Gefahren ionisierender Strahlung

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Gefahren ionisierender Stahlung

Ulmer Expertentreffen

19. Oktober 2014

Interdisziplinäres Treffen von Medizinern, Physikern, Biologen, Mathematiker und Epidemiologen

Ziel: Zusammentragung gesicherter Erkenntnisse zu den gesundheitlichen Folgen ionisierender Strahlung

ippnw information

information der ippnw internationale ärzte für die verhütung des atomkrieges – 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.

Die Ergebnisse des Expertentreffens im Einzelnen:

1. Schon die Hintergrundstrahlung verursacht epidemiologisch nachweisbare Gesundheitsschäden.
2. Medizinische Strahlendiagnostik verursacht epidemiologisch nachweisbare Gesundheitsschäden.
3. Atomenergie-Nutzung und Atomwaffentests verursachen epidemiologisch nachweisbare Gesundheitsschäden.
4. Auf der Grundlage epidemiologischer Studien können mit der Anwendung des Kollektivdosiskonzepts Gesundheitsrisiken im niedrigen Dosisbereich belastbar quantitativ abgeschätzt werden.
5. Die von der ICRP immer noch praktizierte Ableitung der Risikofaktoren aus den Hiroshima- und Nagasaki-Studien ist überholt.
6. Es sollte ein risikobasiertes Strahlenschutzkonzept eingeführt werden, verbunden mit der konsequenten Umsetzung des Minimierungsgebots.

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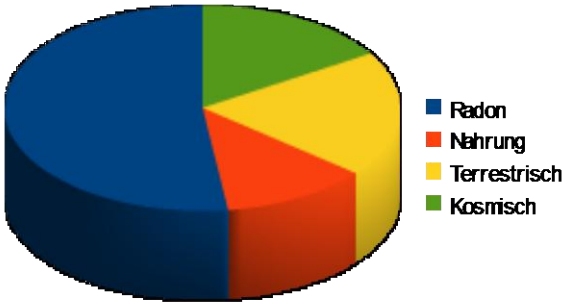
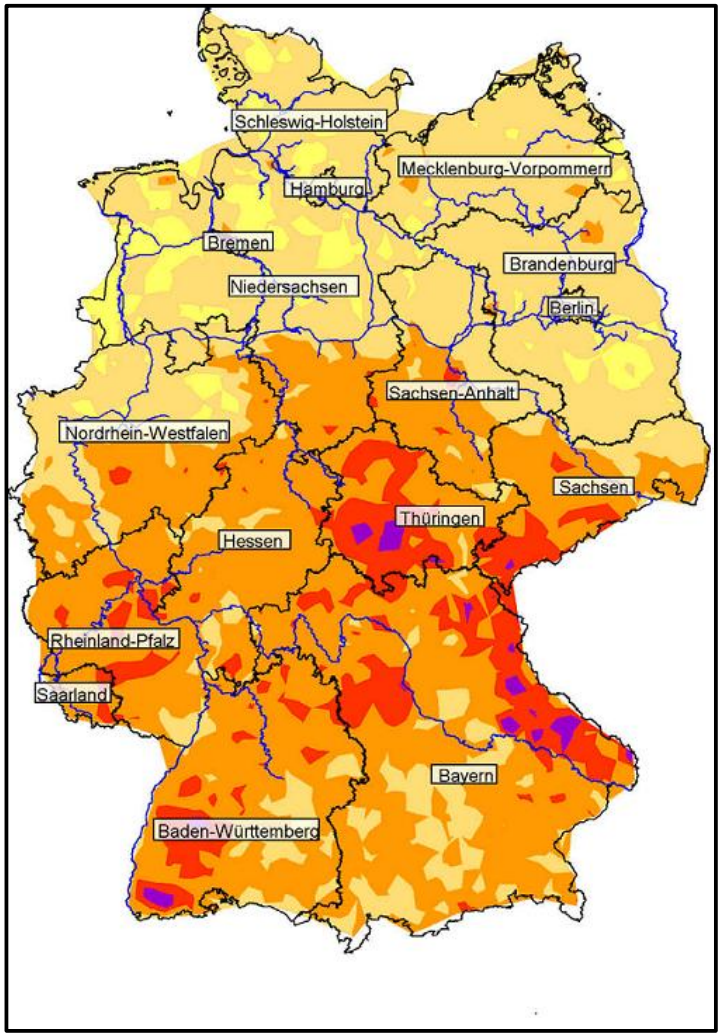
Hintergrundstrahlung

Schon Hintergrundstrahlung verursacht epidemiologisch nachweisbare Gesundheits-schäden





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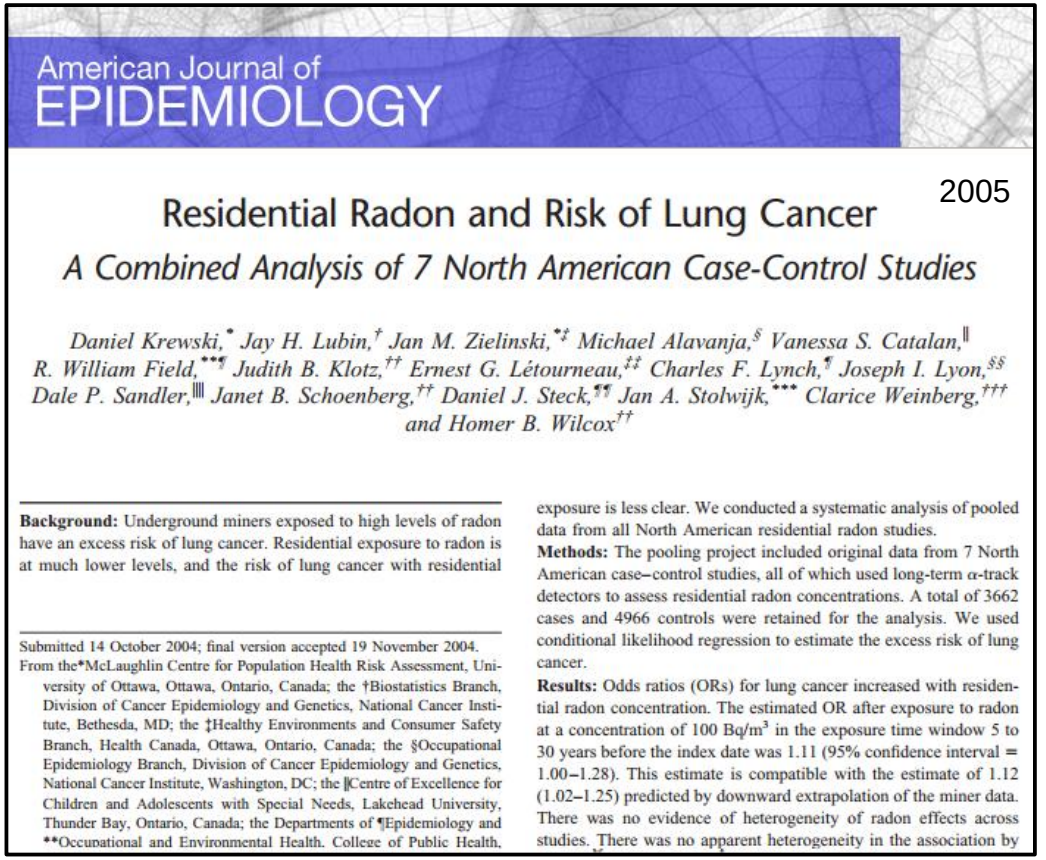
Hintergrundstrahlung

Belastbare Evidenz für Assoziation zwischen Radonbelastung im Haus und Lungenkrebs

11% höheres Risiko pro 100 Bq/m^3 (95% CI 1 - 28 %)

Confounder wie Geschlecht, Bildungsgrad oder Rauchen konnten ausgeschlossen werden



American Journal of EPIDEMIOLOGY

2005

Residential Radon and Risk of Lung Cancer

A Combined Analysis of 7 North American Case-Control Studies

Daniel Krewski,[*] Jay H. Lubin,[†] Jan M. Zielinski,[‡] Michael Alavanja,[§] Vanessa S. Catalan,[‖] R. William Field,[**¶] Judith B. Klotz,[††] Ernest G. Létourneau,[‡‡] Charles F. Lynch,[¶] Joseph I. Lyon,[§§] Dale P. Sandler,[‖‖] Janet B. Schoenberg,[††] Daniel J. Steck,[¶¶] Jan A. Stolwijk,[***] Clarice Weinberg,[†††] and Homer B. Wilcox[††]*

Background: Underground miners exposed to high levels of radon have an excess risk of lung cancer. Residential exposure to radon is at much lower levels, and the risk of lung cancer with residential exposure is less clear. We conducted a systematic analysis of pooled data from all North American residential radon studies.

Methods: The pooling project included original data from 7 North American case–control studies, all of which used long-term α-track detectors to assess residential radon concentrations. A total of 3662 cases and 4966 controls were retained for the analysis. We used conditional likelihood regression to estimate the excess risk of lung cancer.

Results: Odds ratios (ORs) for lung cancer increased with residential radon concentration. The estimated OR after exposure to radon at a concentration of 100 Bq/m^3 in the exposure time window 5 to 30 years before the index date was 1.11 (95% confidence interval = 1.00–1.28). This estimate is compatible with the estimate of 1.12 (1.02–1.25) predicted by downward extrapolation of the miner data. There was no evidence of heterogeneity of radon effects across studies. There was no apparent heterogeneity in the association by

Submitted 14 October 2004; final version accepted 19 November 2004.

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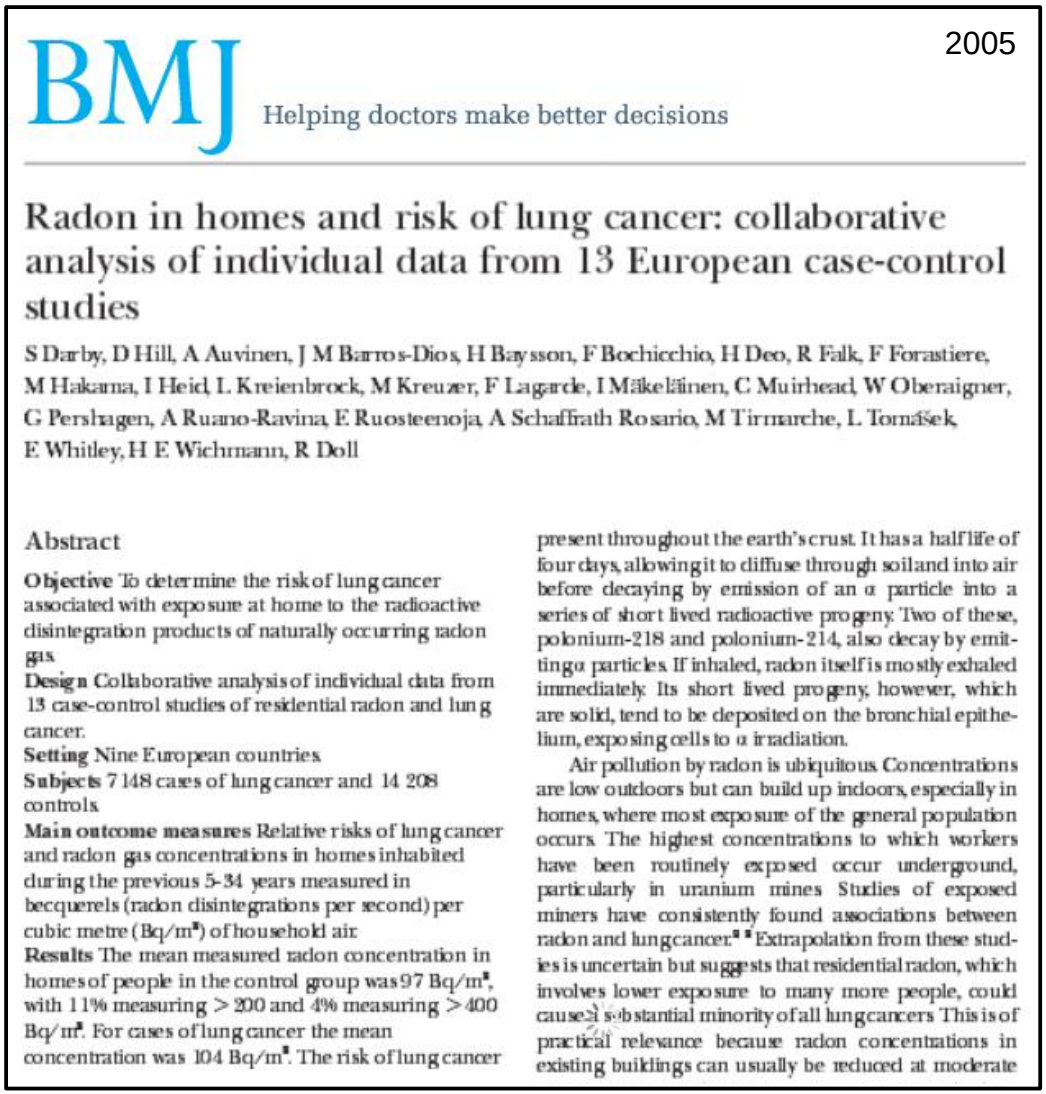
Hintergrundstrahlung

16% höheres Risiko pro 100 Bq/m^3 (95% CI 5 - 31%)

Rauchen ist ein unabhängiger Risikofaktor

Kein unterer Schwellenwert, Dosis-Wirkungs-Beziehung, selbst unterhalb heutiger Grenzwerte

Radon ist verantwortlich für 9% aller Lungenkrebsfälle und 2% aller Todesfälle durch Lungenkrebs



2005

BMJ Helping doctors make better decisions

Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies

S Darby, D Hill, A Auvinen, J M Barros-Dios, H Bayssson, F Bochicchio, H Deo, R Falk, F Forastiere, M Hakama, I Heid, L Kreienbrock, M Kreuzer, F Lagarde, I Mäkeläinen, C Muirhead, W Oberaigner, G Pershagen, A Ruano-Ravina, E Ruosteenoja, A Schaffrath Rosario, M Tirmarche, L Tomášek, E Whitley, H E Wichmann, R Doll

Abstract

Objective To determine the risk of lung cancer associated with exposure at home to the radioactive disintegration products of naturally occurring radon gas.

Design Collaborative analysis of individual data from 13 case-control studies of residential radon and lung cancer.

Setting Nine European countries.

Subjects 7 148 cases of lung cancer and 14 208 controls.

Main outcome measures Relative risks of lung cancer and radon gas concentrations in homes inhabited during the previous 5-34 years measured in becquerels (radon disintegrations per second) per cubic metre (Bq/m^3) of household air.

Results The mean measured radon concentration in homes of people in the control group was 97 Bq/m^3, with 11% measuring > 200 and 4% measuring > 400 Bq/m^3. For cases of lung cancer the mean concentration was 104 Bq/m^3. The risk of lung cancer

present throughout the earth's crust. It has a half life of four days, allowing it to diffuse through soil and into air before decaying by emission of an α particle into a series of short lived radioactive progeny. Two of these, polonium-218 and polonium-214, also decay by emitting α particles. If inhaled, radon itself is mostly exhaled immediately. Its short lived progeny, however, which are solid, tend to be deposited on the bronchial epithelium, exposing cells to α irradiation.

Air pollution by radon is ubiquitous. Concentrations are low outdoors but can build up indoors, especially in homes, where most exposure of the general population occurs. The highest concentrations to which workers have been routinely exposed occur underground, particularly in uranium mines. Studies of exposed miners have consistently found associations between radon and lung cancer.[1 2] Extrapolation from these studies is uncertain but suggests that residential radon, which involves lower exposure to many more people, could cause a substantial minority of all lung cancers. This is of practical relevance because radon concentrations in existing buildings can usually be reduced at moderate

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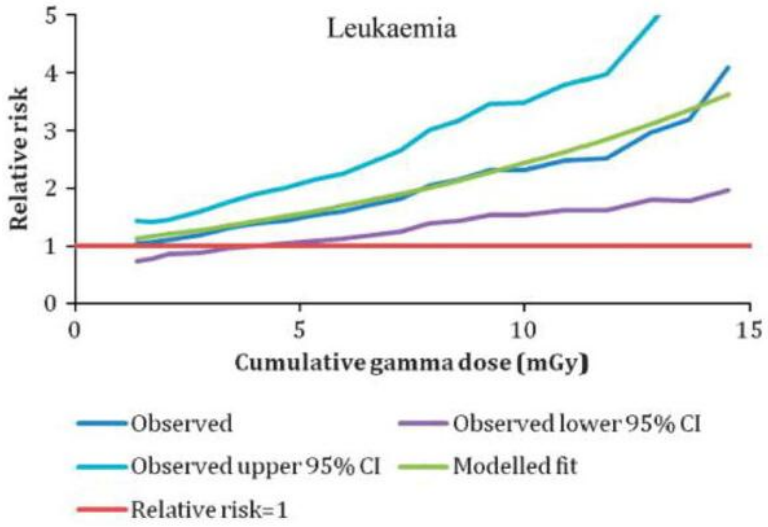
Hintergrundstrahlung

Assoziation von Hintergrundstrahlung mit Leukämie

12% höheres Risiko pro mSv KM-Dosis (95% CI 3 – 22%)



Leukemia

A record-based case–control study of natural background radiation and the incidence of childhood leukaemia and other cancers in Great Britain during 1980–2006

G M Kendall, M P Little, R Wakeford, K J Bunch, J C H Miles, T J Vincent, J R Meara and M F G Murphy

We conducted a large record-based case–control study testing associations between childhood cancer and natural background radiation. Cases (27 447) born and diagnosed in Great Britain during 1980–2006 and matched cancer-free controls (36 793) were from the National Registry of Childhood Tumours. Radiation exposures were estimated for mother's residence at the child's birth from national databases, using the County District mean for gamma rays, and a predictive map based on domestic measurements grouped by geological boundaries for radon. There was 12% excess relative risk (ERR) (95% CI 3, 22; two-sided P=0.01) of childhood leukaemia per millisievert of cumulative red bone marrow dose from gamma radiation; the analogous association for radon was not significant, ERR 3% (95% CI −4, 11; P=0.35). Associations for other childhood cancers were not significant for either exposure. Excess risk was insensitive to adjustment for measures of socio-economic status. The statistically significant leukaemia risk reported in this reasonably powered study (power ~50%) is consistent with high-dose rate predictions. Substantial bias is unlikely, and we cannot identify mechanisms by which confounding might plausibly account for the association, which we regard as likely to be causal. The study supports the extrapolation of high-dose rate risk models to protracted exposures at natural background exposure levels.

P=0.01) of childhood leukaemia per millisievert of cumulative red bone marrow dose from gamma radiation; the analogous

2013

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Gefahren ionisierender Stahlung

Hintergrundstrahlung

15-20% aller Kinderleukämie durch natürliche Hintergrundstrahlung verursacht

Journal of Radiological Protection

Official journal of the Society for Radiological Protection

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]

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[2] Dalton Nuclear Institute, The University of Manchester, Pariser Building—G Floor, PO Box 88, Sackville Street, Manchester M60 1QD, UK
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Abstract
The aetiology of childhood leukaemia remains generally unknown, although exposure to moderate and high levels of ionising radiation, such as was experienced during the atomic bombings of Japan or from radiotherapy, is an established cause. Risk models based primarily upon studies of the Japanese A-bomb survivors imply that low-level exposure to ionising radiation, including to ubiquitous natural background radiation, also raises the risk of childhood leukaemia. In a recent paper (Wakeford *et al* 2009 *Leukaemia* **23** 770–6) we estimated the proportion of childhood leukaemia incidence in Great Britain attributable to natural background radiation to be about 20%. In this paper we employ the two sets of published leukaemia risk models used 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

2009

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Gefahren ionisierender Stahlung

Hintergrundstrahlung

Häusliche Radonbelastung, terrestrische Strahlung, Grundwasserkontamination und kosmische Höhenstrahlung (z.B. im Rahmen von Flügen) erhöhen das Krankheitsrisiko

Gefahren ionisierender Stahlung

Medizinische Strahlung

Medizinische Strahlendiagnostik verursacht epidemiologisch nachweisbare Gesundheitsschäden

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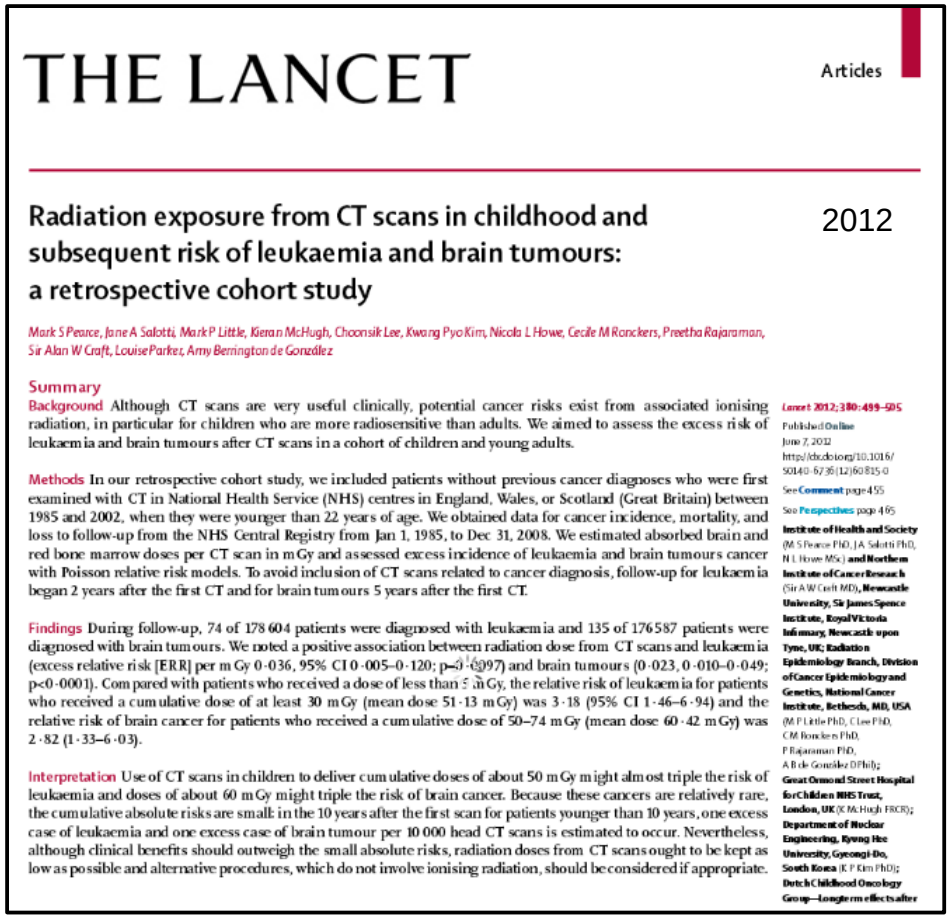
Medizinische Strahlung

Mehr als 355.000 Patienten 1985-2002

Ein CT mit ca. 50-60 mSv kann das Risiko von Leukämien oder Hirntumoren verdreifachen

Confounder konnten nicht identifiziert werden.



THE LANCET

Articles

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

2012

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

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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, Gyeonggi-Do, South Korea** (K P Kim PhD); **Dutch Childhood Oncology Group—Long-term effects after**

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Gefahren ionisierender Stahlung

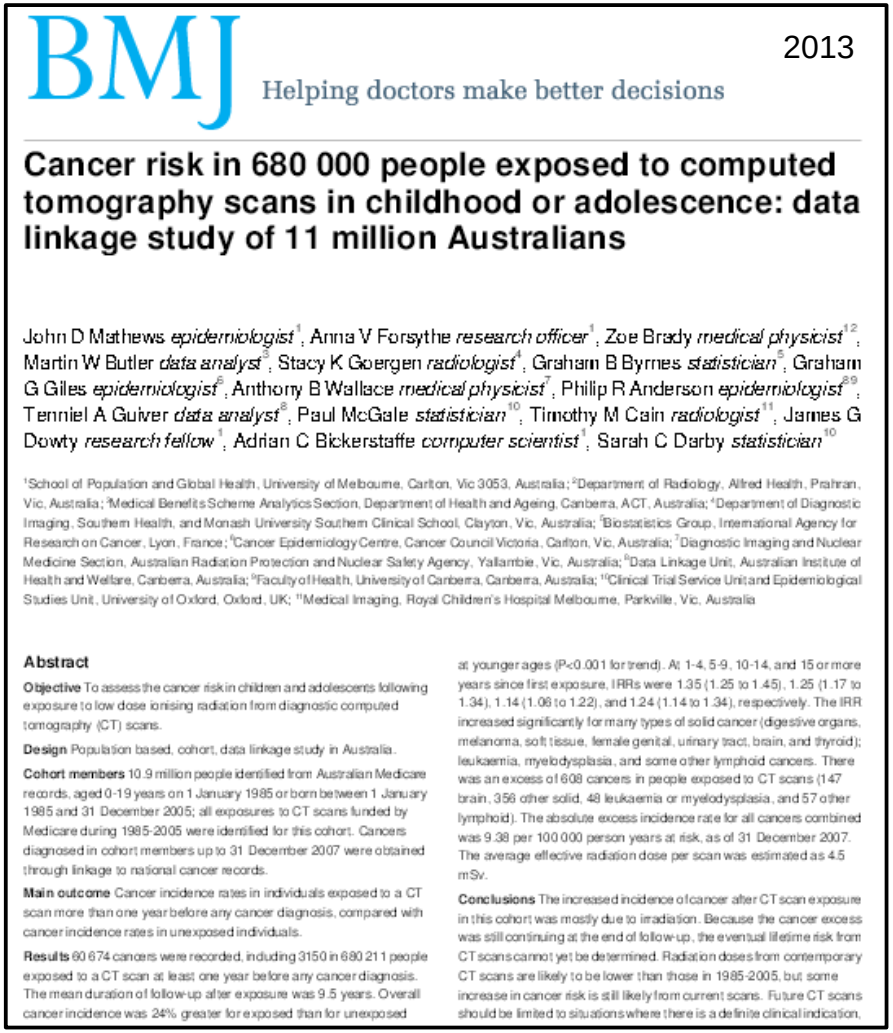
Medizinische Strahlung

10,9 Millionen Patienten 1985-2005

Krebsrisiko steigt um 24% durch 1 CT (4,5 mSv)

Jede weitere CT-Untersuchung erhöht das Risiko um etwa 16%

Je jünger, desto höher das Risiko:
- 1-4 Jahre: 35% höheres Krebsrisiko
- 5-9 Jahre: 25% höheres Krebsrisiko
- 10-14 Jahre: 14% höheres Krebsrisiko



BMJ Helping doctors make better decisions

2013

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]

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Abstract

Objective To assess the cancer risk in children and adolescents following exposure to low dose ionising radiation from diagnostic computed tomography (CT) scans.

Design Population based, cohort, data linkage study in Australia.

Cohort members 10.9 million people identified from Australian Medicare records, aged 0-19 years on 1 January 1985 or born between 1 January 1985 and 31 December 2005; all exposures to CT scans funded by Medicare during 1985-2005 were identified for this cohort. Cancers diagnosed in cohort members up to 31 December 2007 were obtained through linkage to national cancer records.

Main outcome Cancer incidence rates in individuals exposed to a CT scan more than one year before any cancer diagnosis, compared with cancer incidence rates in unexposed individuals.

Results 60 674 cancers were recorded, including 3150 in 680 211 people exposed to a CT scan at least one year before any cancer diagnosis. The mean duration of follow-up after exposure was 9.5 years. Overall cancer incidence was 24% greater for exposed than for unexposed 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 increased significantly for many types of solid cancer (digestive organs, melanoma, soft tissue, female genital, urinary tract, brain, and thyroid); leukaemia, myelodysplasia, and some other lymphoid cancers. There was an excess of 608 cancers in people exposed to CT scans (147 brain, 356 other solid, 48 leukaemia or myelodysplasia, and 57 other lymphoid). The absolute excess incidence rate for all cancers combined was 9.38 per 100 000 person years at risk, as of 31 December 2007. The average effective radiation dose per scan was estimated as 4.5 mSv.

Conclusions The increased incidence of cancer after CT scan exposure in this cohort was mostly due to irradiation. Because the cancer excess was still continuing at the end of follow-up, the eventual lifetime risk from CT scans cannot yet be determined. Radiation doses from contemporary CT scans are likely to be lower than those in 1985-2005, but some increase in cancer risk is still likely from current scans. Future CT scans should be limited to situations where there is a definite clinical indication,

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Gefahren ionisierender Stahlung

Medizinische Strahlung

Sowohl konventionelles Röntgen als auch CT-Untersuchungen erhöhen das Krebsrisiko

In bestimmten Subgruppen ist das individuelle Risiko erhöht (Kinder, Schwangere, Patienten mit Risikofaktoren)

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Gefahren ionisierender Stahlung

Atomindustrie

Die Nutzung von Atomenergie und der Einsatz von Atomwaffen verursachen epidemiologisch nachweisbare Gesundheitsschäden

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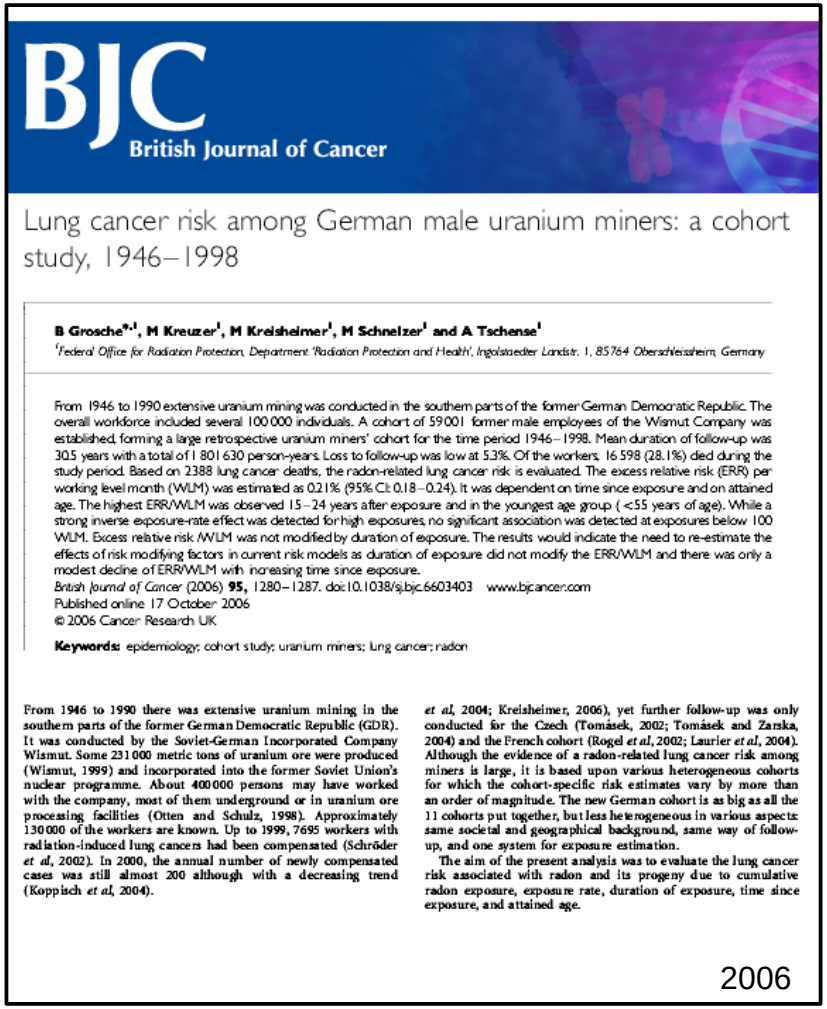
Gefahren ionisierender Stahlung

Uranbergbau

59.001 ehemalige Wismutarbeiter

Zusammenhang zwischen Arbeitszeit und Krebsrisiko

21% höheres Krebsrisiko pro WLM (95% CI 18 - 24)



BJC
British Journal of Cancer

Lung cancer risk among German male uranium miners: a cohort study, 1946–1998

B Grosche*,[1], M Kreuzer[1], M Kreisheimer[1], M Schnelzer[1] and A Tschense[1]
[1]Federal Office for Radiation Protection, Department 'Radiation Protection and Health', Ingolstaedter Landstr. 1, 85764 Oberschleissheim, Germany

From 1946 to 1990 extensive uranium mining was conducted in the southern parts of the former German Democratic Republic. The overall workforce included several 100 000 individuals. A cohort of 59 001 former male employees of the Wismut Company was established, forming a large retrospective uranium miners' cohort for the time period 1946–1998. Mean duration of follow-up was 30.5 years with a total of 1 801 630 person-years. Loss to follow-up was low at 5.3%. Of the workers, 16 598 (28.1%) died during the study period. Based on 2388 lung cancer deaths, the radon-related lung cancer risk is evaluated. The excess relative risk (ERR) per working level month (WLM) was estimated as 0.21% (95% CI: 0.18–0.24). It was dependent on time since exposure and on attained age. The highest ERR/WLM was observed 15–24 years after exposure and in the youngest age group (<55 years of age). While a strong inverse exposure-rate effect was detected for high exposures, no significant association was detected at exposures below 100 WLM. Excess relative risk/WLM was not modified by duration of exposure. The results would indicate the need to re-estimate the effects of risk modifying factors in current risk models as duration of exposure did not modify the ERR/WLM and there was only a modest decline of ERR/WLM with increasing time since exposure.
British Journal of Cancer (2006) **95**, 1280–1287. doi:10.1038/sj.bjc.6603403 www.bjcancer.com
Published online 17 October 2006
© 2006 Cancer Research UK

Keywords: epidemiology; cohort study; uranium miners; lung cancer; radon

From 1946 to 1990 there was extensive uranium mining in the southern parts of the former German Democratic Republic (GDR). It was conducted by the Soviet-German Incorporated Company Wismut. Some 231 000 metric tons of uranium ore were produced (Wismut, 1999) and incorporated into the former Soviet Union's nuclear programme. About 400 000 persons may have worked with the company, most of them underground or in uranium ore processing facilities (Otten and Schulz, 1998). Approximately 130 000 of the workers are known. Up to 1999, 7695 workers with radiation-induced lung cancers had been compensated (Schröder *et al*, 2002). In 2000, the annual number of newly compensated cases was still almost 200 although with a decreasing trend (Koppisch *et al*, 2004).

et al, 2004; Kreisheimer, 2006), yet further follow-up was only conducted for the Czech (Tomásek, 2002; Tomásek and Zarska, 2004) and the French cohort (Rogel *et al*, 2002; Laurier *et al*, 2004). Although the evidence of a radon-related lung cancer risk among miners is large, it is based upon various heterogeneous cohorts for which the cohort-specific risk estimates vary by more than an order of magnitude. The new German cohort is as big as all the 11 cohorts put together, but less heterogeneous in various aspects: same societal and geographical background, same way of follow-up, and one system for exposure estimation.

The aim of the present analysis was to evaluate the lung cancer risk associated with radon and its progeny due to cumulative radon exposure, exposure rate, duration of exposure, time since exposure, and attained age.

2006

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Gefahren ionisierender Stahlung

Uranbergbau

11 Kohortenstudien
- 65.000 Männer
- 2.700 Lungenkrebstote

Linearer Zusammenhang zwischen Radonexposition und Lungenkrebs

Langzeitexposition zeigte größere Effekte als Kurzzeitexposition

Lungenkrebsfälle durch Radon:
- Minenarbeitern 40%
- Allgemeinbevölkerung 10%

OXFORD JOURNALS CONTACT US MY BASKET

JNCI JOURNAL OF THE NATIONAL CANCER INSTITUTE

J Natl Cancer Inst. 1995 Jun 7;87(11):817-27.

Lung cancer in radon-exposed miners and estimation of risk from indoor exposure. 1995

Lubin JH[1], Boice JD Jr, Edling C, Hornung RW, Howe GR, Kunz E, Kusiak RA, Morrison HI, Radford EP, Samet JM, et al.

Abstract

BACKGROUND: Radioactive radon is an inert gas that can migrate from soils and rocks and accumulate in enclosed areas, such as homes and underground mines. Studies of miners show that exposure to radon decay products causes lung cancer. Consequently, it is of public health interest to estimate accurately the consequences of daily, low-level exposure in homes to this known carcinogen. Epidemiologic studies of residential radon exposure are burdened by an inability to estimate exposure accurately, low total exposure, and subsequent small excess risks. As a result, the studies have been inconclusive to date. Estimates of the hazard posed by residential radon have been based on analyses of data on miners, with recent estimates based on a pooling of four occupational cohort studies of miners, including 360 lung cancer deaths.

PURPOSE: To more fully describe the lung cancer risk in radon-exposed miners, we pooled original data from 11 studies of radon-exposed underground miners, conducted a comprehensive analysis, and developed models for estimating radon-associated lung cancer risk.

METHODS: We pooled original data from 11 cohort studies of radon-exposed underground miners, including 65,000 men and more than 2700 lung cancer deaths, and fit various relative risk (RR) regression models.

RESULTS: The RR relationship for cumulative radon progeny exposure was consistently linear in the range of miner exposures, suggesting that exposures at lower levels, such as in homes, would carry some risk. The exposure-response trend for never-smokers was threefold the trend for smokers, indicating a greater RR for exposure in never-smokers. The RR from exposure diminished with time since the exposure occurred. For equal total exposure, exposures of long duration (and low rate) were more harmful than exposures of short duration (and high rate).

CONCLUSIONS: In the miners, about 40% of all lung cancer deaths may be due to radon progeny exposure, 70% of lung cancer deaths in never-smokers, and 39% of lung cancer deaths in smokers. In the United States, 10% of all lung cancer deaths might be due to indoor radon exposure, 11% of lung cancer deaths in smokers, and 30% of lung cancer deaths in never-smokers. This risk model estimates that reducing radon in all homes exceeding the U. S. Environmental Protection Agency's recommended action level may reduce lung cancer deaths about 2%-4%. These estimates should be interpreted with caution, because concomitant exposures of miners to agents such as arsenic or diesel exhaust may modify the radon effect and, when considered together with other differences between homes and mines, might reduce the generalizability of findings in miners.

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Gefahren ionisierender Stahlung

Uranbergbau

Rössing, Namibia
Zaire et al. „Unexpected Rates of Chromosomal Instabilities and Alterations of Hormone Levels in Namibian Uranium Miners“. Rad Res 1997 May;147(5):579-84.

Saskatchewan, Kanada
Rachel et al. „Mortality (1950–1999) and Cancer Incidence (1969–1999) in the Cohort of Eldorado Uranium Workers“. Radiation Research, December 2010, Vol. 174, No. 6a

Jadugoda, Indien
Koide H. „Radioactive contamination around Jadugoda uranium mine in India“. Research Reactor Institute, Kyoto University, 08.07.02.

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Gefahren ionisierender Stahlung

Uranbergbau

Radium Hill, Australien
Woodward et al. „Radon daughter exposures at the Radium Hill uranium mine and lung cancer rates among former workers, 1952-87". Cancer Causes and Control 2:91

Shiprock, USA
Gilliland et al. „Uranium Mining and Lung Cancer Among Navajo Men in New Mexico and Arizona". J Occup Environ Med 42(3):278-283, March 2000.

Elliot Lake, Kanada
Kusiak et al. „Mortality from lung cancer in Ontario uranium miners". Br J Ind Med 1993;50:920-928.

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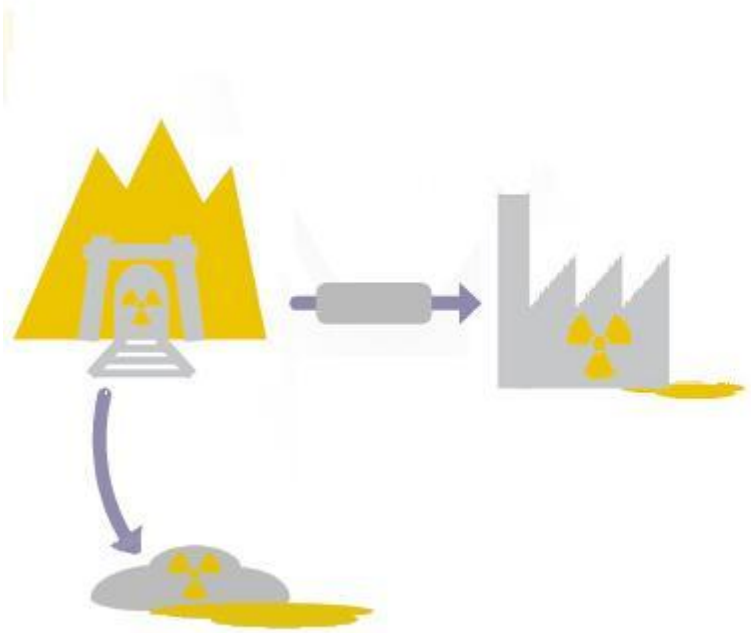

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Gefahren ionisierender Stahlung

Atomarbeiter

154 Standorte
598.000 Arbeiter
> 90% < 50 mSv

Solide Tumore: 97% höheres Risiko pro Sv (95% CI 14 - 197)

Leukämie: 193% höheres Risiko pro Sv (95% CI 0 - 847)

1-2% aller Todesfälle bei Atomarbeitern dürften auf Strahlungseffekte beruhen.

BMJ Helping doctors make better decisions

2005

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 smoking indicate that, although confounding by smoking may be present, it is unlikely to explain all of this increased risk. The excess relative risk for leukaemia excluding chronic lymphocytic leukaemia was 1.93 per Sv (−0.10 to 8.47). On the basis of these estimates, 1-2% of deaths from cancer among workers in this cohort may be attributable to radiation.
Conclusions These estimates, from the largest study of nuclear workers ever conducted, are higher than, but statistically compatible with, the risk estimates used for current radiation protection standards. The results suggest that there is a small excess risk of cancer, even at the low doses and dose rates typically received by nuclear workers in this study.

by the public in the general environment, by patients through repeated diagnostic procedures,[4] 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,[5] but the sample size has limited the precision of these estimates. Analyses of combined cohorts have improved precision.[6,7] 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, production of radioisotopes, or reactor or weapons research. Uranium mining is not included.

Methods

This multinational retrospective cohort study used a common protocol in 15 countries and collected information on nearly 600 000 workers. Study cohorts were defined from employment or dosimetric records of participating facilities or, where available, from centralised national dose registries. The a priori eligibility criteria for inclusion of cohorts[8] were essentially complete and non-selective follow-up for mortality;

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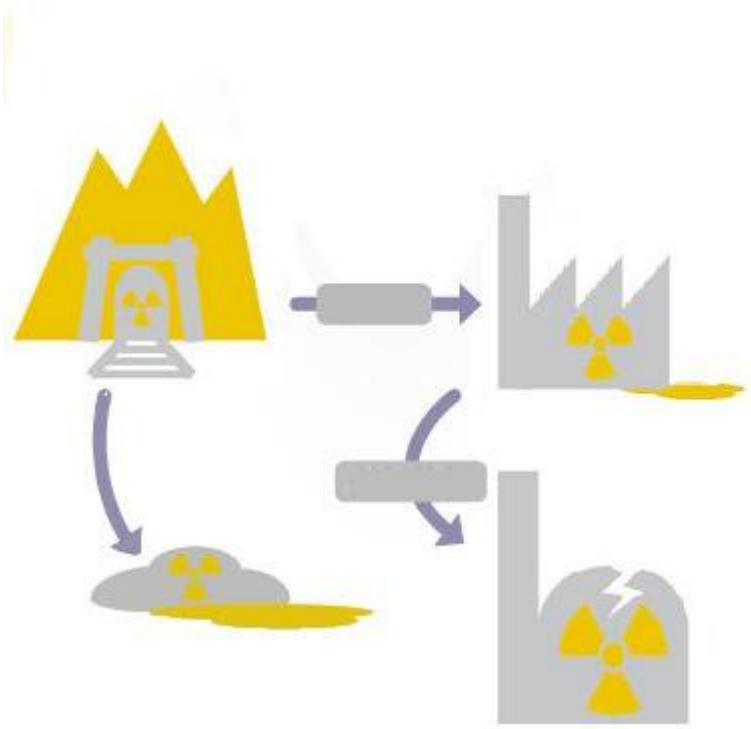

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Gefahren ionisierender Stahlung

Atomkraftwerke

Signifikant erhöhtes Krebsrisiko für Kinder < 5 Jahren in der Nähe von AKWs

Es konnten keine Counfounder identifiziert werden

IJC International Journal of Cancer

Leukaemia in young children living in the vicinity of German nuclear power plants

2008

Peter Kaatsch*, Claudia Spix, Renate Schulze-Rath, Sven Schmiedel and Maria Blettner

Institute for Medical Biostatistics, Epidemiology and Informatics, German Childhood Cancer Registry, Obere Zahlbacher Strasse 69, 55131 Mainz, Germany

A case control study was conducted where cases were children younger than 5 years (diseased between 1980 and 2003) registered at the german childhood cancer registry (GCCR). Population-based matched controls (1:3) were selected from the corresponding registrar's office. Residential proximity to the nearest nuclear power plant was determined for each subject individually (with a precision of about 25 m). The report is focused on leukaemia and mainly on cases in the inner 5-km zone around the plants. The study includes 593 leukaemia cases and 1,766 matched controls. All leukaemia combined show a statistically significant trend for 1/distance with a positive regression coefficient of 1.75 [lower 95%-confidence limit (CL): 0.65]; for acute lymphoid leukaemia 1.63 (lower 95%-CL: 0.39), for acute non-lymphocytic leukaemia 1.99 (lower 95%-CL: −0.41). This indicates a negative trend for distance. Cases live closer to nuclear power plants than the randomly selected controls. A categorical analysis shows a statistically significant odds ratio of 2.19 (lower 95%-CL: 1.51) for residential proximity within 5 km compared to residence outside this area. This result is largely attributed to cases in previous studies of the GCCR (especially in the inner zone) as there is clearly some overlap between those studies. The result was not to be expected under current radiation-epidemiological knowledge. Considering that there is no evidence of relevant accidents and that possible confounders could not be identified, the observed positive distance trend remains unexplained.

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Key words: childhood; leukaemia; nuclear power plants; population-based; cancer registry

reports prompted a study of almost identical design that was based on the data of the German Childhood Cancer Registry (GCCR) and was conducted in the late 1980s. This was an ecological study comparing disease rates within 15 km (roughly 10 miles) of German nuclear plants with those seen in specified control areas. The study period extended from 1980 through 1990 (Study 1). An increased rate of all cancer or, more specifically, leukaemia in children younger than 15 years within a 15-km zone of West German nuclear plants was not confirmed. However, exploratory analyses indicated that, for example, in children younger than 5 years living within the inner 5-km zone, the increase in leukaemia rate was statistically significant.[15] As these results gave rise to controversial discussion and as at the same time a statistically significant leukaemia cluster was seen near the North German nuclear power plant of Krümmel,[16] the study period was extended to cover the years 1991 through 1995 (Study 2).

Study 2 failed to reproduce statistically significant results regarding the subgroup for which results were significantly increased in the exploratory analysis of Study 1. Nevertheless, a tendency was seen towards an increased relative risk (RR) for leukaemia to occur in under 5-year-olds within the 5-km vicinity.[17]

Even after these results had been published, discussions on a potential relationship between the occurrence of childhood leukaemia and close proximity to nuclear plants in routine operation have not ceased. For this reason, a case control study was initiated by the Federal government and started at the GCCR in 2003.

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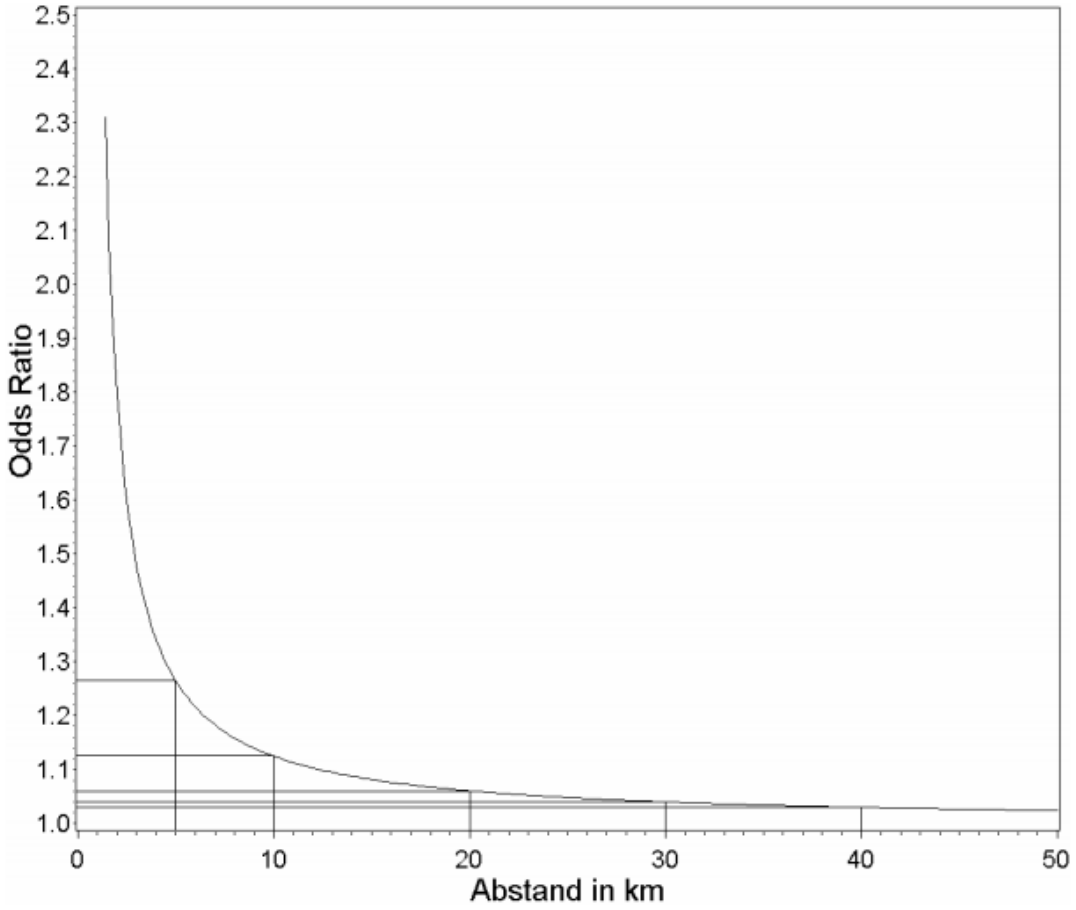
Atomkraftwerke

Risiko abhängig von der Entfernung vom AKW:

- 50 km: 8–18 % mehr Fälle
- 10 km: 20–40 % mehr Fälle
- 5 km: 60–75 % mehr Fälle



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Gefahren ionisierender Stahlung

Atomkraftwerke

Ähnliche relative Risiken für Kinder rund um Atomkraftwerke in Großbritannien, der Schweiz und Deutschland

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

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International Journal of **Epidemiology**

2012

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

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Untere Soeldnersgasse 8, D-90403 Nuremberg, Germany. E-mail: alfred.koerblein@gmx.de

ARTICLE

In their recent article on childhood cancer near nuclear power plants (NPPs) in Switzerland, Spycher *et al.*[1] state that they found little evidence for an association between the risk of childhood cancer and living near NPPs. The IRR (incidence rate ratio) of leukaemia in children aged <5 years was 1.2 in the 5-km zone relative to distances >15 km from residence at birth. However, the 95% confidence interval for IRR was large (0.60–2.41) and includes the RR of 2.2 in the 5-km zone found in the German case-control study (KiKK).

In the abstract they say that the results were similar for residence at diagnosis and at birth. But the IRR for the 'residence cohort' is 1.41, so the increase of risk is twice as large as in the 'birth cohort'.

Recent ecological studies in Great Britain[2] and Germany[3] also evaluated residence at diagnosis and found similar leukaemia risks in children <5 years of age living near (0–5 km) nuclear power stations (Table 1). The standardized incidence ratio (SIR) is 1.40 in Switzerland (CH), 1.36 in

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Atomunglücke

Durch Tschernobyl:
• 16.000 (3.400-72.000) Schilddrüsenkrebsfälle
.
• 25.000 (11.000-59.000) Andere Krebsfälle

> 15.000 zusätzliche Krebstodesfälle

IJC International Journal of Cancer

2006

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]

[1]*International Agency for Research on Cancer, Lyon, France*
[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

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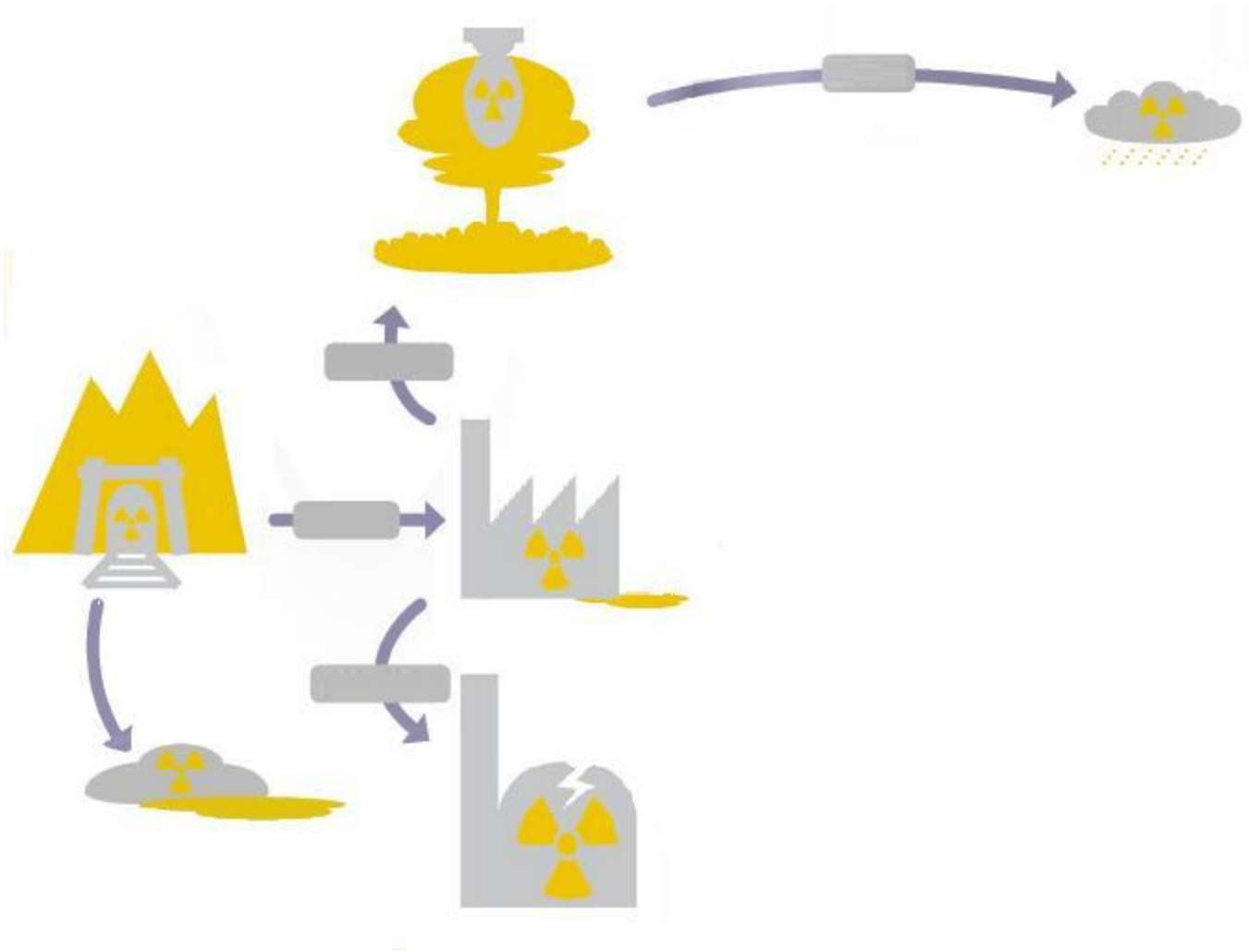

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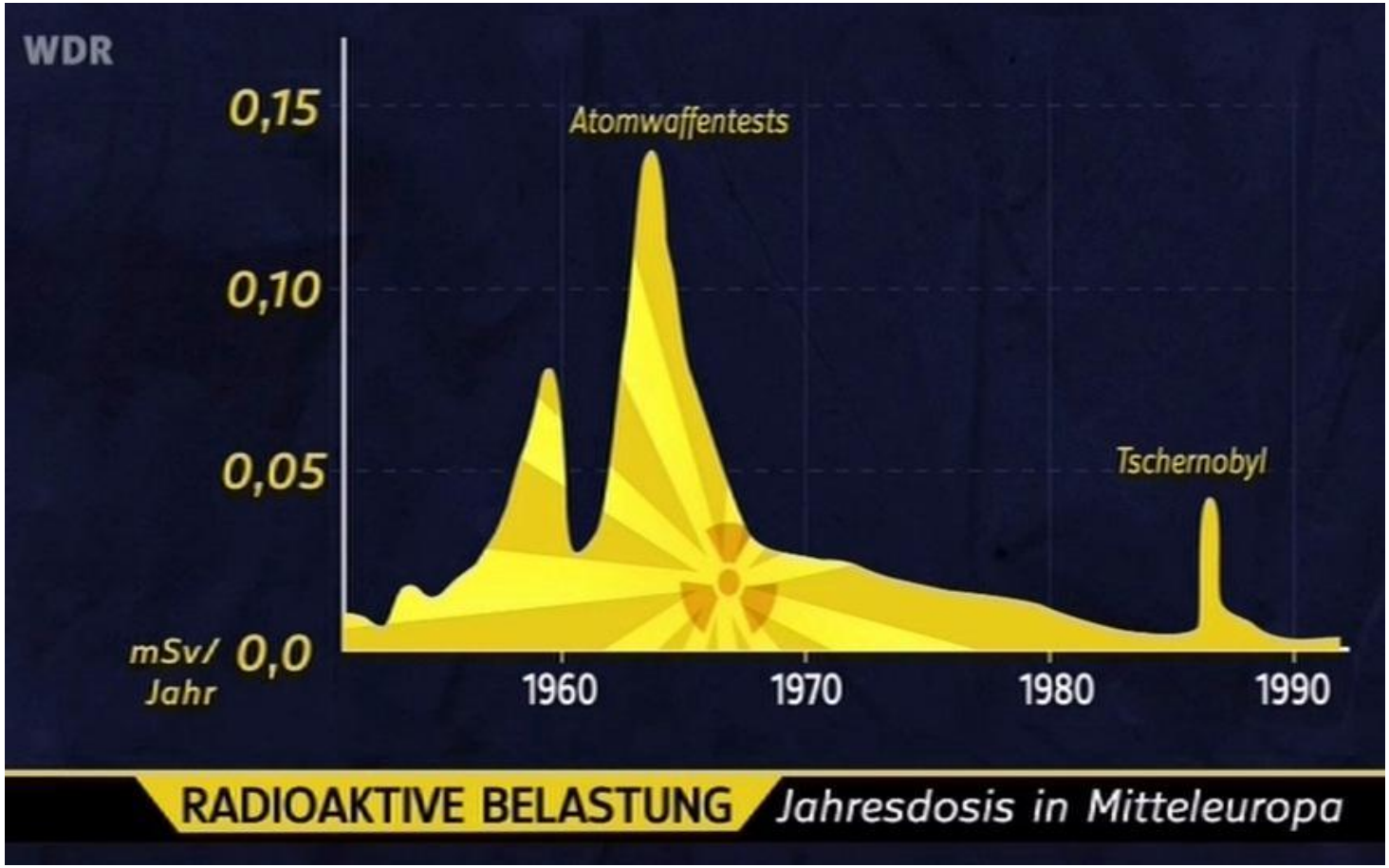
Atomwaffen



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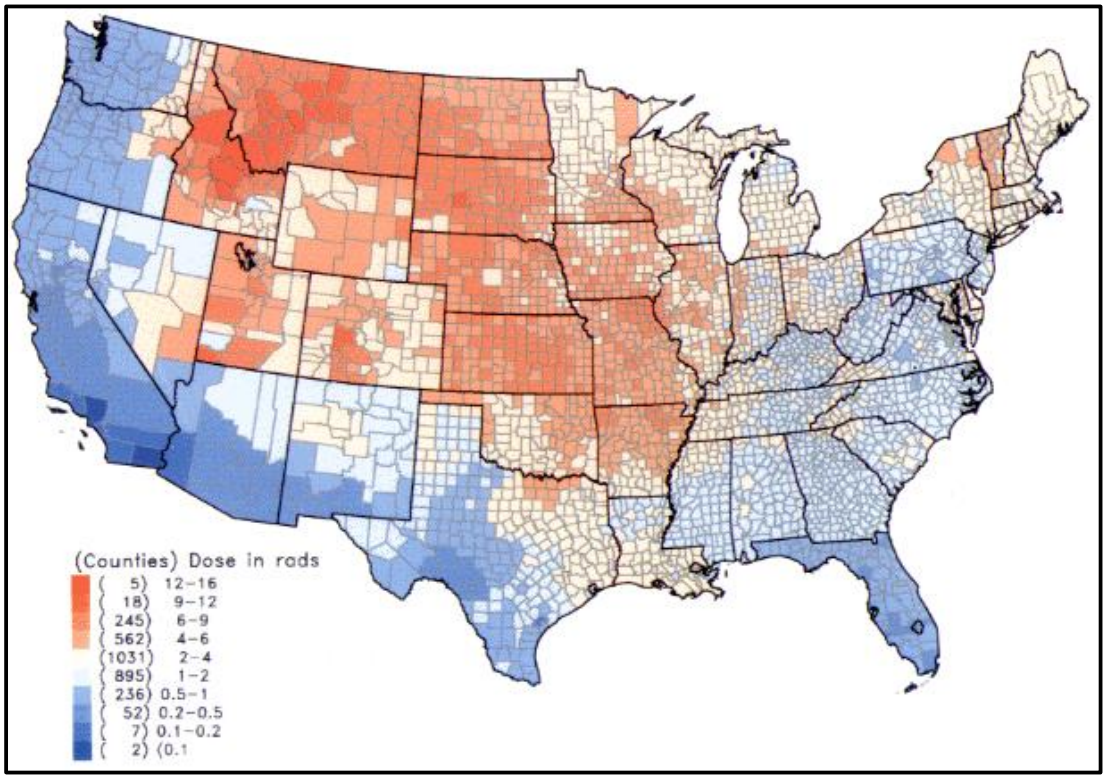
Atomwaffen

US National Cancer Institute (2006):

90 Atomtests 1952-1957

5,55 EBq (10^{18} Bq) Iod-131

Schilddrüsendosen:
- Maximal 120-160 mSv
- Durchschnittlich 20 mSv



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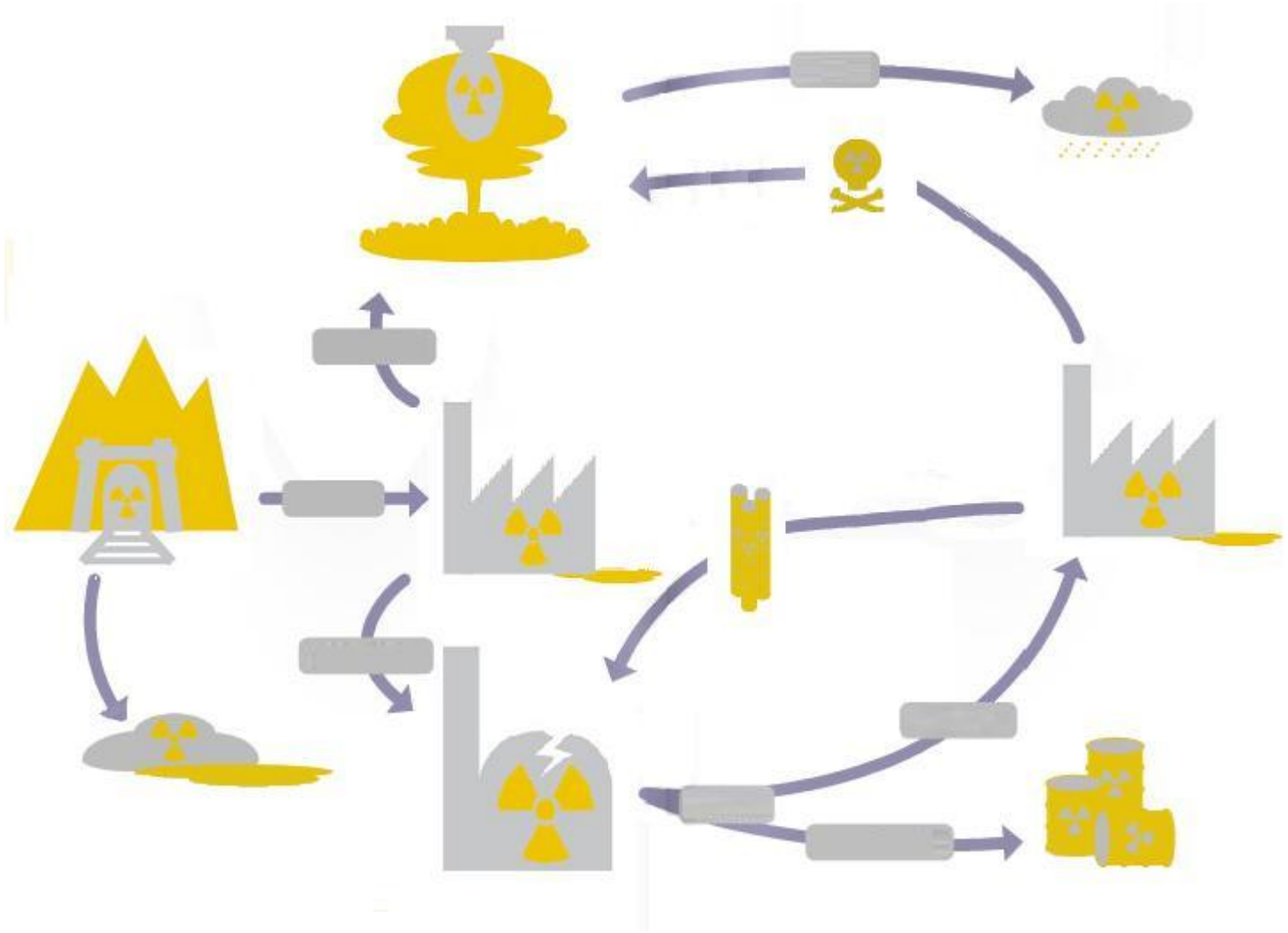
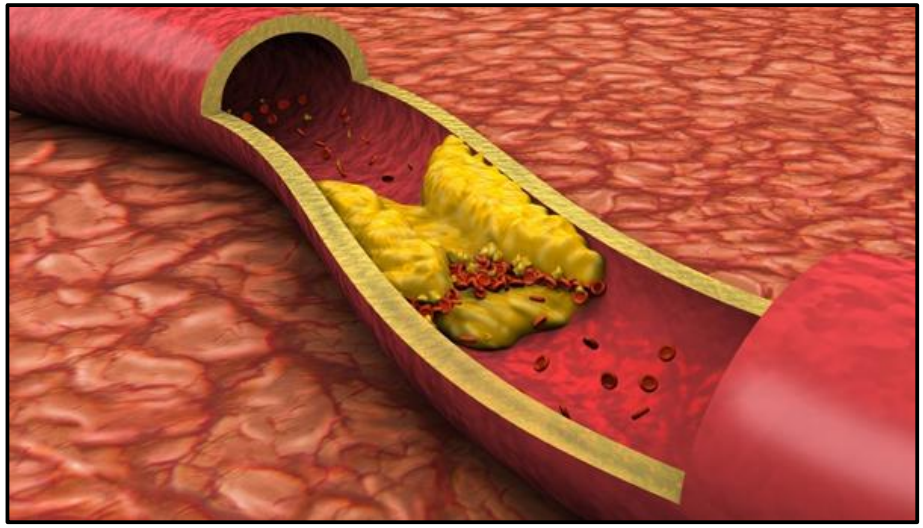


Gefahren ionisierender Stahlung

Nicht-Krebserkrankungen

Niedrige Strahlendosen können auch zu benignen Tumoren, kardiovaskulären, zerebrovaskulären, respiratorischen, gastrointestinalen, endokrinologischen Erkrankungen, Intelligenzminderung und Katarakten führen.



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Gefahren ionisierender Stahlung

Nicht-Krebserkrankungen

Kreislauferkrankungen 1 – 13 % pro Sv

Ähnlich hohe Mortalität durch Nicht-Krebserkrankungen wie durch Krebserkrankungen (5 % pro Sv)

ehp 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]

[1]Radiation Epidemiology Branch, National Cancer Institute, National Institutes of Health, Department of Health and Human Services, Rockville, Maryland, USA; [2]Southern Urals Biophysics Institute, Ozyorsk, Russia; [3]Research Center for Radiation Medicine, Kyiv, Ukraine; [4]Health Protection Agency, Centre for Radiation, Chemical and Environmental Hazards, Chilton, United Kingdom; [5]Center for Research in Environmental Epidemiology (CREAL), Barcelona, Spain; [6]Medical Radiological Research Center of Russian Academy of Medical Sciences, Obninsk, Russia; [7]NASA Johnson Space Center, Space Radiation Program, Houston, Texas, USA; [8]Radiation Epidemiology Group, INSERM (Institut National de la Santé et de la Recherche Médicale) Unité U1018, Institut Gustave Roussy, Villejuif, France; [9]Department of Medical Epidemiology and Biostatistics, Karolinska Institute, Stockholm, Sweden; [10]Department of Radiotherapy and Radiation Oncology, University of Leipzig, Leipzig, Germany; [11]Department of Radiotherapy and Radiation Oncology, University of Rostock, Rostock, Germany; [12]Federal Office for Radiation Protection, Department of Radiation Protection and Health, Oberschleissheim, Germany; [13]Laboratoire d'Epidémiologie, Institut de Radioprotection et de Sûreté Nucleaire, Fontenay-aux-Roses, France; [14]Department of Epidemiology, Radiation Effects Research Foundation, Hiroshima City, Japan; [15]CEPN (Nuclear Evaluation Protection Center), Fontenay-aux-Roses, France; [16]Helmholtz Zentrum München, German Research Centre for Environmental Health, Institute of Radiation Biology (ISB), Radiation Proteomics, Oberschleissheim, Germany; [17]University College London Institute of Cardiovascular Sciences & Great Ormond Street Hospital for Children, London, United Kingdom; [18]Department of Epidemiology and Biostatistics, Imperial College Faculty of Medicine, London, United Kingdom; [19]Dalton Nuclear Institute, University of Manchester, Manchester, United Kingdom; [20]Department of Epidemiology and Biostatistics, University of California San Francisco School of Medicine, San Francisco, California, USA; [21]Department of Pediatrics, Leonard M. Miller School of Medicine, University of Miami, Miami, Florida, USA

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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Gefahren ionisierender Stahlung

Nicht-Krebserkrankungen

Data	Reference	Mean heart/brain dose (range) (Sv)	No. in cohort (person-years follow-up)	End point (mortality)[a]	ERR/Sv (95% CI)
Japanese atomic-bomb survivors					
Mortality	Shimizu et al. 2010	0.1 (0 to 4)[b]	86,611 (NA)	IHD (ICD-9 410–414)	0.02 (–0.10, 0.15)
				Rheumatic heart disease (ICD-9 393–398)	0.86 (0.25, 1.72)
				Heart failure (ICD-9 428)	0.22 (0.07, 0.39)
				Other heart disease (ICD-9 390–392, 415–427, 429)	–0.01 (–0.21, 0.24)
				CVA total (ICD-9 430–438)[c]	0.12 (0.05, 0.19)[c]
				Circulatory disease apart from heart disease and stroke (ICD-9 390–392, 401, 403, 405, 439–459)[c]	0.58 (0.45, 0.72)[c]
Morbidity	Yamada et al. 2004	0.1 (0 to 4)[d]	10,339 (NA)	Hypertension incidence, 1958–1998 (ICD-9 401)	0.05 (–0.01, 0.10)[d]
				Hypertensive heart disease incidence, 1958–1998 (ICD-9 402, 404)	–0.01 (–0.09, 0.09)[d]
				IHD incidence, 1958–1998 (ICD-9 410–414)	0.05 (–0.05, 0.16)[d]
				Aortic aneurysm incidence, 1958–1998 (ICD-9 441, 442)	0.02 (–0.22, 0.41)[d]
				CVA incidence, 1958–1998 (ICD-9 430, 431, 433, 434, 436)	0.07 (–0.08, 0.24)[d]
Occupational studies					
Mayak workers	Azizova et al. 2010a, 2010b	0.83 (0 to 5.92)[e]	12,210 (205,249)	IHD morbidity (ICD-9 410–414)	0.119 (0.051, 0.186)[e,f]
			12,210 (249,530)	CVA morbidity (ICD-9 430–432, 434, 436)	0.449 (0.338, 0.559)[e,f]
Chernobyl emergency workers	Ivanov et al. 2006	0.109 (0 to > 0.5)	61,017 (NA)	Hypertension (ICD-10 I10–I15) morbidity	0.26 (–0.04, 0.56)
				IHD (ICD-10 I20–I25) morbidity	0.41 (0.05, 0.78)
				Other heart disease (ICD-10 I30–I52) morbidity	–0.26 (–0.81, 0.28)
				CVA (ICD-10 I60–I69) morbidity	0.45 (0.11, 0.80)
				Morbidity from diseases of arteries, arterioles, and capillaries (ICD-10 I70–I79)	0.47 (–0.15, 1.09)
				Morbidity from diseases of veins, lymphatic vessels, and lymph nodes (ICD-10 I80–I89)	–0.26 (–0.70, 0.18)
German uranium miner study	Kreuzer et al. 2006	0.041 (0 to 0.909)[e]	59,001 (1,801,626)	CVA (ICD-10 I60–I69)	0.09 (–0.6, 0.8)[e]
EdF workers	Laurent et al. 2010	0.0215 (0 to 0.6)	22,393 (440,984)	IHD (ICD-10 I20–I25)	4.1 (–2.9, 13.7)[g]
				CVA (ICD-10 I60–I69)	17.4 (0.2, 43.9)[g]
Eldorado uranium miners and processing (male) workers	Lane et al. 2010	0.0522 (< 0.0234 to > 0.1215)	16,236 (508,673)	IHD (ICD-10 I20–I25)	0.15 (–0.14, 0.58)
				CVA (ICD-10 I60–I69)	–0.29 (< –0.29, 0.27)
Third analysis of UK National Registry for Radiation Workers	Muirhead et al. 2009	0.0249 (< 0.01 to > 0.4)	174,541 (3,900,000)	IHD (ICD-9 410–414)	0.259 (–0.05, 0.61)
				CVA (ICD-9 430–438)	0.161 (–0.42, 0.91)
IARC 15-country nuclear worker study	Vrijheid et al. 2007	0.0207 (0.0 to > 0.5)	275,312 (4,067,861)	IHD (ICD-10 I20–I25)	–0.01 (–0.59, 0.69)
				Heart failure (ICD-10 I50)	–0.03 (< 0, 4.91)
				CVA (ICD-10 I60–I69)	0.88 (–0.67, 3.16)

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Gefahren ionisierender Stahlung

Nicht-Krebserkrankungen

Ca. 3.000 Kinder nach Strahlentherapie bei kutanen Hämangiomen

Umfangreiche Dosisermittlung (mittlere Hirndosis < 100 mGy)

Negative Auswirkungen auf:
- Besuch weiterführender Schulen
- Lernfähigkeitstests
- Logische Schlussfolgerung

BMJ Helping doctors make better decisions

2004

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 9094 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 92% 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 0.25 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.

We analysed cognitive function in a large population based cohort of men at the time of military enlistment who had received low dose ionising radiation for cutaneous haemangioma before age 18 months. Based on previous experience, we hypothesised that damage to the frontal part of the brain would have a more severe effect on mental capacity than damage to the posterior part.[11]

Participants and methods

Our cohort comprised all boys treated by radiotherapy for cutaneous haemangioma aged under 18 months at the Karolinska University Hospital in Stockholm. This cohort has been described in detail previously.[12,17]

Around 95% of Swedish men aged 18 or 19 years are tested before military service. During the period of our study, about 2% of the men tested were exempted from military service for medical or psychological reasons.[18] We were given permission to search the Swedish war archives.

From the military register we obtained information on age at enlistment, education, number of siblings, birth order, father's occupation, and cognitive test results. Father's occupation, a proxy for socioeconomic status, was categorised into four groups: unknown and farmers, blue collar workers, low level white collar workers, and high level white collar workers. Categorisation was based on the socioeconomic index, which takes education into consideration.[19]

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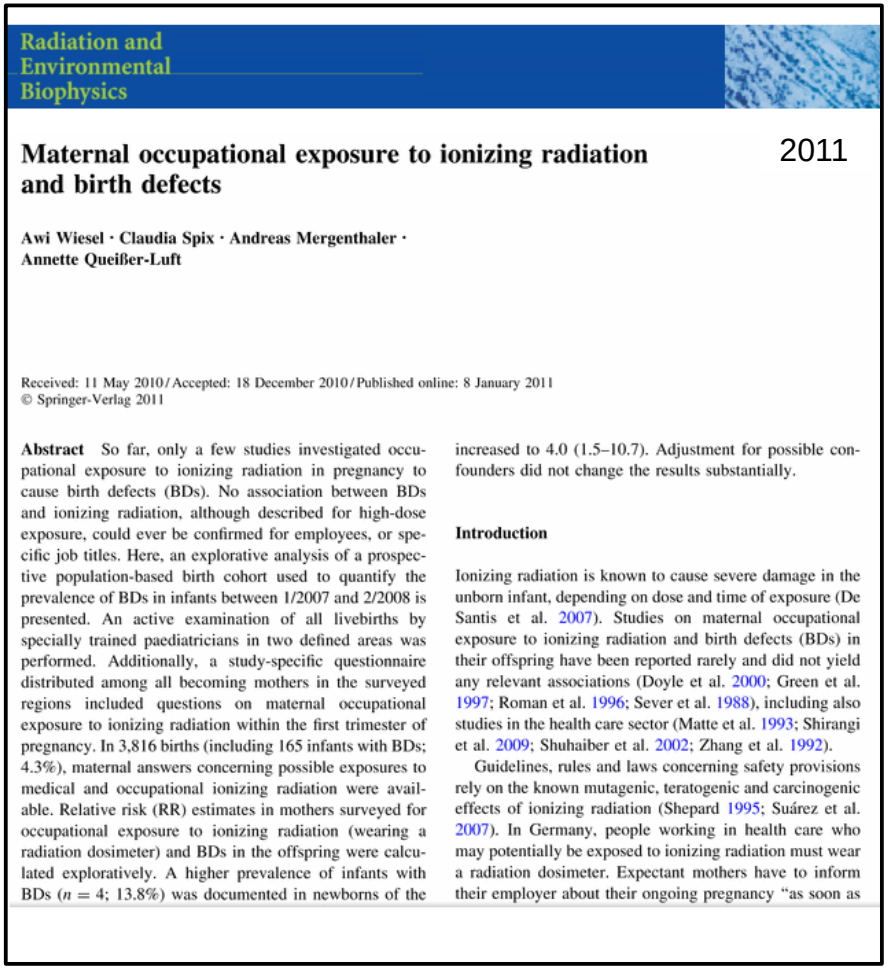
Gefahren ionisierender Stahlung

Nicht-Krebserkrankungen

Relatives Risiko für kindliche Fehlbildungen bei strahlenexponierten Müttern = 3.2 (1.2-8.7)

Substantielle Confounder konnten nicht gefunden weren.



Radiation and Environmental Biophysics

2011

Maternal occupational exposure to ionizing radiation and birth defects

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

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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.

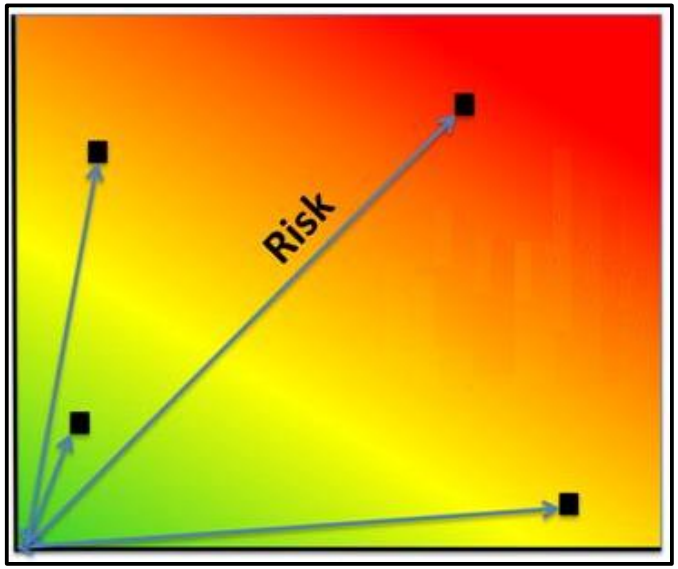
Introduction

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

Berechnung von Risiken

Auf der Grundlage epidemiologischer Studien können mit der Anwendung des Kollektivdosiskonzepts Gesundheitsrisiken im niedrigen Dosisbereich belastbar quantitativ abgeschätzt werden



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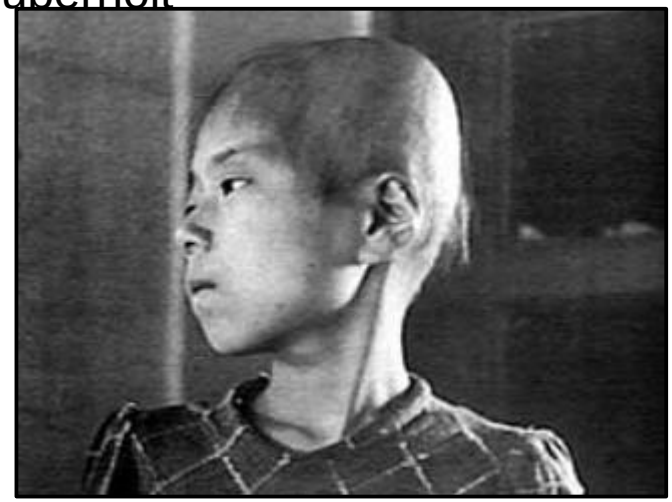
Gefahren ionisierender Stahlung

Berechnung von Risiken

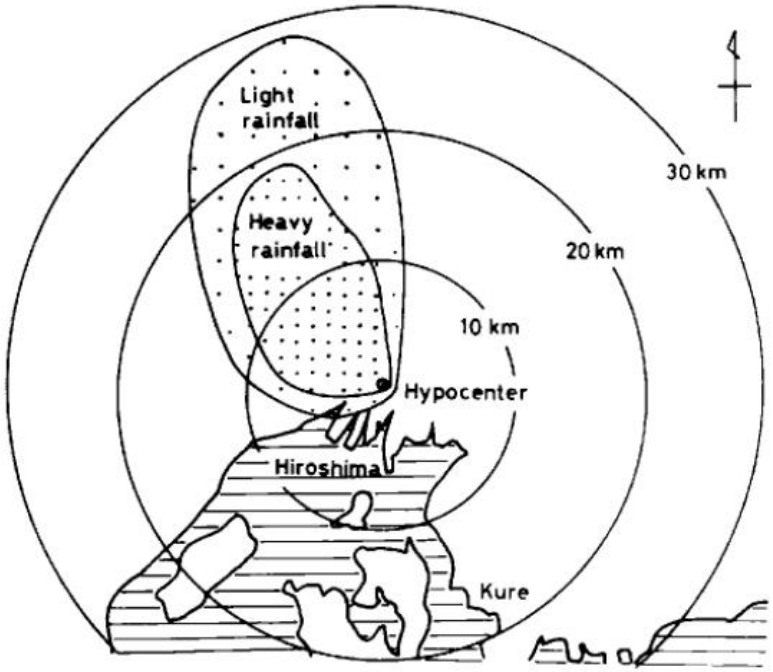
Die von der ICRP immer noch praktizierte Ableitung der Risikofaktoren aus den Hiroshima- und Nagasaki-Studien ist überholt



Gefahren ionisierender Stahlung

Berechnung von Risiken

• Die Dosisanteile durch radioaktiven Fallout und Neutronenaktivierung wurden bei der Dosisabschätzung nicht berücksichtigt, obwohl sie signifikante Effekte verursacht haben.



Takada J et al. „Uranium Isotopes in Hiroshima“. Journal of Radiation Research”, Vol.24,Vo.3(1983)pp.229-23

Gefahren ionisierender Stahlung

Berechnung von Risiken

Dadurch kommt es zu einer Unterschätzung der Strahlenwirkung

Environmental Health
and Preventive Medicine

Hiroshima survivors exposed to very low doses of A-bomb primary radiation showed a high risk for cancers 2009

Tomoyuki Watanabe · Masaru Miyao · Ryumon Honda · Yuichi Yamada

Received: 24 December 2007 / Accepted: 15 May 2008 / Published online: 5 July 2008
© The Japanese Society for Hygiene 2008

Abstract
Objectives The aim of this study was to compare the risk for cancers of A-bomb survivors in the ongoing life span study (LSS) with unexposed groups consisting of the entire populations of Hiroshima prefecture and neighboring Okayama prefecture.
Methods The subjects consisted of the Hiroshima group reported in LSS report 12 (LSS-H group) and a control group (the entire populations of Hiroshima and Okayama—HPCG and OPCG, respectively). We estimated the expected number of deaths due to all causes and to cancers of various causes among the exposed survivors of the Hiroshima bombing in the LSS report 12 who died in the follow-up interval at ages similar to those of people in Hiroshima and Okayama prefectures who were aged 0–34 years at the time of the bombing in 1945. We compared the standardized mortality ratio (SMR) of the LSS-H group to that of the HPCG and OPCG (SMR-H and SMR-O, respectively).
subjects, and for uterus and liver cancers in female subjects, respectively. The results show that, if the dose estimations of the dosimetry system 1986 (DS86) are correct, there are significantly increased risks of cancer among even survivors exposed to the very low dose level.
Conclusions The dose assumptions of DS86 have been criticized for underestimating doses in areas distant from the hypocenter. The contribution of residual radiation, ignored in LSS, and that of neutrons, underestimated by DS86, is suggested to be fairly high.

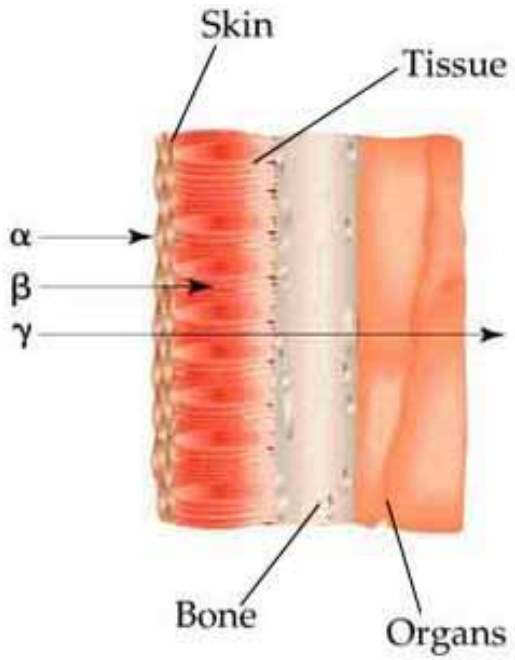
Keywords Atomic bomb · Cancer · Hiroshima survivors · Radiation · SMR

Gefahren ionisierender Stahlung

Berechnung von Risiken

• Kurzdauernde, hochenergetische, durchdringende Gammastrahlen sind weniger Gewebewirksam als interne Alpha- und Betastrahlung nach Radionuklidinkorporation oder andauernde Strahlung.

Eine Halbierung der Risikofaktoren ist daher nicht zulässig



Gefahren ionisierender Stahlung

Berechnung von Risiken

Consideration of uncertainty led to the development of probability distributions of DDREF for use in risk assessment (89). Still there is a lack of a full understanding of the processes leading to cancer after low-dose radiation exposure. The solid cancer risk in 12 epidemiological studies of radiation-exposed workers and of the population residing at the contaminated Techa River in the Southern Urals, Russia, was compared to cancer risks among the Japanese atomic bomb survivors (74). Overall, risk estimates were similar to those among the atomic bomb survivors, suggesting that a DDREF of 1 would be reasonable. A meta-analysis has considered recent epidemiological evidence on leukaemia mortality and incidence risks from protracted low-dose and low-dose-rate exposures to γ-rays. It included an extensive literature review of studies on groups of people who were either occupationally or environmentally exposed (92). The main risk measure value reported in this meta-analysis (ERR) indicated that the baseline leukaemia risk (i.e. risk for a group of unexposed persons) increases by 19% after exposure to a dose of 100 mGy. This increase was reported to agree closely with the risk from acute exposure of the Japanese atomic bomb survivors and is therefore an indication that leukaemia risks are similar for protracted and acute exposures[5].

World Health Organization (WHO): Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami based on a preliminary dose estimation. 2013, 32

Gefahren ionisierender Stahlung

Berechnung von Risiken

• Daten wurden erst ab 1950 gesammelt

• Hibakusha waren eine geächtete Gruppe, daher vermutlich fehlerhafte Angaben

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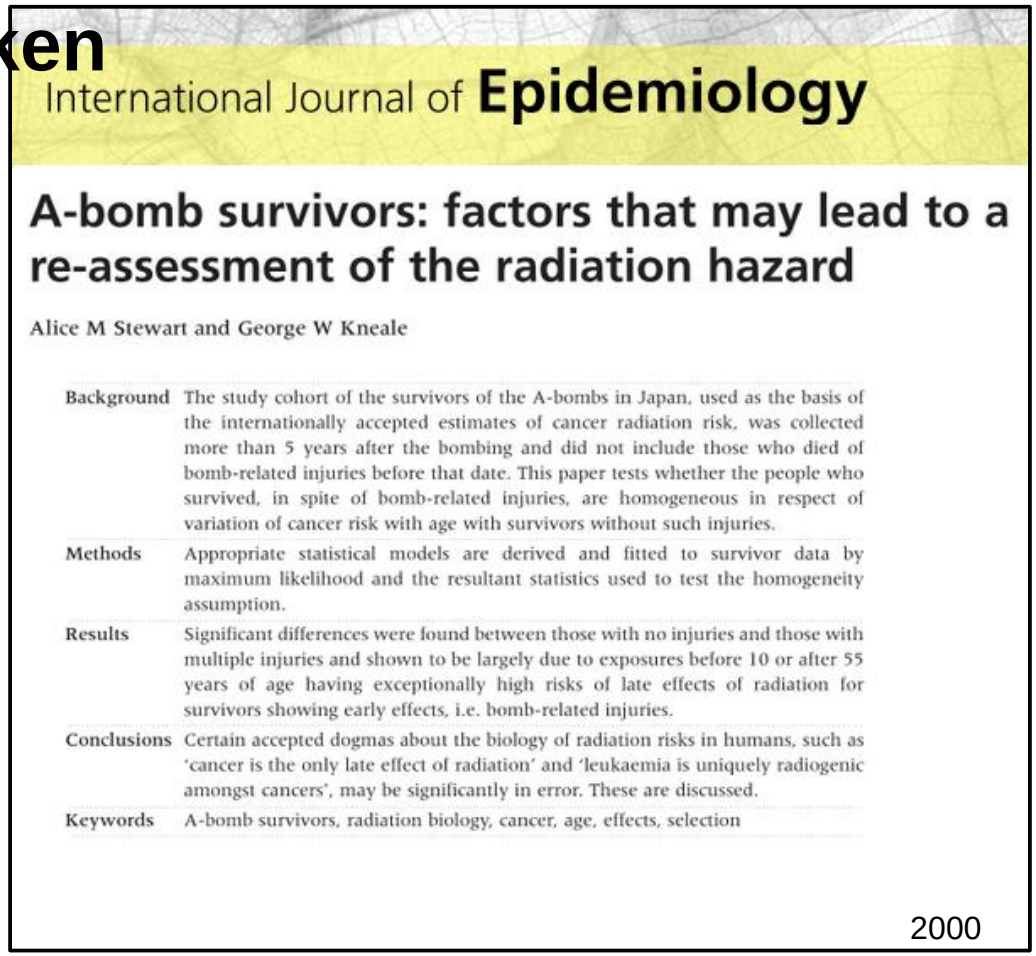
Gefahren ionisierender Stahlung

Berechnung von Risiken

• Selektierte Gruppe der besonders Widerstandsfähigen, daher Unterschätzung des Strahlenrisikos um ca 30%.



International Journal of **Epidemiology**

A-bomb survivors: factors that may lead to a re-assessment of the radiation hazard

Alice M Stewart and George W Kneale

Background The study cohort of the survivors of the A-bombs in Japan, used as the basis of the internationally accepted estimates of cancer radiation risk, was collected more than 5 years after the bombing and did not include those who died of bomb-related injuries before that date. This paper tests whether the people who survived, in spite of bomb-related injuries, are homogeneous in respect of variation of cancer risk with age with survivors without such injuries.

Methods Appropriate statistical models are derived and fitted to survivor data by maximum likelihood and the resultant statistics used to test the homogeneity assumption.

Results Significant differences were found between those with no injuries and those with multiple injuries and shown to be largely due to exposures before 10 or after 55 years of age having exceptionally high risks of late effects of radiation for survivors showing early effects, i.e. bomb-related injuries.

Conclusions Certain accepted dogmas about the biology of radiation risks in humans, such as 'cancer is the only late effect of radiation' and 'leukaemia is uniquely radiogenic amongst cancers', may be significantly in error. These are discussed.

Keywords A-bomb survivors, radiation biology, cancer, age, effects, selection

2000

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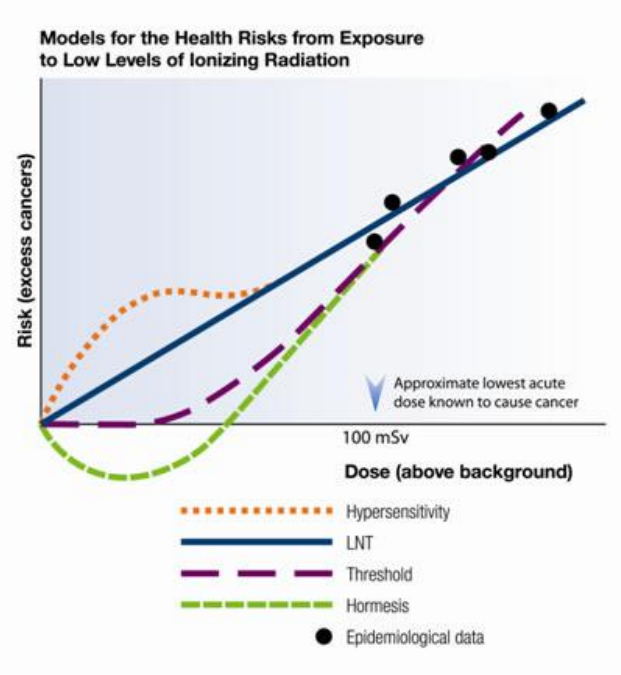
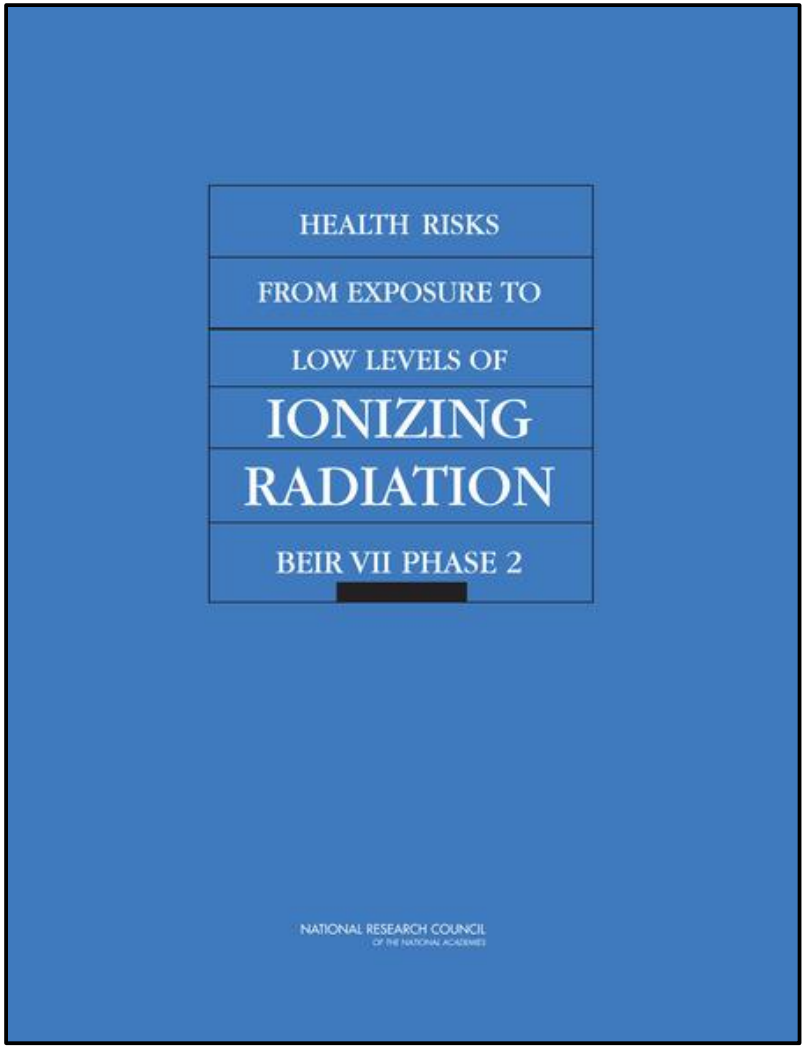
Berechnung von Risiken

Linear non-threshold model (LNT)





Berechnung von Risiken

Alle Krebsarten ohne Schilddrüsen- und Hautkrebs:

- 615/10.000 PSv x 1,5 DDREF-Korrektur = 923/10.000 PSv = 9% pro PSv
- 1.190/10.000 PSv x 1,5 DDREF-Korrektur = 1.785 cases/10.000 PSv = 18% pro PSv
- 2.305/10.000 PSv x 1,5 DDREF-Korrektur = 3.458 cases/10.000 PSv = 35% pro PSv

BEIR VII report, table 12-5A, p. 279

Berechnung von Risiken

Alle Krebsarten ohne Schilddrüsen- und Hautkrebs:

- 305/10.000 PSv x 1,5 DDREF-Korrektur = 458/10.000 PSv = 5% pro PSv
- 610/10.000 PSv x 1,5 DDREF-Korrektur = 915/10.000 PSv = 9% pro PSv
- 1.240/10.000 PSv x 1,5 DDREF-Korrektur = 1.860 cases/10.000 PSv = 19 % pro PSv

BEIR VII report, table 12-5B, p. 280

Berechnung von Risiken

Neuere Studien legen höhere Risikofaktoren nahe:
0,4/PSv für Krebsinzidenz
0,2/PSv für Krebsmortalität

• Körblein A, Hoffmann W: Background radiation and cancer mortality in Bavaria: an ecological analysis. Arch Environ Occup Health 2006, 61(3),109-114

• Cardis E, Vrijheid M, Blettner M, Gilbert E et al.: The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: estimates of radiation-related cancer risks. Radiat Res 2007, 167, 396-416

• Bauer S, Gusev BI, Pivina LM, Apsalikov KN et al.: Radiation exposure due to local fallout from Soviet atmospheric nuclear weapons testing in Kazakhstan: solid cancer mortality in the Semipalatinsk historical cohort, 1960-1999. Radiat Res. 2005, 164

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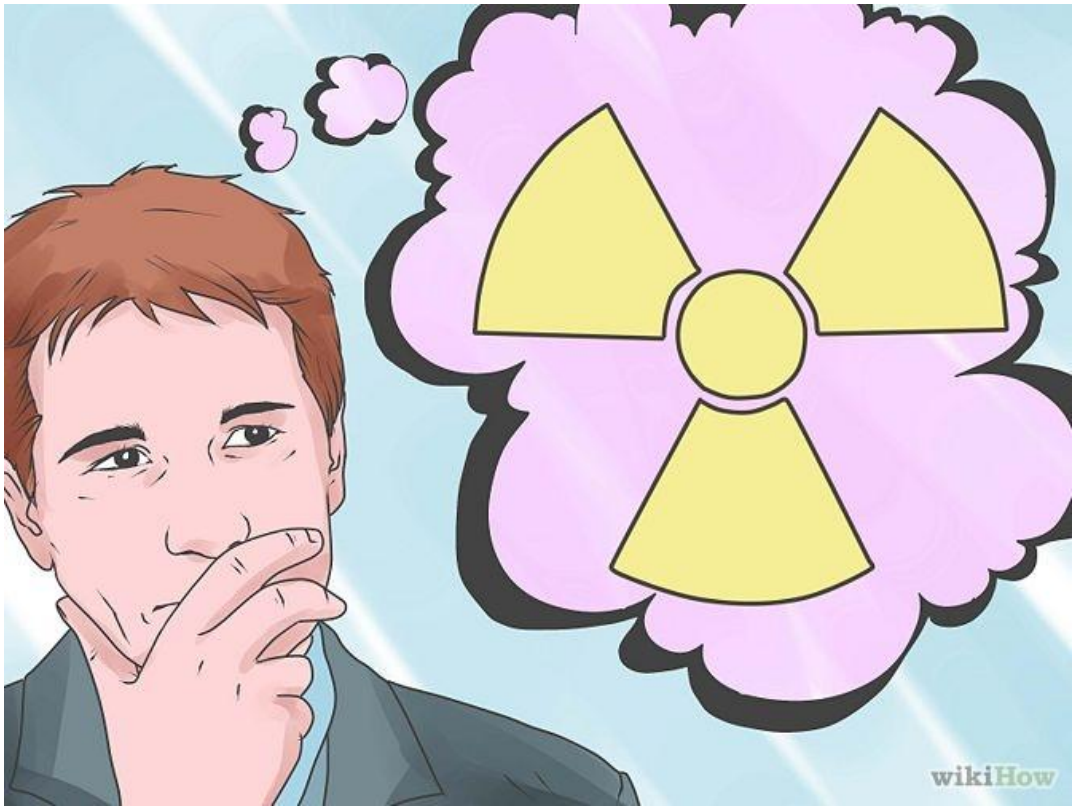
Gefahren ionisierender Stahlung

Berechnung von Risiken

Diese Risikofaktoren beziehen sich auf die Gesamtbevölkerung.

„The relative risks for certain cancers in certain population groups (notably following exposure as fetus, or during infancy and childhood) are higher than for the population Average." (UNSCEAR, 2014)

Der Strahlenschutz muss deshalb die Erwachsenenmodelle ergänzen und sich dabei an der besonderen Vulnerabilität von Ungeborenen und Kindern orientieren.

Gefahren ionisierender Stahlung

Vielen Dank für die Aufmerksamkeit