed dose and leukaemia and lymphoma mortality.

Findings Doses were accrued at very low rates (mean 1·1 mGy per year, SD 2·6). The excess relative risk of leukaemia mortality (excluding chronic lymphocytic leukaemia) was 2·96 per Gy (90% CI 1·17–5·21; lagged 2 years), most notably because of an association between radiation dose and mortality from chronic myeloid leukaemia (excess relative risk per Gy 10·45, 90% CI 4·48–19·65).

Interpretation This study provides strong evidence of positive associations between protracted low-dose radiation exposure and leukaemia.

www.thelancet.com/haematology Published online June 22, 2015 http://dx.doi.org/10.1016/S2352-3026(15)00094-0

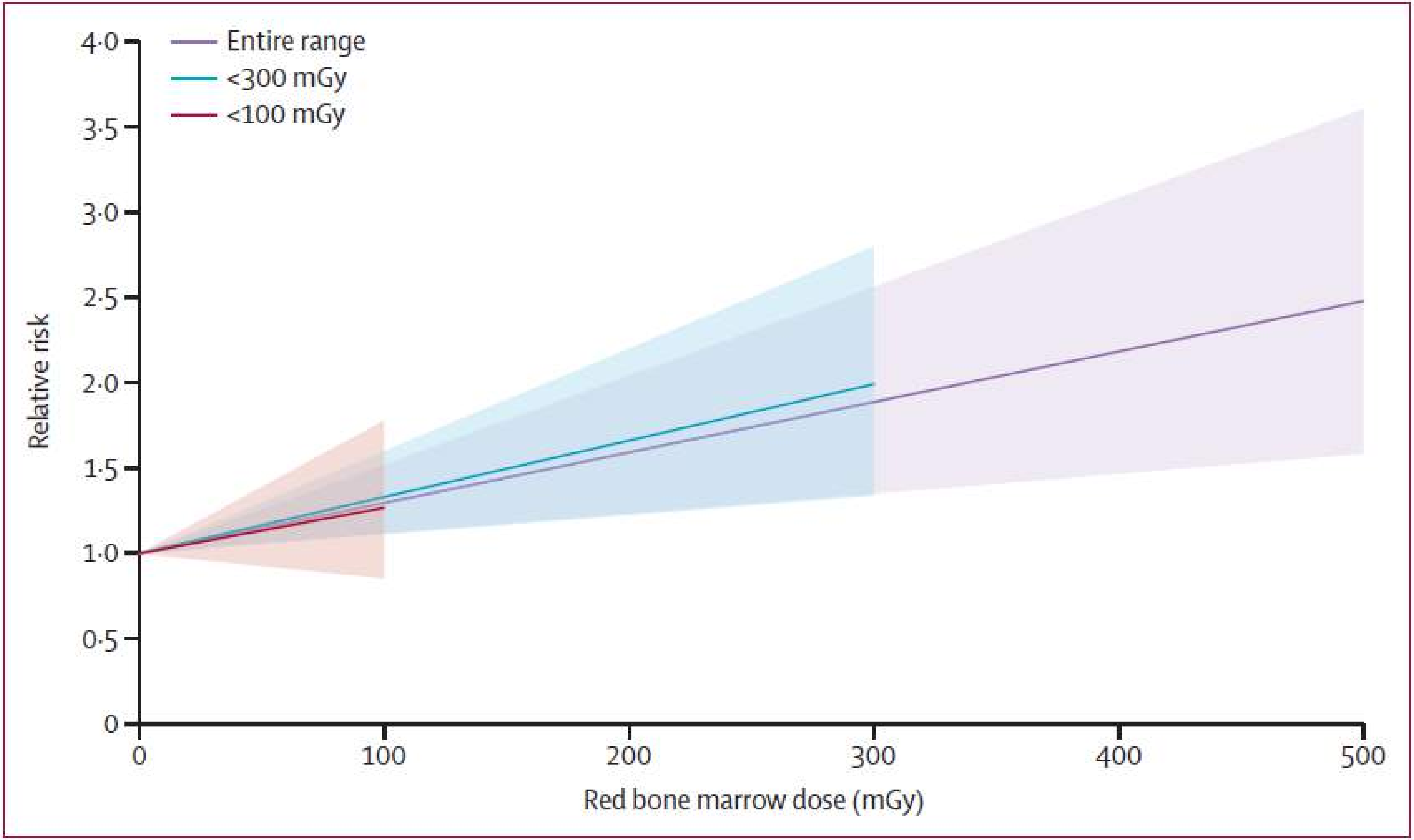


Figure: **Relative risk of leukaemia excluding chronic lymphocytic leukaemia associated with 2-year lagged cumulative red bone marrow dose**

The lines are the fitted linear dose–response model and the shading represents the 90% CIs.

Implications of all the available evidence

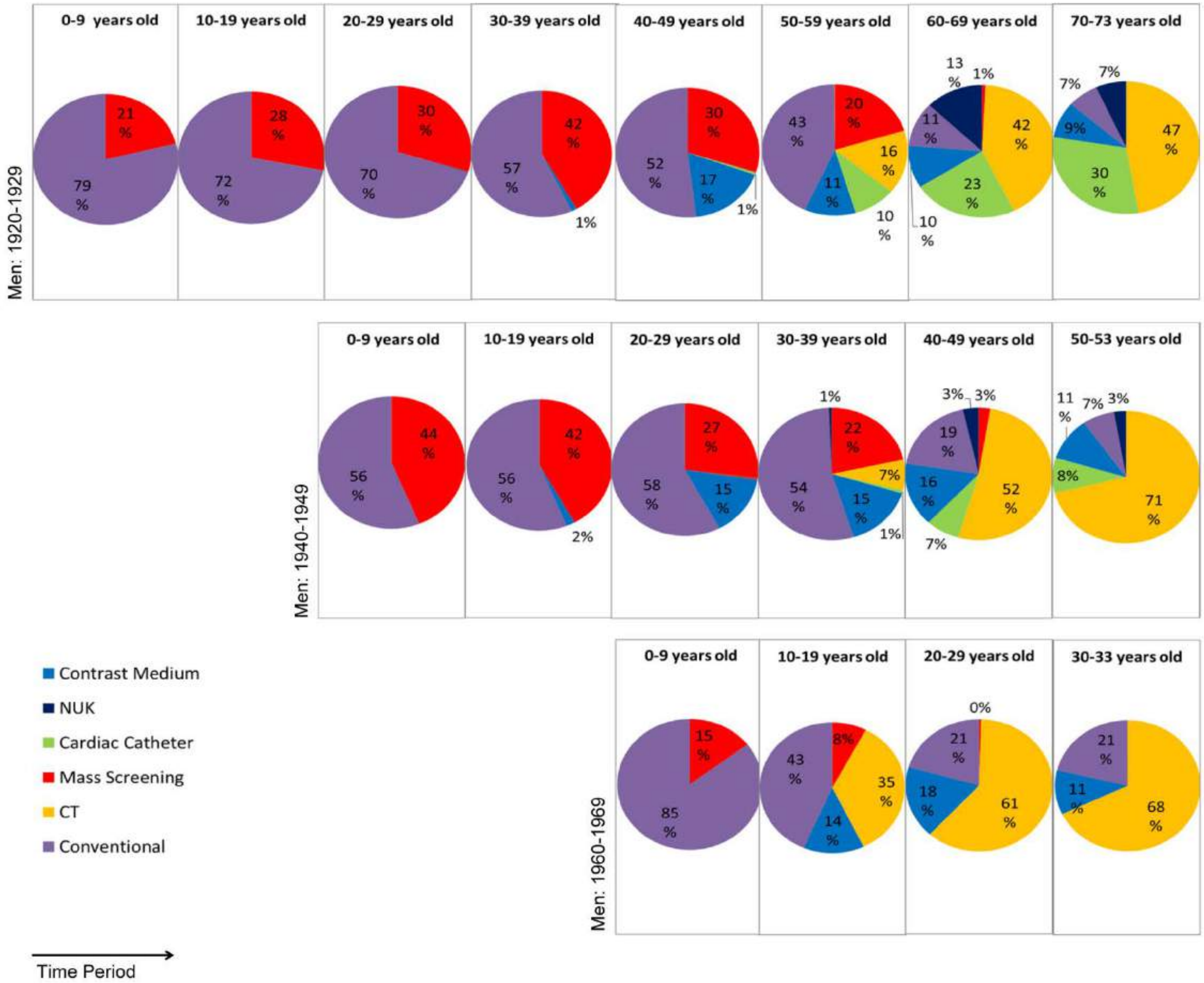
The present study provides strong evidence of a positive association between radiation exposure and leukaemia even for low-dose exposure. This finding shows the importance of adherence to the basic principles of radiation protection—to optimise protection to reduce exposures as much as reasonably achievable and—in the case of patient exposure—to justify that the exposure does more good than harm.

www.thelancet.com/haematology Published online June 22, 2015 http://dx.doi.org/10.1016/S2352-3026(15)00094-0

Distribution of red bon marrow dose: Males

Kalender-
jahre

1920- 1930- 1940- 1950- 1960- 1970- 1980- 1990-



Hoffmann W et al., PLOS one, 8.11 (2013), e78027 (RM 1742)

Projected Cancer Risks From Computed Tomographic Scans Performed in the United States in 2007

Amy Berrington de González, DPhil; Mahadevappa Mahesh, MS, PhD; Kwang-Pyo Kim, PhD; Mythreyi Bhargavan, PhD; Rebecca Lewis, MPH; Fred Mettler, MD; Charles Land, PhD

Background: The use of computed tomographic (CT) scans in the United States (US) has increased more than 3-fold since 1993 to approximately 70 million scans annually. Despite the great medical benefits, there is concern about the potential radiation-related cancer risk. We conducted detailed estimates of the future cancer risks from current CT scan use in the US according to age, sex, and scan type.

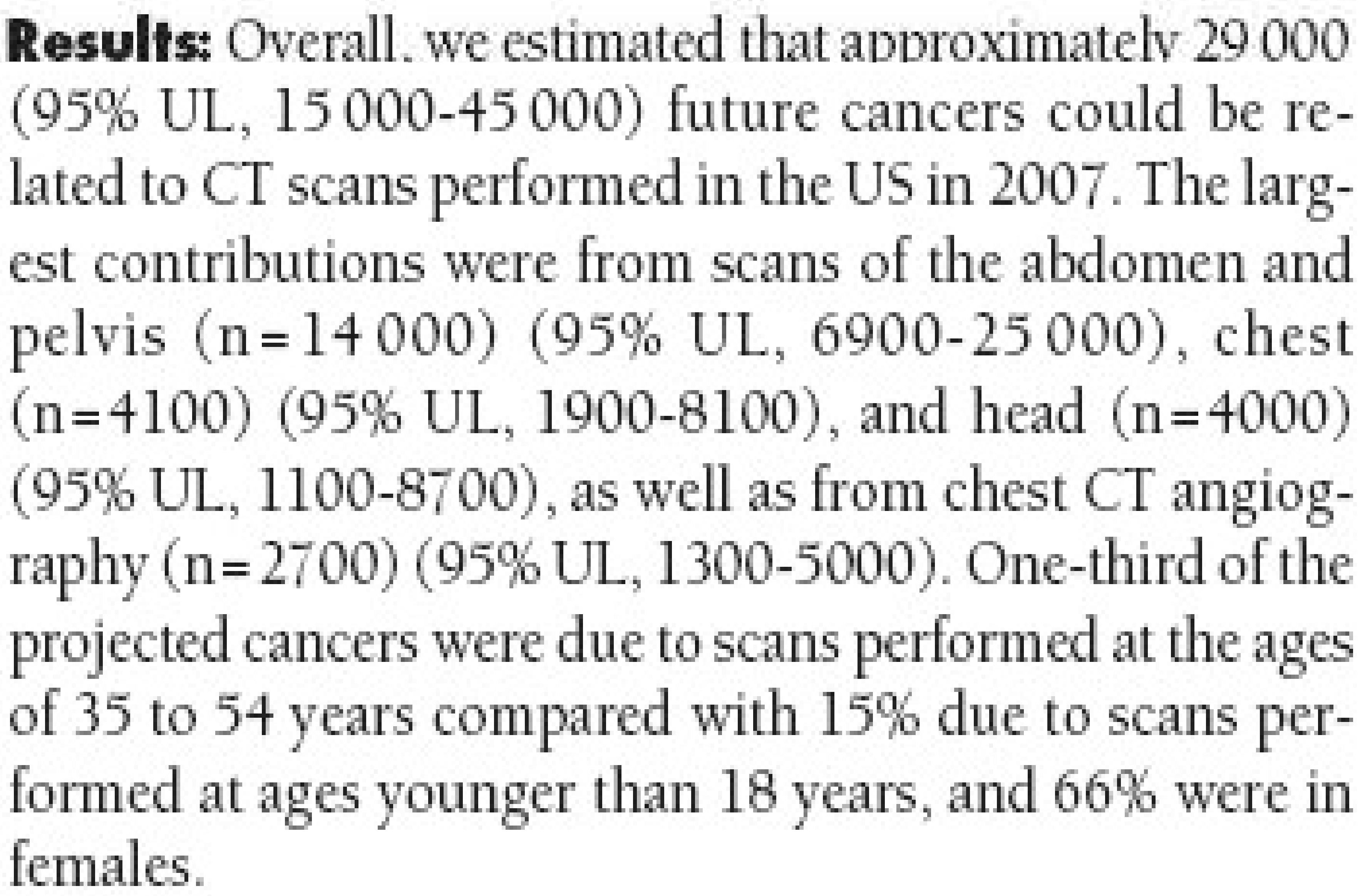
Methods: Risk models based on the National Research Council's "Biological Effects of Ionizing Radiation" report and organ-specific radiation doses derived from a national survey were used to estimate age-specific cancer risks for each scan type. These models were combined with age- and sex-specific scan frequencies for the US in 2007 obtained from survey and insurance claims data. We estimated the mean number of radiation-related incident cancers with 95% uncertainty limits (UL) using Monte Carlo simulations.

Results: Overall, we estimated that approximately 29 000 (95% UL, 15 000-45 000) future cancers could be related to CT scans performed in the US in 2007. The largest contributions were from scans of the abdomen and pelvis (n=14 000) (95% UL, 6900-25 000), chest (n=4100) (95% UL, 1900-8100), and head (n=4000) (95% UL, 1100-8700), as well as from chest CT angiography (n=2700) (95% UL, 1300-5000). One-third of the projected cancers were due to scans performed at the ages of 35 to 54 years compared with 15% due to scans performed at ages younger than 18 years, and 66% were in females.

Conclusions: These detailed estimates highlight several areas of CT scan use that make large contributions to the total cancer risk, including several scan types and age groups with a high frequency of use or scans involving relatively high doses, in which risk-reduction efforts may be warranted.

Arch Intern Med. 2009;169(22):2071-2077

Quelle: Berrington de,G.A. et al.: Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med, 169 (22), 2009, 2071-7.



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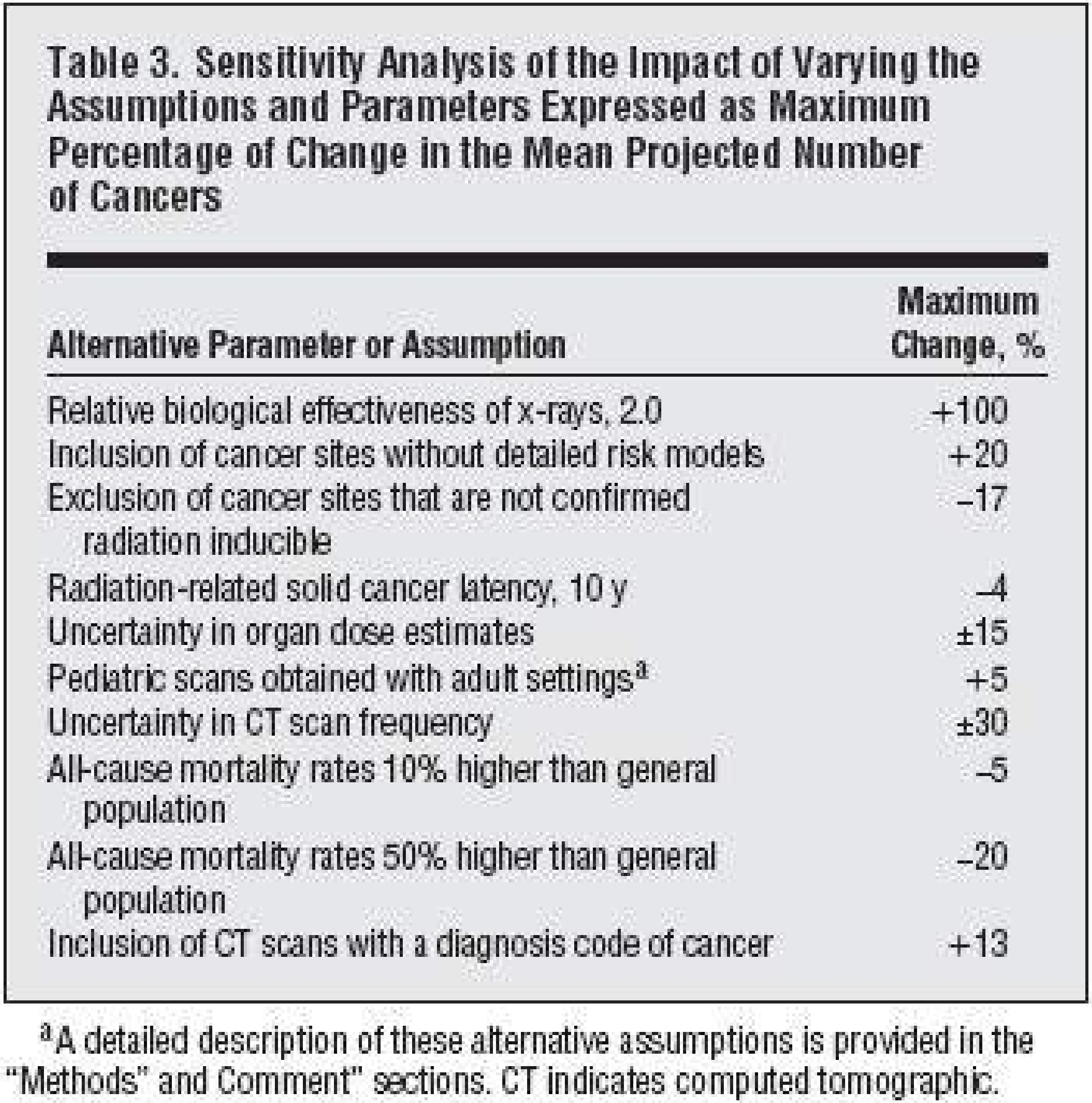
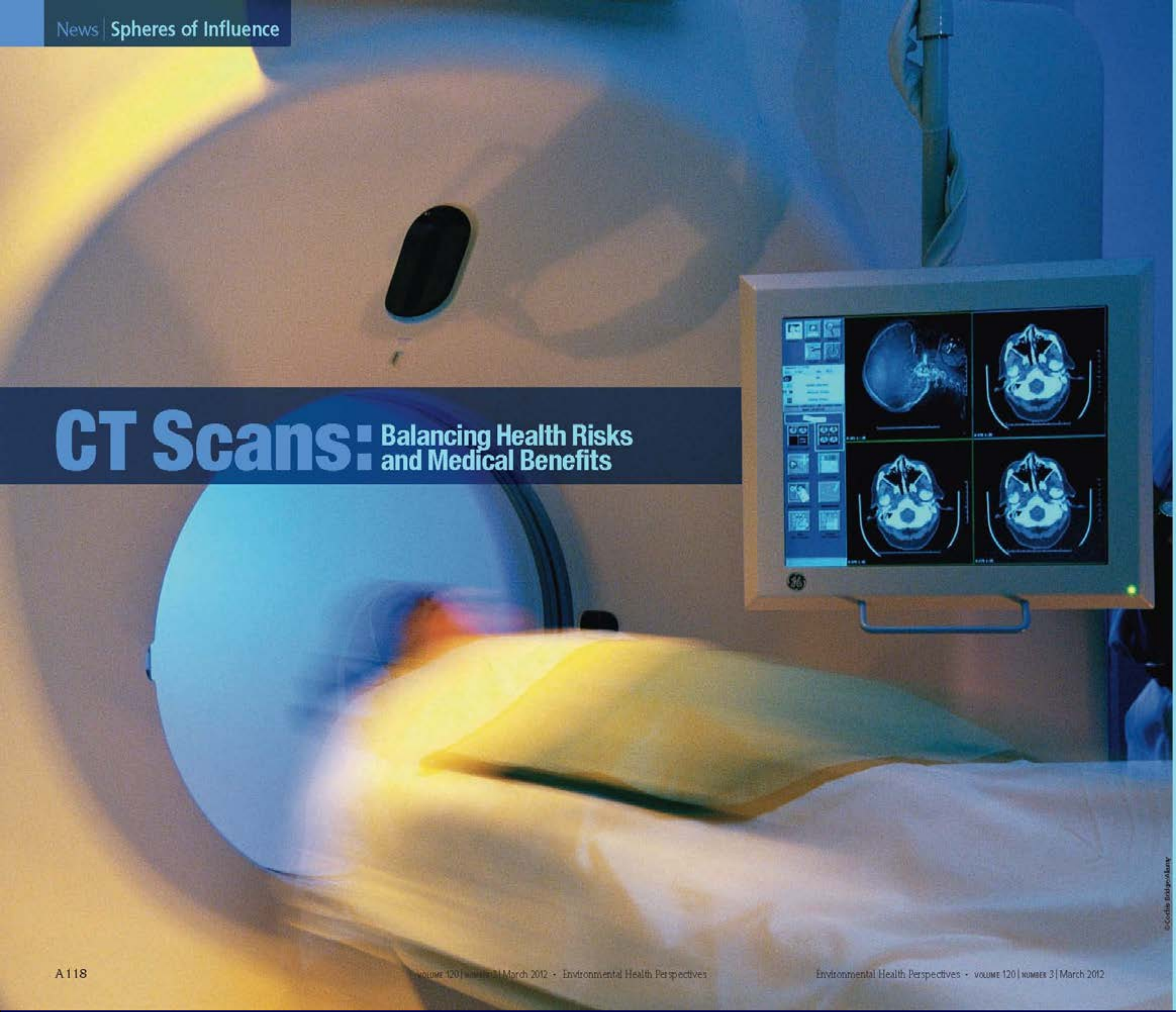


Table 3. Sensitivity Analysis of the Impact of Varying the Assumptions and Parameters Expressed as Maximum Percentage of Change in the Mean Projected Number of Cancers

Alternative Parameter or Assumption	Maximum Change, %
Relative biological effectiveness of x-rays, 2.0	+100
Inclusion of cancer sites without detailed risk models	+20
Exclusion of cancer sites that are not confirmed radiation inducible	−17
Radiation-related solid cancer latency, 10 y	−4
Uncertainty in organ dose estimates	±15
Pediatric scans obtained with adult settings[a]	+5
Uncertainty in CT scan frequency	±30
All-cause mortality rates 10% higher than general population	−5
All-cause mortality rates 50% higher than general population	−20
Inclusion of CT scans with a diagnosis code of cancer	+13

[a] A detailed description of these alternative assumptions is provided in the "Methods" and Comment" sections. CT indicates computed tomographic.

Quelle: Berrington de,G.A. et al.: Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med, 169 (22), 2009, 2071-7.



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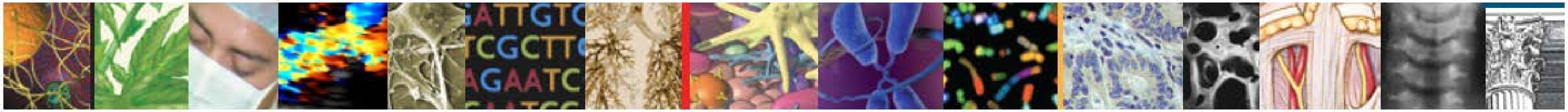
CT Scans: Balancing Health Risks and Medical Benefits

Computed tomography (CT) has been a boon for medical care. By generating detailed anatomical pictures, the technology can improve diagnoses, limit unneeded medical procedures, and enhance treatment. However, CT scans also dose patients with ionizing radiation, a known human carcinogen, posing a potential downside for public health. Mounting health worries over radiation risks are now driving efforts to limit avoidable CT scans and to reduce radiation doses where possible. "There's a national focus on this issue right now," says Marilyn Goske, a professor of radiology at Cincinnati Children's Hospital Medical Center and chairwoman of the Image Gently campaign, a pediatric education and awareness campaign from the Alliance for Radiation Safety in Pediatric Imaging.

In December 2011 the Institute of Medicine (IOM) published a report concluding that ionizing radiation contributes more to the development of breast cancer than any other type of routine environmental exposure.[1] About half the U.S. annual exposure to ionizing radiation comes from natural sources, including cosmic rays, but most of the rest comes from medical imaging and from CT scans in particular.[1] The IOM cited research by Amy Berrington de González, a senior investigator in the Radiation Epidemiology Branch of the National Cancer Institute (NCI), whose calculations suggest that the CT scans performed in the United States in 2007 might produce up to 29,000 cancers in the future, about 6% of them in the breast and the remainder in the lungs, brain, and other organs.[2]

But the spotlight on CT safety has also drawn a backlash from those who say the risks are overblown. On 13 December 2011 the American Association of Physicists in Medicine (AAPM) issued a statement claiming that



The NEW ENGLAND JOURNAL of MEDICINE

Perspective

JULY 1, 2010

Is Computed Tomography Safe?

Rebecca Smith-Bindman, M.D.

„… We found that the risk of cancer from a single CT scan could be as high as 1 in 80 — unacceptably high, given the capacity to reduce these doses. …“

„… Evidence suggests the radiation dose from CT could be reduced by 50% or more without reducing diagnostic accuracy.[4]

„… We need to establish diagnostic reference levels, on the basis of clinically relevant outcomes and safety, not the creation of the greatest-quality images, if such quality does not improve outcomes. …“

„… the FDA could take the lead in creating standards and assessing compliance. Facilities that could not meet the standards should not be certified to conduct CT. …“

Radiati
subseq
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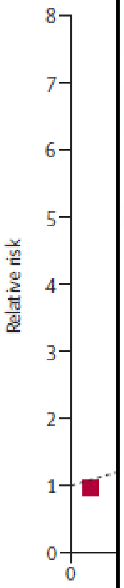
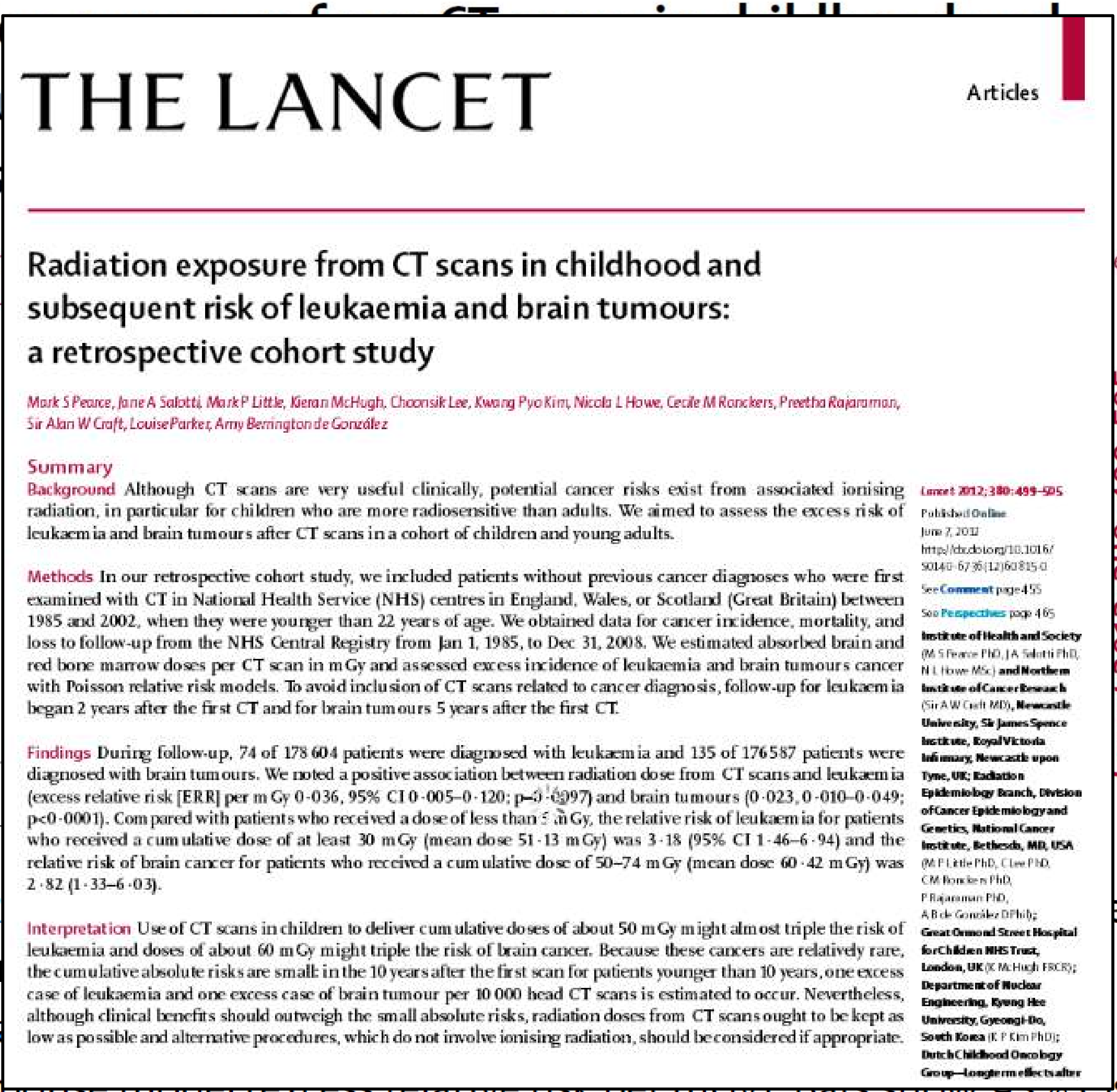
Mark S Pearce, Jar … eetha Rajaraman,
Sir Alan W Craft, L





THE LANCET

Articles

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Pearce, Jane A Salotti, Mark P Little, Kieran McHugh, Choonsik Lee, Kwang Pyo Kim, Nicola L Howe, Cecile M Ronckers, Preetha Rajaraman, Sir Alan W Craft, Louise Parker, Amy Berrington de González

Summary

Background Although CT scans are very useful clinically, potential cancer risks exist from associated ionising radiation, in particular for children who are more radiosensitive than adults. We aimed to assess the excess risk of leukaemia and brain tumours after CT scans in a cohort of children and young adults.

Methods In our retrospective cohort study, we included patients without previous cancer diagnoses who were first examined with CT in National Health Service (NHS) centres in England, Wales, or Scotland (Great Britain) between 1985 and 2002, when they were younger than 22 years of age. We obtained data for cancer incidence, mortality, and loss to follow-up from the NHS Central Registry from Jan 1, 1985, to Dec 31, 2008. We estimated absorbed brain and red bone marrow doses per CT scan in mGy and assessed excess incidence of leukaemia and brain tumours cancer with Poisson relative risk models. To avoid inclusion of CT scans related to cancer diagnosis, follow-up for leukaemia began 2 years after the first CT and for brain tumours 5 years after the first CT.

Findings During follow-up, 74 of 178 604 patients were diagnosed with leukaemia and 135 of 176 587 patients were diagnosed with brain tumours. We noted a positive association between radiation dose from CT scans and leukaemia (excess relative risk [ERR] per mGy 0·036, 95% CI 0·005–0·120; p=0·0097) and brain tumours (0·023, 0·010–0·049; p<0·0001). Compared with patients who received a dose of less than 5 mGy, the relative risk of leukaemia for patients who received a cumulative dose of at least 30 mGy (mean dose 51·13 mGy) was 3·18 (95% CI 1·46–6·94) and the relative risk of brain cancer for patients who received a cumulative dose of 50–74 mGy (mean dose 60·42 mGy) was 2·82 (1·33–6·03).

Interpretation Use of CT scans in children to deliver cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy might triple the risk of brain cancer. Because these cancers are relatively rare, the cumulative absolute risks are small: in the 10 years after the first scan for patients younger than 10 years, one excess case of leukaemia and one excess case of brain tumour per 10 000 head CT scans is estimated to occur. Nevertheless, although clinical benefits should outweigh the small absolute risks, radiation doses from CT scans ought to be kept as low as possible and alternative procedures, which do not involve ionising radiation, should be considered if appropriate.

Lancet 2012; 380: 499–505

See **Comment** page 455

See **Perspectives** page 465

Institute of Health and Society (M S Pearce PhD, J A Salotti PhD, N L Howe MSc) **and Northern Institute of Cancer Research** (Sir A W Craft MD), **Newcastle University, Sir James Spence Institute, Royal Victoria Infirmary, Newcastle upon Tyne, UK; Radiation Epidemiology Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, MD, USA** (M P Little PhD, C Lee PhD, C M Ronckers PhD, P Rajaraman PhD, A B de González DPhil); **Great Ormond Street Hospital for Children NHS Trust, London, UK** (K McHugh FRCR); **Department of Nuclear Engineering, Kyung Hee University, Gyeongi-Do, South Korea** (K P Kim PhD); **Dutch Childhood Oncology Group—Long-term effects after**

Figure: R … estimated
radiatio
(A) Leuk
dose-res … (excess relative risk per mGy). Bars show 95% CIs.

Lancet 2012; 380: 499–505

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BMJ

BMJ 2013;346:f2360 doi: 10.1136/bmj.f2360 (Published 22 May 2013)

RESEARCH

BMJ Helping doctors make better decisions

Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians

John D Mathews *epidemiologist*[1], Anna V Forsythe *research officer*[1], Zoe Brady *medical physicist*[1,2], Martin W Butler *data analyst*[3], Stacy K Goergen *radiologist*[4], Graham B Byrnes *statistician*[5], Graham G Giles *epidemiologist*[6], Anthony B Wallace *medical physicist*[7], Philip R Anderson *epidemiologist*[8,9], Tenniel A Guiver *data analyst*[8], Paul McGale *statistician*[10], Timothy M Cain *radiologist*[11], James G Dowty *research fellow*[1], Adrian C Bickerstaffe *computer scientist*[1], Sarah C Darby *statistician*[10]

[1]School of Population and Global Health, University of Melbourne, Carlton, Vic 3053, Australia; [2]Department of Radiology, Alfred Health, Prahran, Vic, Australia; [3]Medical Benefits Scheme Analytics Section, Department of Health and Ageing, Canberra, ACT, Australia; [4]Department of Diagnostic Imaging, Southern Health, and Monash University Southern Clinical School, Clayton, Vic, Australia; [5]Biostatistics Group, International Agency for Research on Cancer, Lyon, France; [6]Cancer Epidemiology Centre, Cancer Council Victoria, Carlton, Vic, Australia; [7]Diagnostic Imaging and Nuclear Medicine Section, Australian Radiation Protection and Nuclear Safety Agency, Yallambie, Vic, Australia; [8]Data Linkage Unit, Australian Institute of Health and Welfare, Canberra, Australia; [9]Faculty of Health, University of Canberra, Canberra, Australia; [10]Clinical Trial Service Unit and Epidemiological Studies Unit, University of Oxford, Oxford, UK; [11]Medical Imaging, Royal Children's Hospital Melbourne, Parkville, Vic, Australia

Abstract

Objective To assess the cancer risk in children and adolescents following exposure to low dose ionising radiation from diagnostic computed

at younger ages ($P<0.001$ for trend). At 1-4, 5-9, 10-14, and 15 or more years since first exposure, IRRs were 1.35 (1.25 to 1.45), 1.25 (1.17 to 1.34), 1.14 (1.06 to 1.22), and 1.24 (1.14 to 1.34), respectively. The IRR

What is already known on this topic

CT scanning rates have risen substantially since the 1980s. Although large doses of ionising radiation are known to cause cancer, there is uncertainty about the risks following the lower doses from CT scans (5-50 mGy per organ)

A recent study of 180 000 young people exposed to CT scans in the United Kingdom found an increasing risk of leukaemia and brain cancer with increasing radiation dose

What this study adds

Among 680 000 Australians exposed to a CT scan when aged 0-19 years, cancer incidence was increased by 24% (95% confidence interval 20% to 29%) compared with the incidence in over 10 million unexposed people. The proportional increase in risk was evident at short intervals after exposure and was greater for persons exposed at younger ages

By 31 December 2007, with an average follow-up of 9.5 years after exposure, the absolute excess cancer incidence rate was 9.38 per 100 000 person years at risk

Incidence rates were increased for most individual types of solid cancer, and for leukaemias, myelodysplasias, and some other lymphoid cancers

individuals exposed to three or more scans was 3.5. (Web figure A shows corresponding results based on lag periods of five and 10 years)

BMJ

BMJ 2012;345:e5660 doi: 10.1136/bmj.e5660 (Published 6 September 2012)

Exposure to diagnostic radiation and risk of breast cancer among carriers of BRCA1/2 mutations: retrospective cohort study (GENE-RAD-RISK)

Anouk Pijpe *postdoctoral research fellow*[1], Nadine Andrieu *senior researcher*[2 3 4], Douglas F Easton *professor*[5], Ausrele Kesminiene *study coordinator*[6], Elisabeth Cardis *professor*[7], Catherine Noguès *oncogeneticist*[8], Marion Gauthier-Villars *oncogeneticist*[9], Christine Lasset *oncogeneticist*[10], Jean-Pierre Fricker *oncogeneticist*[11], Susan Peock *study coordinator*[5], Debra Frost *research assistant*[5], D Gareth Evans *professor*[12], Rosalind A Eeles *clinical cancer geneticist*[13], Joan Paterson *clinical geneticist*[14], Peggy Manders *postdoctoral research fellow*[1 15], Christi J van Asperen *clinical geneticist*[16], Margreet G E M Ausems *clinical geneticist*[17], Hanne Meijers-Heijboer *clinical geneticist*[18], Isabelle Thierry-Chef *researcher*[6], Michael Hauptmann *statistician*[1], David Goldgar *senior researcher*[19], Matti A Rookus *senior research fellow*[1], Flora E van Leeuwen *professor*[1], on behalf of GENEPSO, EMBRACE, and HEBON

BMJ

BMJ 2012;345:e5660 doi: 10.1136/bmj.e5660 (Published 6 September 2012)

Table 6| **Analyses of estimated cumulative breast dose of diagnostic radiation before age 30 and risk of breast cancer for BRCA1/2 mutation carriers who had never undergone mammography**

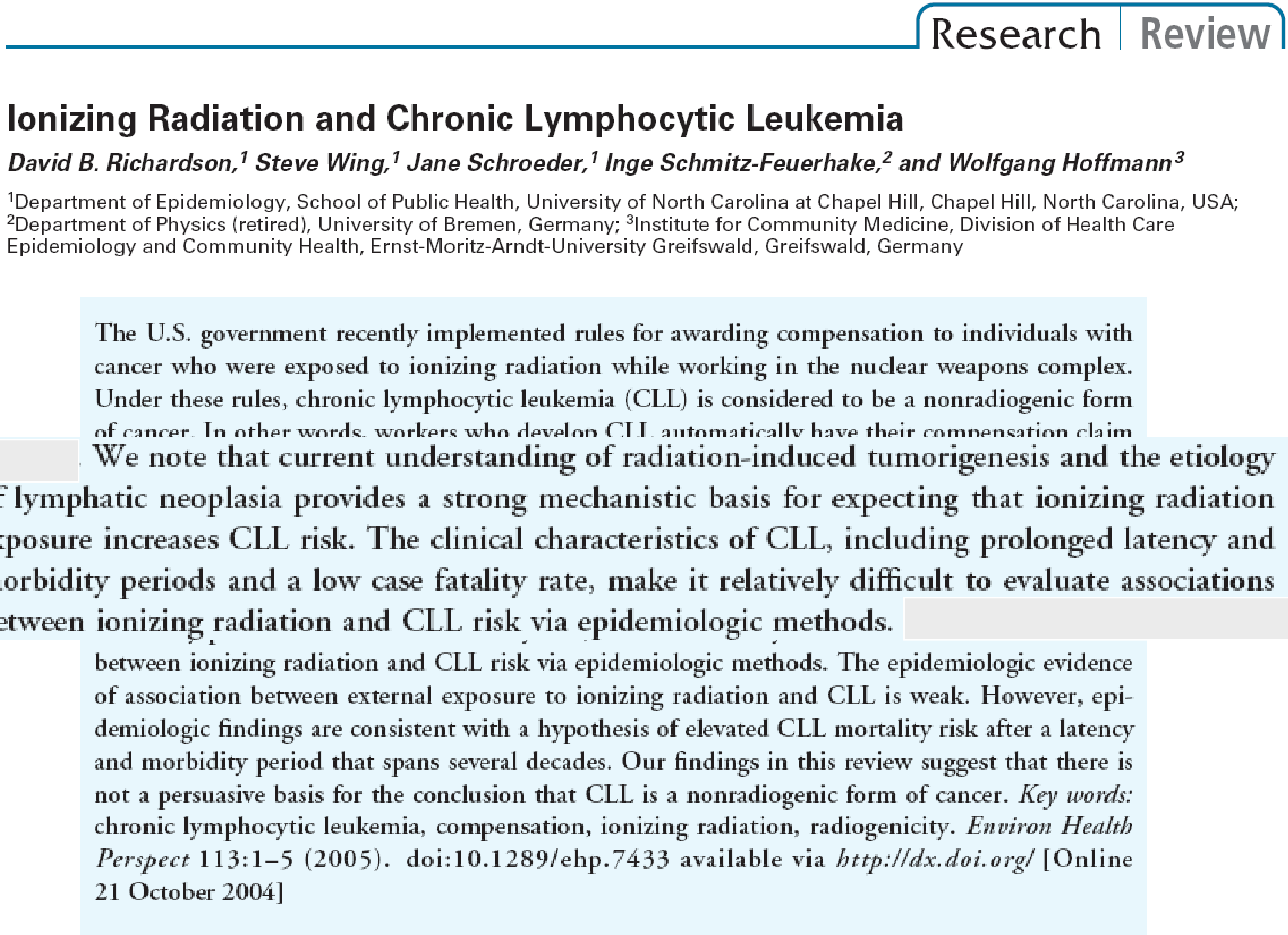
	Subcohort (n=955; 144 cases)*		
Exposure	**Person years**	**Cases**	**Unweighted hazard ratio (95% CI)†**
Never	1679	57	1.00
Ever	1412	58	1.65 (1.11 to 2.46)
Dose category:			
<0.0020 Gy	874	33	1.48 (0.94 to 2.33)
0.0020-0.0065 Gy	280	12	1.55 (0.81 to 2.98)
0.0066-0.0173 Gy	147	6	1.90 (0.69 to 5.21)
≥0.0174 Gy	109	7	4.16 (2.01 to 8.62)

* Subcohort includes carriers diagnosed or censored within five years before questionnaire completion, with follow-up being counted only during this five year period.

†Unweighted time varying Cox proportional hazards model, stratified for gene (BRCA1 and BRCA2), country, and birth cohort (<1955, 1955-61, 1962-68, >1968), clustered on family (816 clusters), and adjusted for age at entry in subcohort, parity (no children; 1-2 children; >2 children; time varying), and menopause (premenopausal; natural menopause; bilateral prophylactic oophorectomy; time varying); proportional hazards assumption for each covariate evaluated by inspecting ln(−ln(survival)) curve, and using goodness of fit test; missing values were coded as additional category.

③ Radiation epidemiology: quantifying risk

B. unexpected additional diseases



Research | Review

Ionizing Radiation and Chronic Lymphocytic Leukemia

David B. Richardson,[1] Steve Wing,[1] Jane Schroeder,[1] Inge Schmitz-Feuerhake,[2] and Wolfgang Hoffmann[3]

[1]Department of Epidemiology, School of Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA; [2]Department of Physics (retired), University of Bremen, Germany; [3]Institute for Community Medicine, Division of Health Care Epidemiology and Community Health, Ernst-Moritz-Arndt-University Greifswald, Greifswald, Germany

The U.S. government recently implemented rules for awarding compensation to individuals with cancer who were exposed to ionizing radiation while working in the nuclear weapons complex. Under these rules, chronic lymphocytic leukemia (CLL) is considered to be a nonradiogenic form of cancer. In other words, workers who develop CLL automatically have their compensation claim

We note that current understanding of radiation-induced tumorigenesis and the etiology of lymphatic neoplasia provides a strong mechanistic basis for expecting that ionizing radiation exposure increases CLL risk. The clinical characteristics of CLL, including prolonged latency and morbidity periods and a low case fatality rate, make it relatively difficult to evaluate associations between ionizing radiation and CLL risk via epidemiologic methods.

between ionizing radiation and CLL risk via epidemiologic methods.

The epidemiologic evidence of association between external exposure to ionizing radiation and CLL is weak. However, epidemiologic findings are consistent with a hypothesis of elevated CLL mortality risk after a latency and morbidity period that spans several decades. Our findings in this review suggest that there is not a persuasive basis for the conclusion that CLL is a nonradiogenic form of cancer.

Key words: chronic lymphocytic leukemia, compensation, ionizing radiation, radiogenicity. *Environ Health Perspect* 113:1–5 (2005). doi:10.1289/ehp.7433 available via *http://dx.doi.org/* [Online 21 October 2004]

Available online at www.sciencedirect.com

ScienceDirect

Leukemia Research 32 (2008) 523–525

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Editorial

Have we been wrong about ionizing radiation and chronic lymphocytic leukemia?

Terry J. Hamblin
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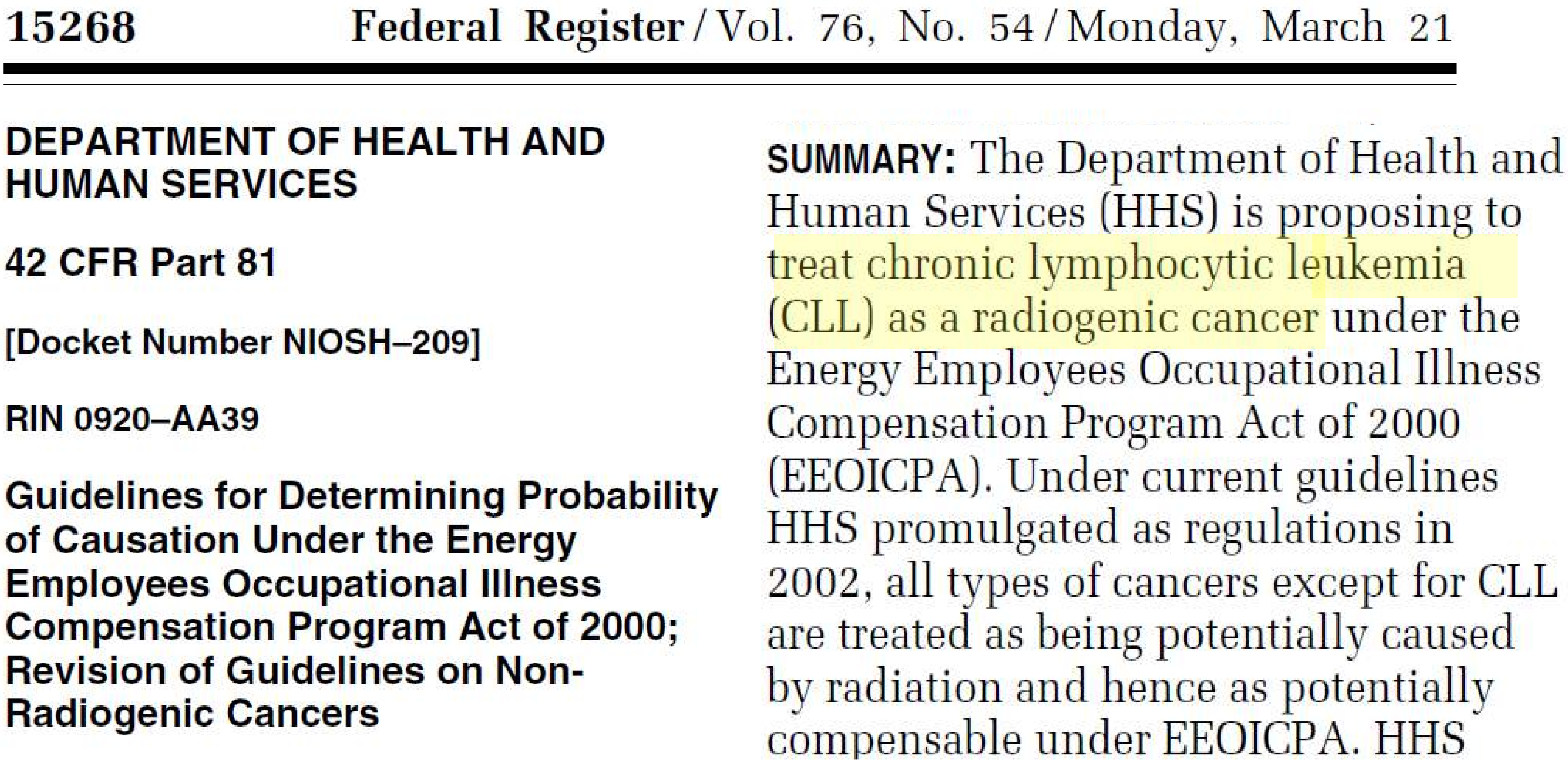
20 August 2007



15268 **Federal Register** / Vol. 76, No. 54 / Monday, March 21

DEPARTMENT OF HEALTH AND HUMAN SERVICES

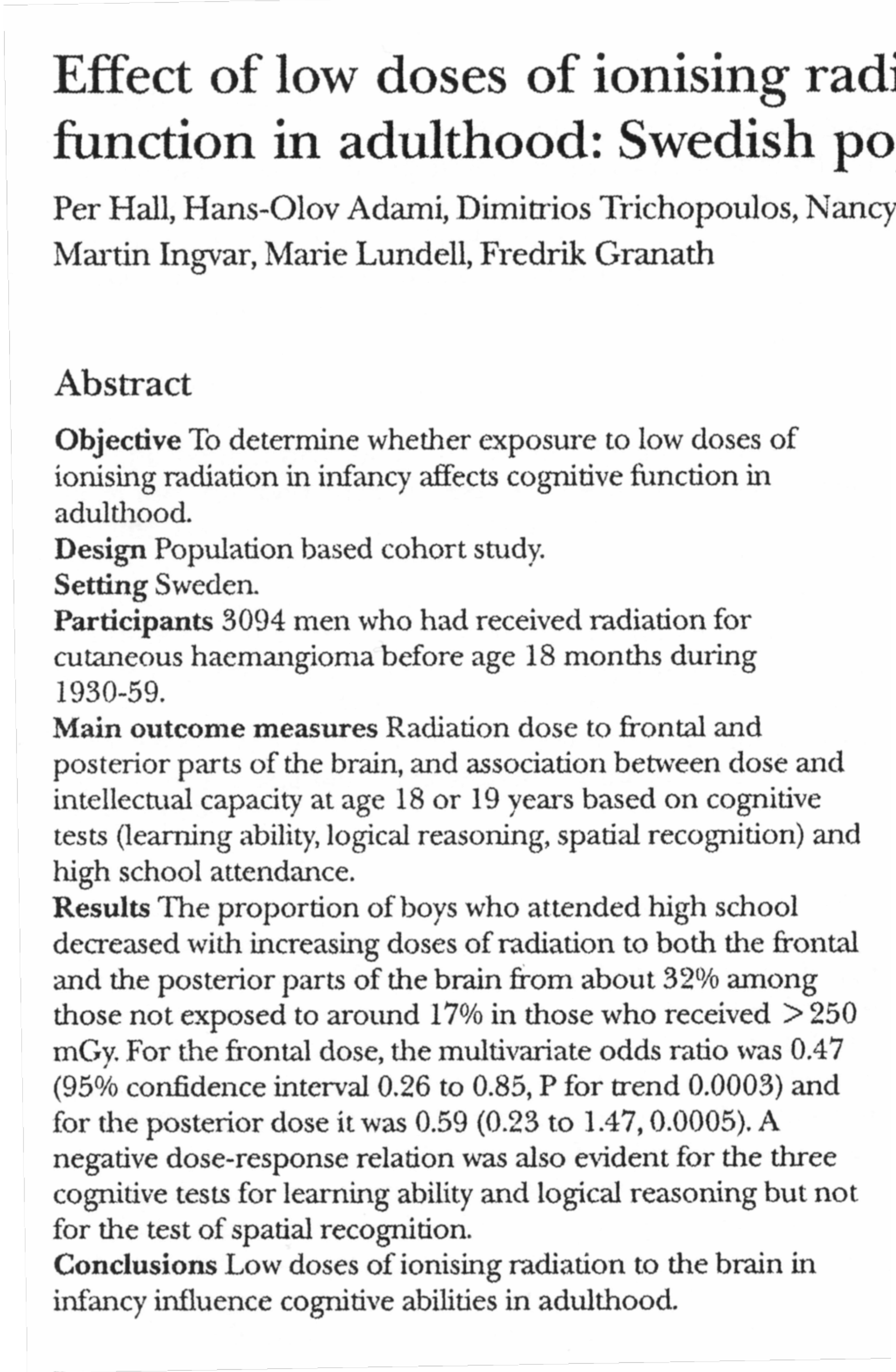
42 CFR Part 81

[Docket Number NIOSH–209]

RIN 0920–AA39

Guidelines for Determining Probability of Causation Under the Energy Employees Occupational Illness Compensation Program Act of 2000; Revision of Guidelines on Non-Radiogenic Cancers

SUMMARY: The Department of Health and Human Services (HHS) is proposing to treat chronic lymphocytic leukemia (CLL) as a radiogenic cancer under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA). Under current guidelines HHS promulgated as regulations in 2002, all types of cancers except for CLL are treated as being potentially caused by radiation and hence as potentially compensable under EEOICPA. HHS



Effect of low doses of ionising radiation in infancy on cognitive function in adulthood: Swedish population based cohort study

Per Hall, Hans-Olov Adami, Dimitrios Trichopoulos, Nancy L Pedersen, Pagona Lagiou, Anders Ekbom, Martin Ingvar, Marie Lundell, Fredrik Granath

Abstract

Objective To determine whether exposure to low doses of ionising radiation in infancy affects cognitive function in adulthood.
Design Population based cohort study.
Setting Sweden.
Participants 3094 men who had received radiation for cutaneous haemangioma before age 18 months during 1930-59.
Main outcome measures Radiation dose to frontal and posterior parts of the brain, and association between dose and intellectual capacity at age 18 or 19 years based on cognitive tests (learning ability, logical reasoning, spatial recognition) and high school attendance.
Results The proportion of boys who attended high school decreased with increasing doses of radiation to both the frontal and the posterior parts of the brain from about 32% among those not exposed to around 17% in those who received >250 mGy. For the frontal dose, the multivariate odds ratio was 0.47 (95% confidence interval 0.26 to 0.85, P for trend 0.0003) and for the posterior dose it was 0.59 (0.23 to 1.47, 0.0005). A negative dose-response relation was also evident for the three cognitive tests for learning ability and logical reasoning but not for the test of spatial recognition.
Conclusions Low doses of ionising radiation to the brain in infancy influence cognitive abilities in adulthood.

3094 males after radiation therapy of hemangioma before 18th month

Comprehensive retrospective dose assessment (mean brain dose < 100, max.>250 mGy)

High school attendance, military cognitive tests (learning ability, logical reasoning)

Risks consistently increased

Limited impact of confounding

Stat. sign. trends

Higher risks for hemangioma in frontal brain

Mean organ dose similar to organ dose in diagnostic CT for young children.

BMJ 328(2004), 19-24, bmj.com

What is already known on this topic

High doses of ionising radiation to the developing human brain cause mental retardation

It is unknown whether low level exposure in infancy has more subtle effects on cognitive function

What this study adds

Intellectual development is adversely affected when the infant brain is exposed to ionising radiation at doses equivalent to those from computed tomography of the skull

Diagnostic evaluation of children with minor head injures needs to be re-evaluated

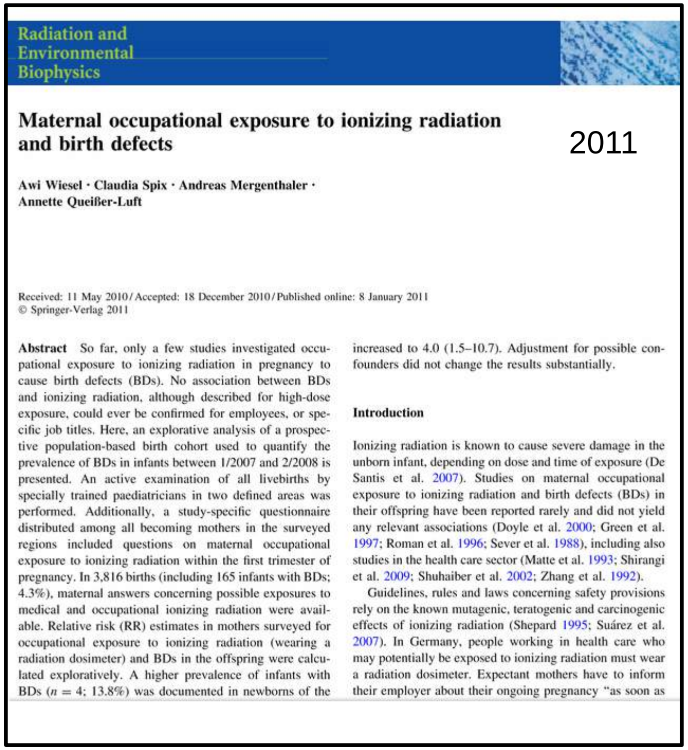
BMJ 328(2004), 19-24, bmj.com

Radiat Environ Biophys (2011) 50:325–328
DOI 10.1007/s00411-010-0350-9

SHORT COMMUNICATION

Maternal occupational exposure to ionizing radiation and birth defects

**Awi Wiesel · Claudia Spix · Andreas Mergenthaler ·
Annette Queißer-Luft**



Radiation and
Environmental
Biophysics

Maternal occupational exposure to ionizing radiation and birth defects

2011

Awi Wiesel · Claudia Spix · Andreas Mergenthaler ·
Annette Queißer-Luft

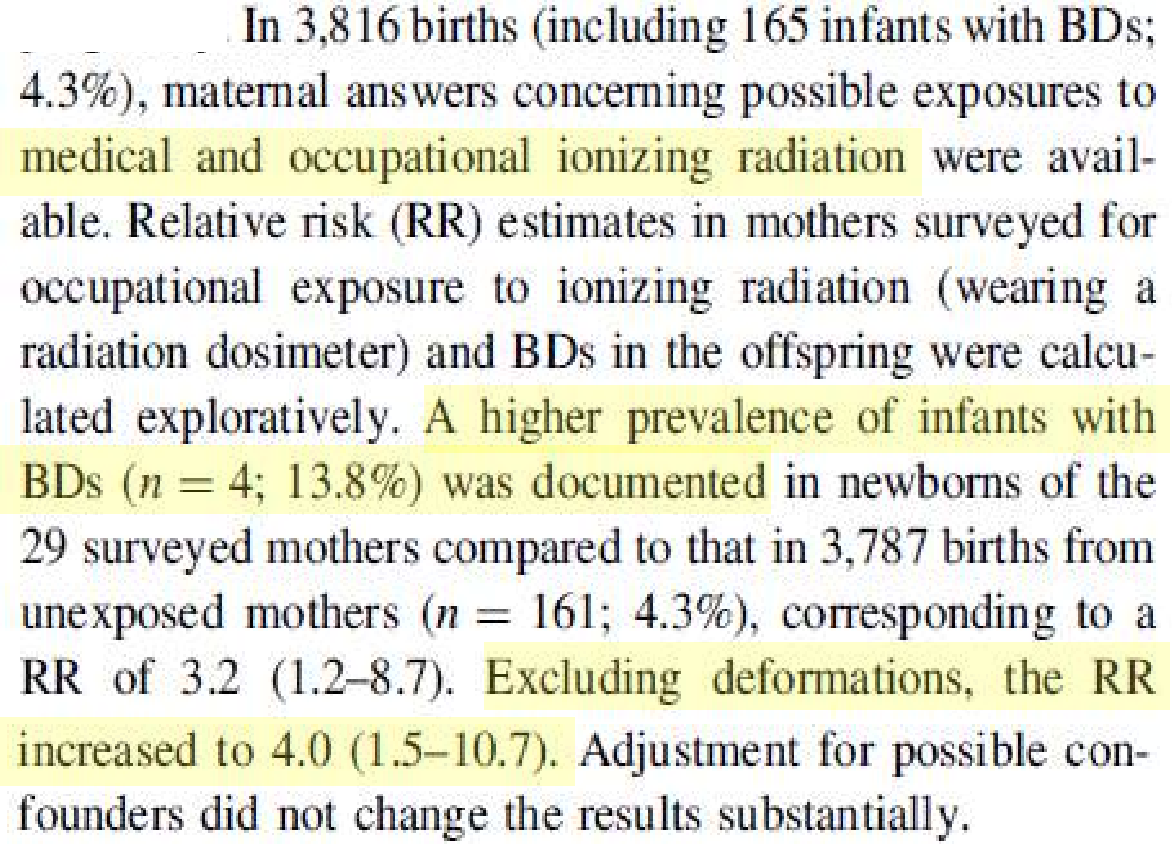
Received: 11 May 2010 / Accepted: 18 December 2010 / Published online: 8 January 2011

Abstract So far, only a few studies investigated occupational exposure to ionizing radiation in pregnancy to cause birth defects (BDs). No association between BDs and ionizing radiation, although described for high-dose exposure, could ever be confirmed for employees, or specific job titles. Here, an explorative analysis of a prospective population-based birth cohort used to quantify the prevalence of BDs in infants between 1/2007 and 2/2008 is presented. An active examination of all livebirths by specially trained paediatricians in two defined areas was performed. Additionally, a study-specific questionnaire distributed among all becoming mothers in the surveyed regions included questions on maternal occupational exposure to ionizing radiation within the first trimester of pregnancy. In 3,816 births (including 165 infants with BDs; 4.3%), maternal answers concerning possible exposures to medical and occupational ionizing radiation were available. Relative risk (RR) estimates in mothers surveyed for occupational exposure to ionizing radiation (wearing a radiation dosimeter) and BDs in the offspring were calculated exploratively. A higher prevalence of infants with BDs ($n = 4$; 13.8%) was documented in newborns of the increased to 4.0 (1.5–10.7). Adjustment for possible confounders did not change the results substantially.

Introduction

Ionizing radiation is known to cause severe damage in the unborn infant, depending on dose and time of exposure (De Santis et al. 2007). Studies on maternal occupational exposure to ionizing radiation and birth defects (BDs) in their offspring have been reported rarely and did not yield any relevant associations (Doyle et al. 2000; Green et al. 1997; Roman et al. 1996; Sever et al. 1988), including also studies in the health care sector (Matte et al. 1993; Shirangi et al. 2009; Shuhaiber et al. 2002; Zhang et al. 1992).

Guidelines, rules and laws concerning safety provisions rely on the known mutagenic, teratogenic and carcinogenic effects of ionizing radiation (Shepard 1995; Suárez et al. 2007). In Germany, people working in health care who may potentially be exposed to ionizing radiation must wear a radiation dosimeter. Expectant mothers have to inform their employer about their ongoing pregnancy "as soon as



In 3,816 births (including 165 infants with BDs; 4.3%), maternal answers concerning possible exposures to medical and occupational ionizing radiation were available. Relative risk (RR) estimates in mothers surveyed for occupational exposure to ionizing radiation (wearing a radiation dosimeter) and BDs in the offspring were calculated exploratively. A higher prevalence of infants with BDs ($n = 4$; 13.8%) was documented in newborns of the 29 surveyed mothers compared to that in 3,787 births from unexposed mothers ($n = 161$; 4.3%), corresponding to a RR of 3.2 (1.2–8.7). Excluding deformations, the RR increased to 4.0 (1.5–10.7). Adjustment for possible confounders did not change the results substantially.

Occupational Exposure to Ionizing Radiation Is Associated with Autoimmune Thyroid Disease

Henry Völzke, André Werner, Henri Wallaschofski, Nele Friedrich, Daniel M. Robinson, Stefan Kindler, Matthias Kraft, Ulrich John, and Wolfgang Hoffmann

Institute of Epidemiology and Social Medicine (H.V., A.W., N.F., S.K., U.J.), Medical Department (H.W., D.M.R., M.K.), and Institute for Community Medicine (W.H.), Ernst Moritz Arndt University, D-17487 Greifswald, Germany

The Journal of Clinical Endocrinology & Metabolism 90(8):4587–4592
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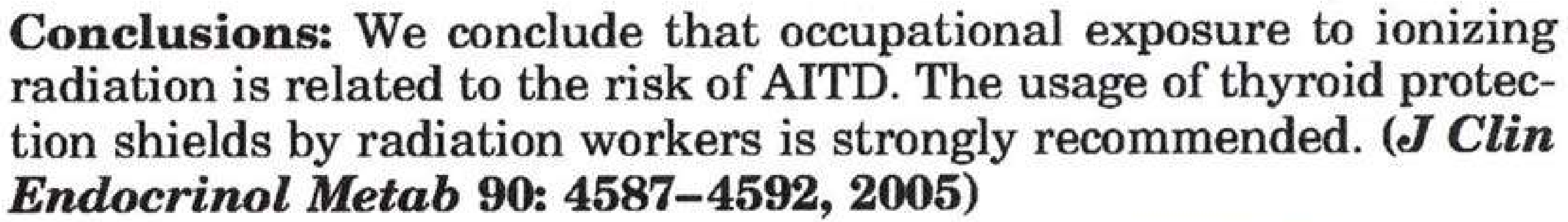
doi: 10.1210/jc.2005-0286



Conclusions: We conclude that occupational exposure to ionizing radiation is related to the risk of AITD. The usage of thyroid protection shields by radiation workers is strongly recommended. (***J Clin Endocrinol Metab*** **90: 4587–4592, 2005)**

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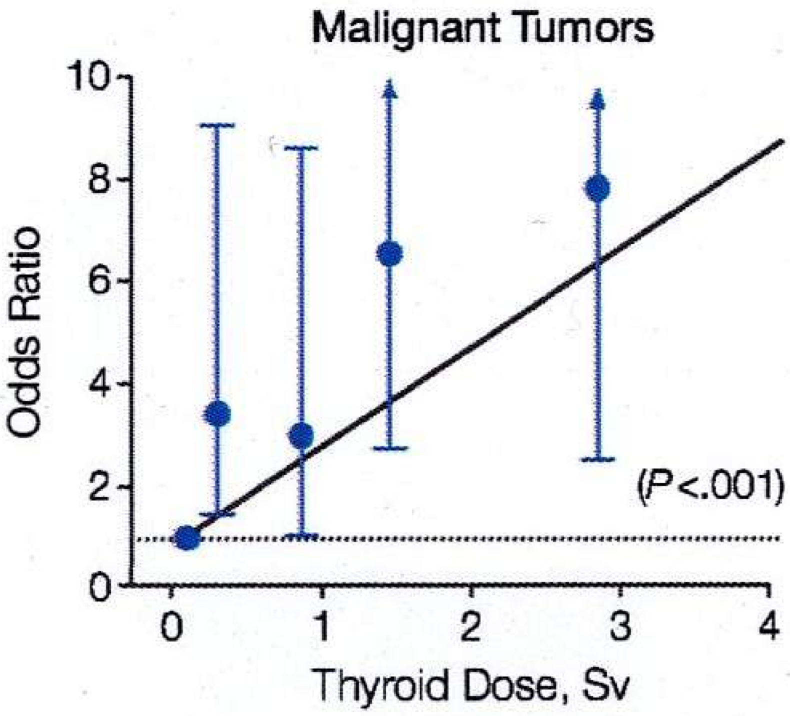
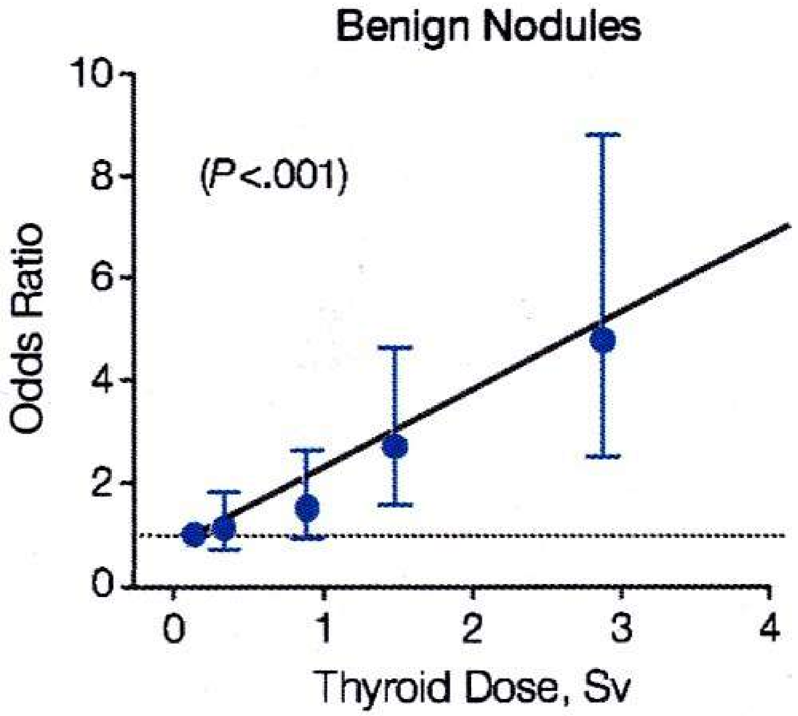
Radiation Dose-Response Relationships for Thyroid Nodules and Autoimmune Thyroid Diseases in Hiroshima and Nagasaki Atomic Bomb Survivors 55-58 Years After Radiation Exposure



JAMA. 2006;295:1011-1022



JAMA. 2006;295:1011-1022

American Journal of Epidemiology
Published by the Johns Hopkins Bloomberg School of Public Health 2008.

Vol. 168, No. 6
DOI: 10.1093/aje/kwn171
Advance Access publication July 29, 2008

Original Contribution

Risk of Cataract after Exposure to Low Doses of Ionizing Radiation: A 20-Year Prospective Cohort Study among US Radiologic Technologists

In conclusion, our study provides evidence that exposure to relatively low doses of ionizing radiation may be harmful to the lens of the eye and increases the long-term risk of cataract formation. Our findings and the results of recent studies suggest that likelihood of cataract formation increases with increasing exposure to ionizing radiation with no apparent threshold level, a finding that challenges the National Council on Radiation Protection and International Commission on Radiological Protection assumptions that a radiation dose of at least 2 Gy is associated with increased cataract risk.

Radiation exposure and circulatory disease risk: Hiroshima and Nagasaki atomic bomb survivor data, 1950-2003

Yukiko Shimizu, visiting research associate,[1] Kazunori Kodama, chief scientist,[2] Nobuo Nishi, assistant department chief ,[1] Fumiyoshi Kasagi, assistant department chief,[1] Akihiko Suyama, department chief,[3] Midori Soda, assistant department chief,[3] Eric J Grant, associate senior scientist,[1] Hiromi Sugiyama, research scientist,[1] Ritsu Sakata, research scientist,[1] Hiroko Moriwaki, research assistant,[1] Mikiko Hayashi, research assistant,[1] Manami Konda, research assistant,[1] Roy E Shore, vice chairman and chief of research[2]

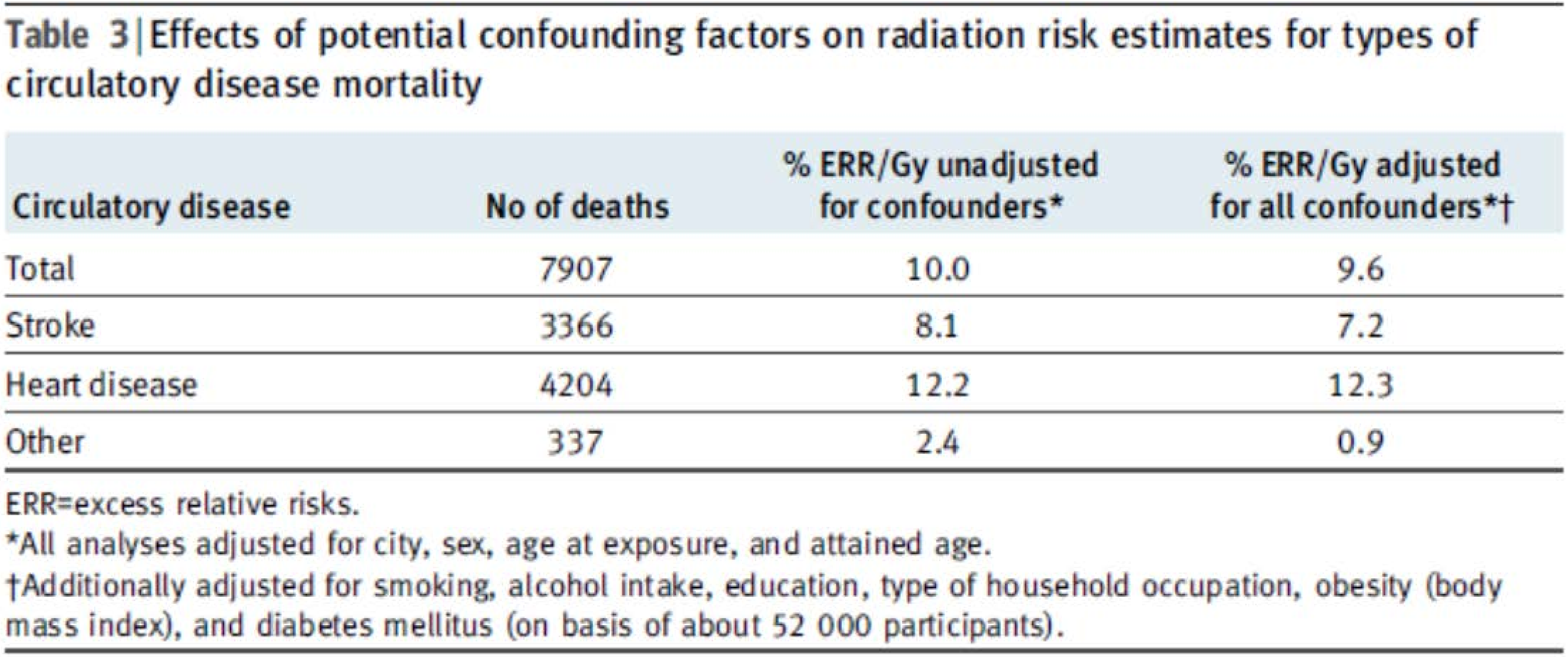


Table 3 | Effects of potential confounding factors on radiation risk estimates for types of circulatory disease mortality

Circulatory disease	No of deaths	% ERR/Gy unadjusted for confounders*	% ERR/Gy adjusted for all confounders*†
Total	7907	10.0	9.6
Stroke	3366	8.1	7.2
Heart disease	4204	12.2	12.3
Other	337	2.4	0.9

ERR=excess relative risks.

*All analyses adjusted for city, sex, age at exposure, and attained age.

†Additionally adjusted for smoking, alcohol intake, education, type of household occupation, obesity (body mass index), and diabetes mellitus (on basis of about 52 000 participants).

Quelle: BMJ 2010,340:b5349

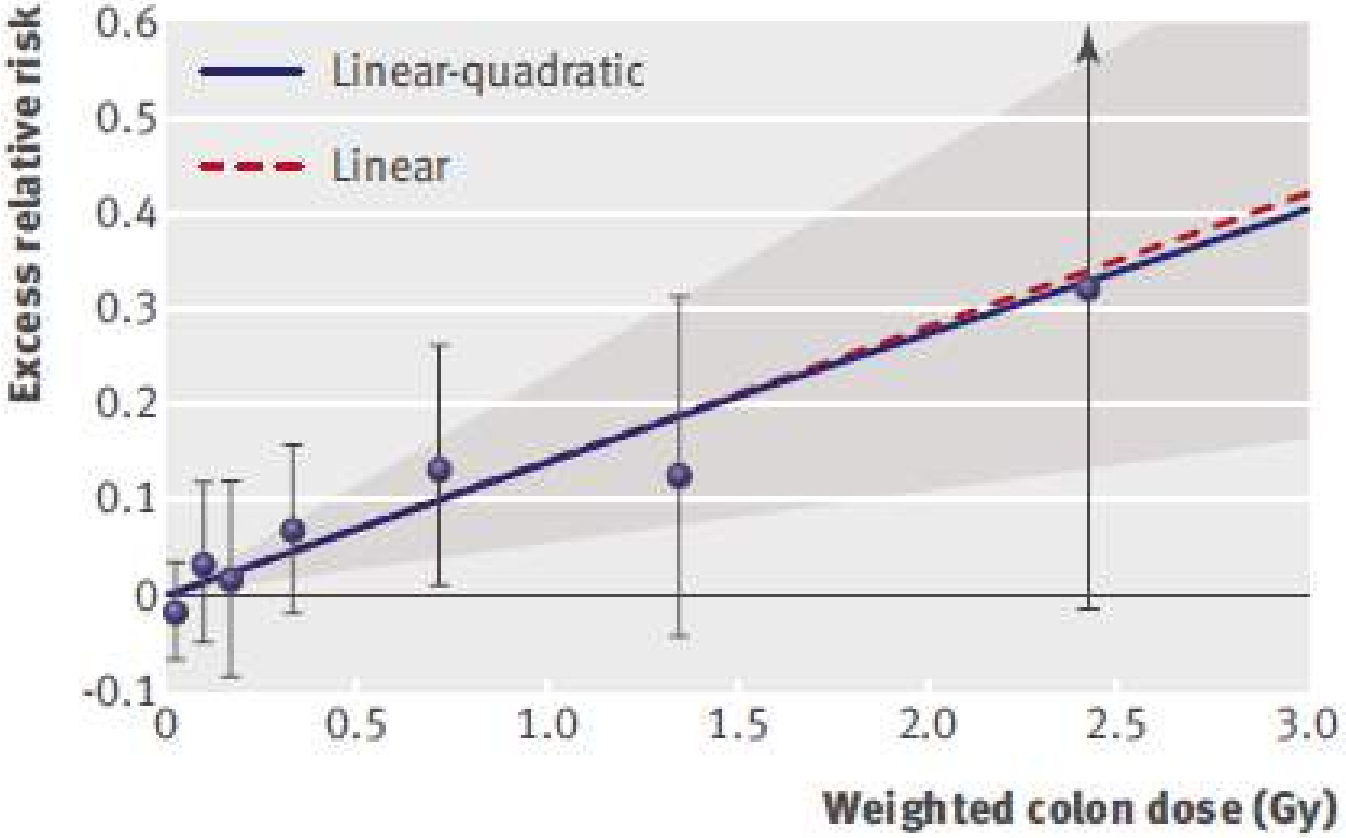


Fig 2 | Radiation dose-response relation (excess relative risk) for death from heart disease, showing linear and linear-quadratic functions. Shaded area is 95% confidence region for fitted linear line. Vertical lines are 95% confidence intervals for specific dose category risks. Point estimates of risk for each dose category are indicated by circles

Quelle: BMJ 2010,340:b5349

Non-cancer deaths due to ionizing radiation

Cardio-vascular deaths:
1 – 13% / Sv

Similar excess mortality due to
non-cancer diseases as from cancers
(5% / Sv)

ENVIRONMENTAL HEALTH PERSPECTIVES

2012

Systematic Review and Meta-analysis of Circulatory Disease from Exposure to Low-Level Ionizing Radiation and Estimates of Potential Population Mortality Risks

Mark P. Little,[1] Tamara V. Azizova,[2] Dimitry Bazyka,[3] Simon D. Bouffler,[4] Elisabeth Cardis,[5] Sergey Chekin,[6] Vadim V. Chumak,[3] Francis A. Cucinotta,[7] Florent de Vathaire,[8] Per Hall,[9] John D. Harrison,[4] Guido Hildebrandt,[10,11] Victor Ivanov,[6] Valeriy V. Kashcheev,[6] Sergiy V. Klymenko,[3] Michaela Kreuzer,[12] Olivier Laurent,[13] Kotaro Ozasa,[14] Thierry Schneider,[15] Soile Tapio,[16] Andrew M. Taylor,[17] Ioanna Tzoulaki,[18] Wendy L. Vandoolaeghe,[18] Richard Wakeford,[19] Lydia B. Zablotska,[20] Wei Zhang,[4] and Steven E. Lipshultz[21]

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BACKGROUND: Although high doses of ionizing radiation have long been linked to circulatory disease, evidence for an association at lower exposures remains controversial. However, recent analyses suggest excess relative risks at occupational exposure levels.

OBJECTIVES: We performed a systematic review and meta-analysis to summarize information on circulatory disease risks associated with moderate- and low-level whole-body ionizing radiation exposures.

METHODS: We conducted PubMed/ISI Thomson searches of peer-reviewed papers published since 1990 using the terms "radiation" AND "heart" AND "disease," OR "radiation" AND "stroke," OR "radiation" AND "circulatory" AND "disease." Radiation exposures had to be whole-body, with a cumulative mean dose of < 0.5 Sv, or at a low dose rate (< 10 mSv/day). We estimated population risks of circulatory disease from low-level radiation exposure using excess relative risk estimates from this meta-analysis and current mortality rates for nine major developed countries.

RESULTS: Estimated excess population risks for all circulatory diseases combined ranged from 2.5%/Sv [95% confidence interval (CI): 0.8, 4.2] for France to 8.5%/Sv (95% CI: 4.0, 13.0) for Russia.

CONCLUSIONS: Our review supports an association between circulatory disease mortality and low and moderate doses of ionizing radiation. Our analysis was limited by heterogeneity among studies (particularly for noncardiac end points), the possibility of uncontrolled confounding in some occupational groups by lifestyle factors, and higher dose groups (> 0.5 Sv) generally driving the observed trends. If confirmed, our findings suggest that overall radiation-related mortality is about twice that currently estimated based on estimates for cancer end points alone (which range from 4.2% to 5.6%/Sv for these populations).

KEY WORDS: cancer, circulatory disease, heart disease, radiation, stroke. *Environ Health Perspect* 120:1503–1511 (2012). http://dx.doi.org/10.1289/ehp.1204982 [Online 22 June 2012]

a review by the Health Protection Agency's AGIR in the United Kingdom estimated substantial excess risks for ischemic heart disease (IHD) and stroke, but concluded that a significantly elevated risk was detectable only for exposures above about 0.5 Gy (AGIR 2010).

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Supplemental Material is available online (http://dx.doi.org/10.1289/ehp.1204982).

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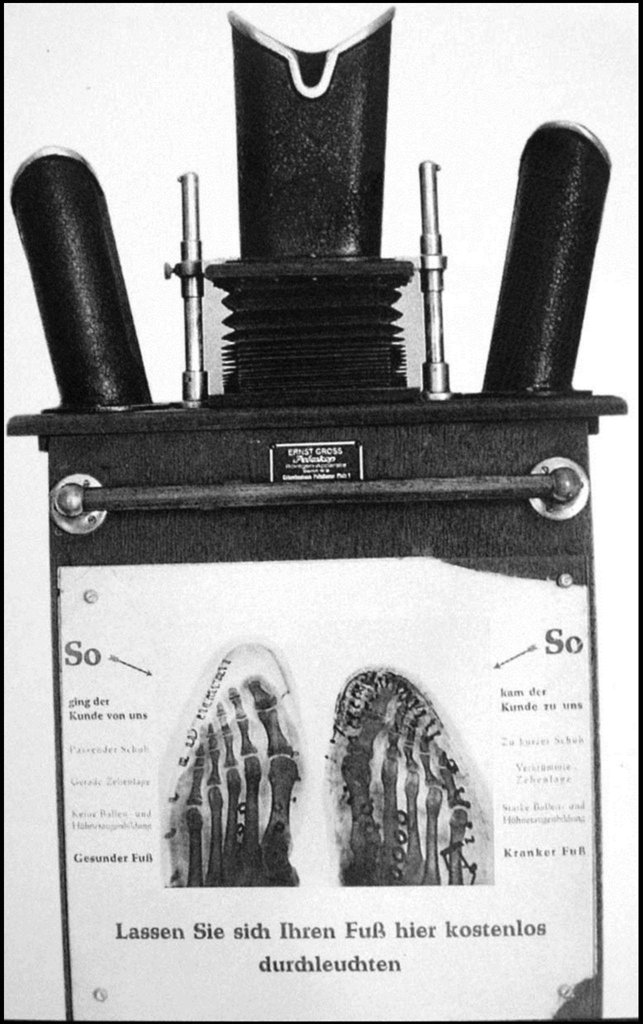
Quelle: Ausbildung in Radioaktivität – Fachkunde zum Strahlenschutz. Bericht vom 53. Radiometrischen Seminar Theuren am 29. April 2011, in: Strahlenschutz Praxis, 7, 3, 2011, S. 79.



ERNST GROSS
Pedoskop
So
ging der Kunde von uns
Passender Schuh
Gerade Zehenlage
Keine Ballen- und Hühneraugenbildung
Gesunder Fuß
So
kam der Kunde zu uns
Zu kurzer Schuh
Verkrümmte Zehenlage
Starke Ballen- und Hühneraugenbildung
Kranker Fuß
Lassen Sie sich Ihren Fuß hier kostenlos durchleuchten

Bodyscan-Lastwagen: *Wanderheiler vor der Dorfkirche*

Der Spiegel 30/2002

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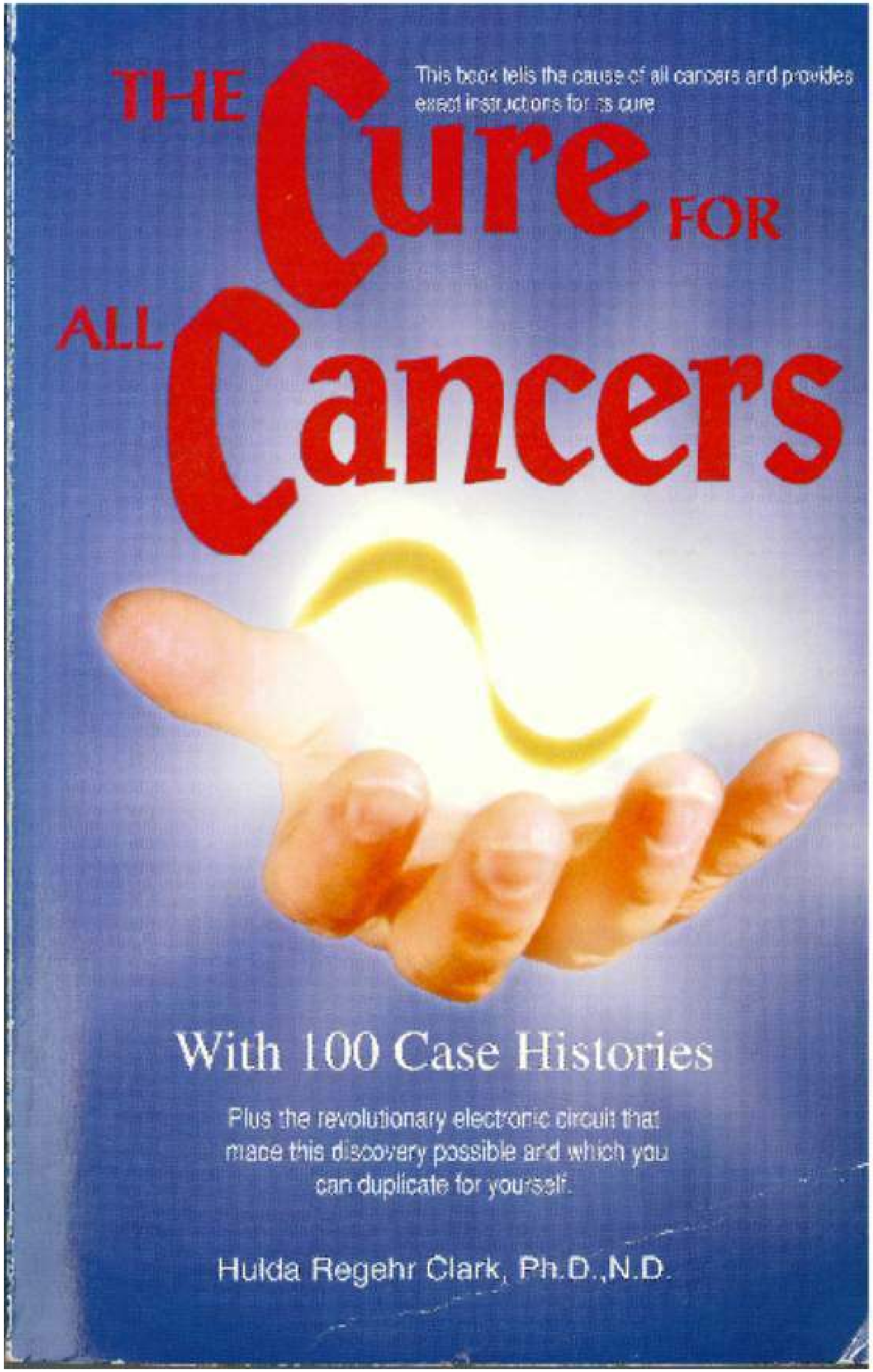

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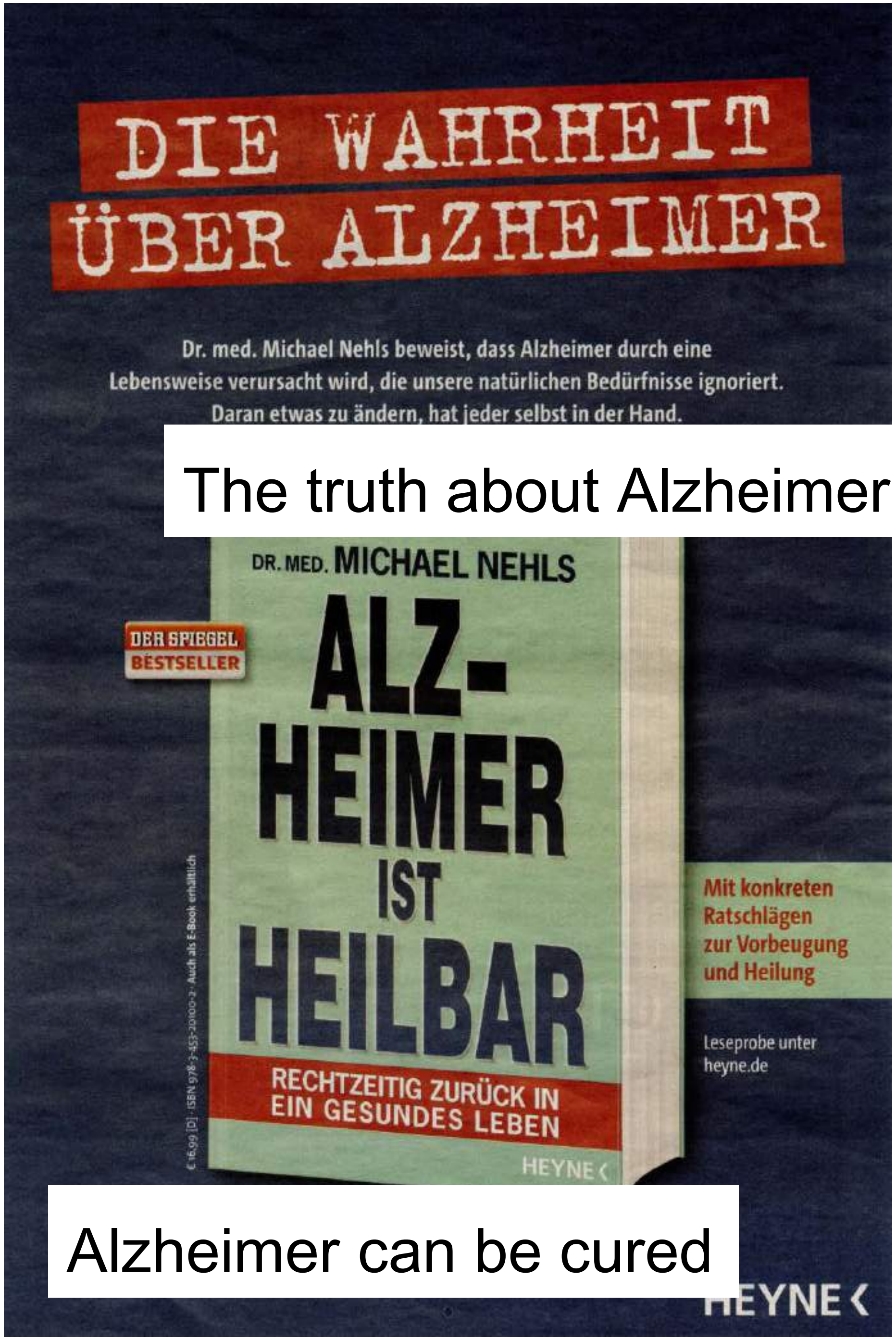
Hulda Regehr Clark, Ph.D.,N.D.



DIE WAHRHEIT ÜBER ALZHEIMER

Dr. med. Michael Nehls beweist, dass Alzheimer durch eine Lebensweise verursacht wird, die unsere natürlichen Bedürfnisse ignoriert. Daran etwas zu ändern, hat jeder selbst in der Hand.

DR. MED. MICHAEL NEHLS

DER SPIEGEL BESTSELLER

ALZHEIMER IST HEILBAR

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Health risks of ionising radiation

Ulm meeting

19. Oktober 2013

Interdisciplinary workshop with physicians, physicists, biologists, mathematicians, epidemiologigists

Agenda: Review and compilation of scientific evidence on health effects of ionisiing radiation

ippnw information

information der ippnw
internationale ärzte
für die verhütung des
atomkriegs – ärzte in
sozialer verantwortung

Gefahren ionisierender Strahlung:
Ergebnisse des Ulmer Expertentreffens vom 19. Oktober 2013

Ärzte und Wissenschaftler warnen vor Gesundheitsschäden durch ionisierende Strahlung. Schon Strahlendosen in der Größenordnung von 1 Millisievert (mSv) erhöhen nachweislich das Erkrankungsrisiko. Es gibt keinen Schwellenwert, unterhalb dessen Strahlung unwirksam wäre.

Am 19. Oktober 2013 fand auf Einladung der Ärzteorganisation IPPNW in Ulm ein Expertentreffen von ÄrztInnen und WissenschaftlerInnen aus der Strahlenbiologie, Epidemiologie, Statistik und Physik aus Deutschland und der Schweiz statt. Die TeilnehmerInnen diskutierten den aktuellen Wissensstand zu den Gefahren ionisierender Strahlung im Niedrigdosisbereich.

Die Expertenrunde fordert eine Anpassung des Strahlenschutzes an den aktuellen Stand der Wissenschaft. Ionisierende Strahlung führt zu manifesten gesundheitlichen Schäden. Für einen Teil der Risiken lassen neue epidemiologische Untersuchungen eine quantitative Bestimmung zu. Die Risikobewertung aufgrund statistischer Erhebungen an Atombombenüberlebenden von Hiroshima und Nagasaki als Referenzkollektiv ist überholt. Schon kleinste Strahlendosen verursachen Erkrankungen.

1. Schon die Hintergrundstrahlung verursacht epidemiologisch nachweisbare Gesundheitsschäden

Bereits die niedrigen Dosen der Hintergrundstrahlung (inhaliertes Radon, terrestrische und kosmische Strahlung, mit der Nahrung aufgenommene natürliche Radioisotope) führen zu epidemiologisch nachweisbaren Gesundheitsschäden. Das Argument, eine Strahlenbelastung bewege sich „nur" im Dosisbereich der „natürlichen" Hintergrundstrahlung und sei deshalb unbedenklich, ist daher irreführend.

Foto: Jan Thomas Ash, documentingjan.com

Die Ergebnisse des Expertentreffens im Einzelnen:

http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Ulmer_Expertentreffen_-_Gefahren_ionisierender_Strahlung.pdf