Ionizing Radiation: Medical Risks – New Aspects

HUMAN RIGHTS, FUTURE GENERATIONS & CRIMES IN THE NUCLEAR AGE

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Ionizing Radiation / Biological Effects / Hibakusha Worldwide

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Contents

- Ionising radiation – a few basics
- Studies in Japanese A-bomb survivors
- New scientific studies on medical risks of low dose ionising radiation (LDIR) in different situations
- Call for revision of recommendations of the International Commission for Radiological Protection (ICRP)

Health risks induced by ionising radiation

Mechanism: Energy of ionising radiation

→ mutations in the genome (nuclear and mitochondrial DNA), «bystander effect»

→ pathological cell phenotype / tissue

→ disease / pathology e.g. skin erythema; cancer, cardiovascular, neurological, ocular and endocrine diseases, malformations, genetic effects e.g. shifts in sex odds ratio at birth (Ref.1)

Lung cancer from uranium mining in Germany known since >> 100 years

Known occupational risk for radiologists since earliest days of diagnostic radiology

Ionising radiation – the sources

- ***Natural sources*** (background radiation, radon)

  and

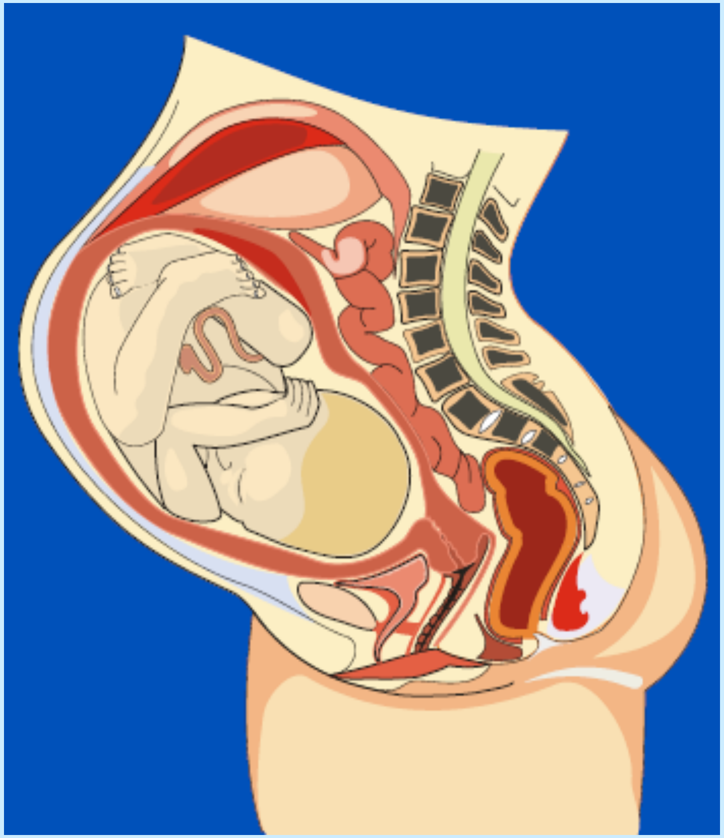
- ***Artificial sources***

  - Uranium mining – processing – nuclear fuel production
  - Nuclear power plant immissions („regular“, disasters)
  - Military radioimmissions (A-bomb, included testing, Depleted Uranium DU)
  - Nuclear waste
  - Medical diagnostics: x-rays, CT-Scan, Szintigraphy, PET (Positron Emission Tomography) = *main source of human exposure to artificial ionising radiation in modern life*
  - Radiotherapy

→ ***Exposure of huge populations to different types and levels of IR***

Dr. Alice Stewart (1906 – 2002, epidemiologist):

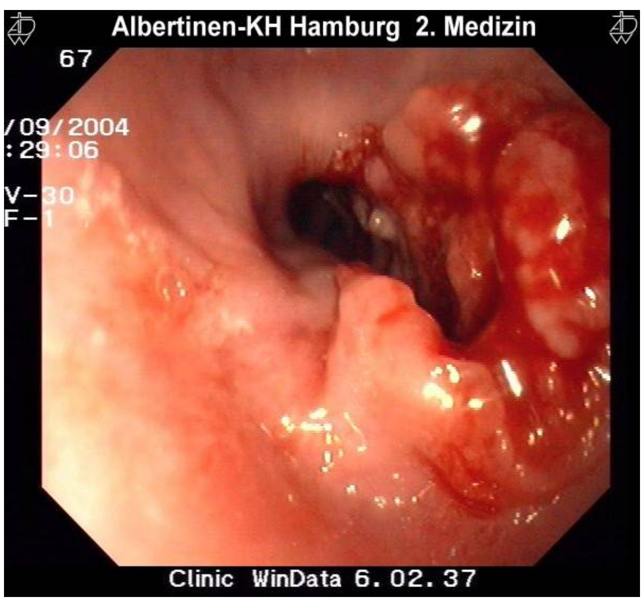
"Overall, children who were exposed to radiation in utero had about a 40% greater risk of cancer than children who were not exposed" Lancet 1956 (Ref. 2;3)

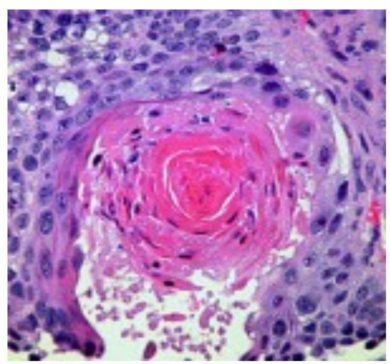


Cancer =

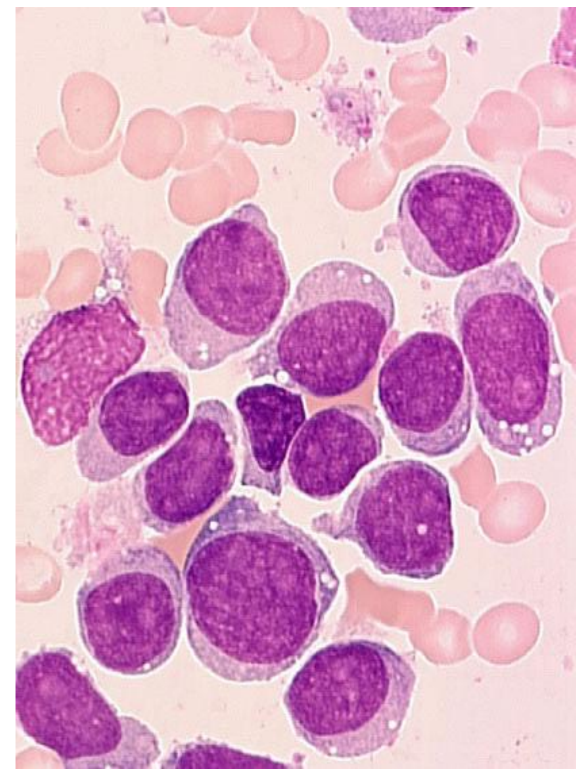
malignant disease based on dysregulated cell proliferation leading to locally infiltrating or distant (metastatic) destructive pathological tissue growth

Solid cancer: eg esophageal cancer





Blood cancer: Leukemia



Leukemia induced by irradiaton from A-bomb

佐々木 禎子

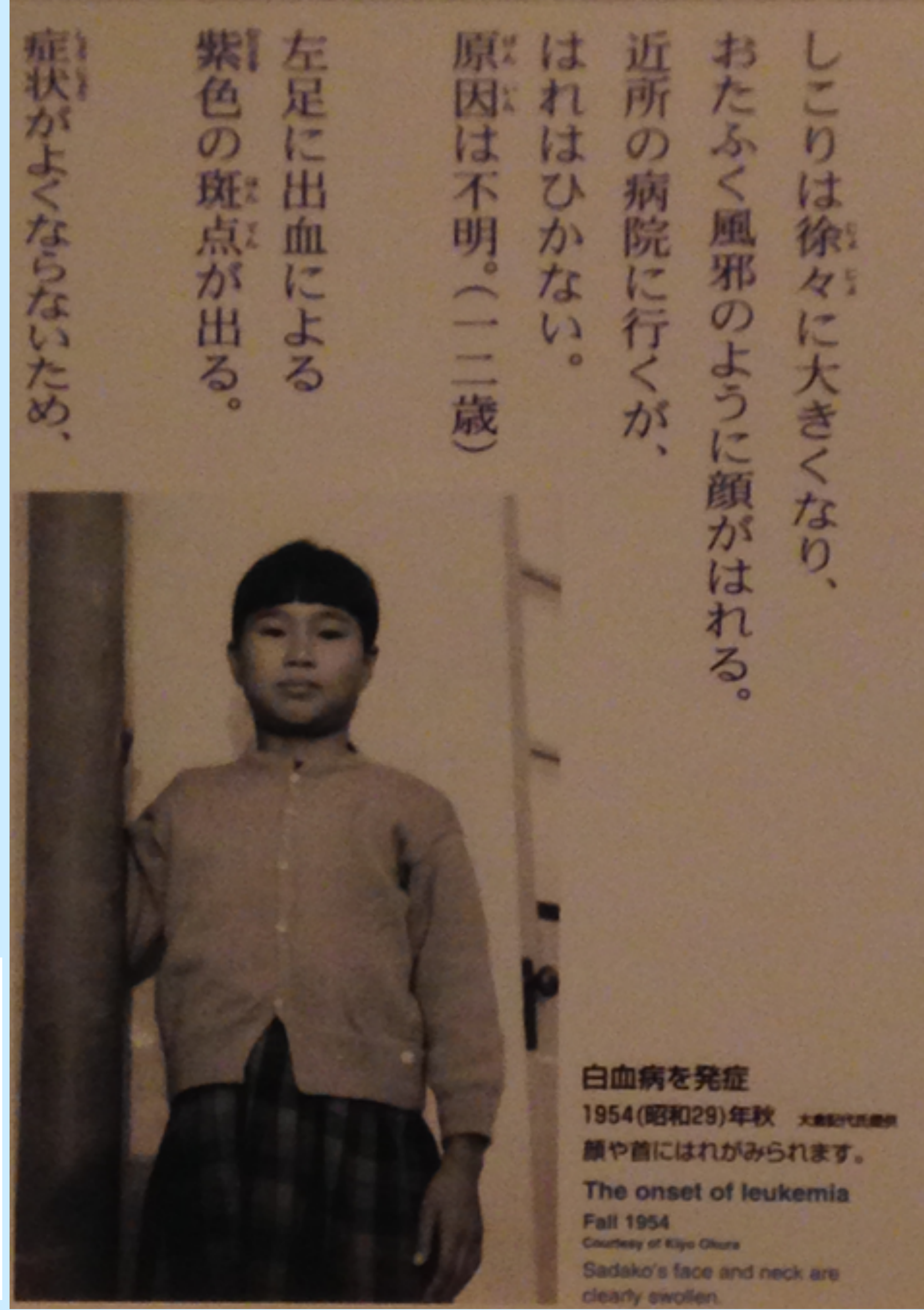
Sasaki Sadako

* 7. January 1943

in Hiroshima;

† 25. October 1955

In Hiroshima



Paper cranes – symbols of peace

千羽鶴, Sembazuru

1600 Origami - cranes were folded by Sasako hoping to overcome her leukemia

How dangerous is ionising radiation really ?

- **Life Span Study (LSS):** Important study on health effects in 120 000 japanese A-bomb survivors (Ref. 4; 5) - long follow up (still 48% of exposed population surviving on 1.January 2004)

- Actual ionising radiation ***riks calculations*** mainly based on LSS

- *EAR* (excess absolute risk) **for cancer mortality: 5.5 % / Sievert (Sv)**

- *ERR* (excess relative risk) for leukemia mortality : 3.1 / Gray (Gy)

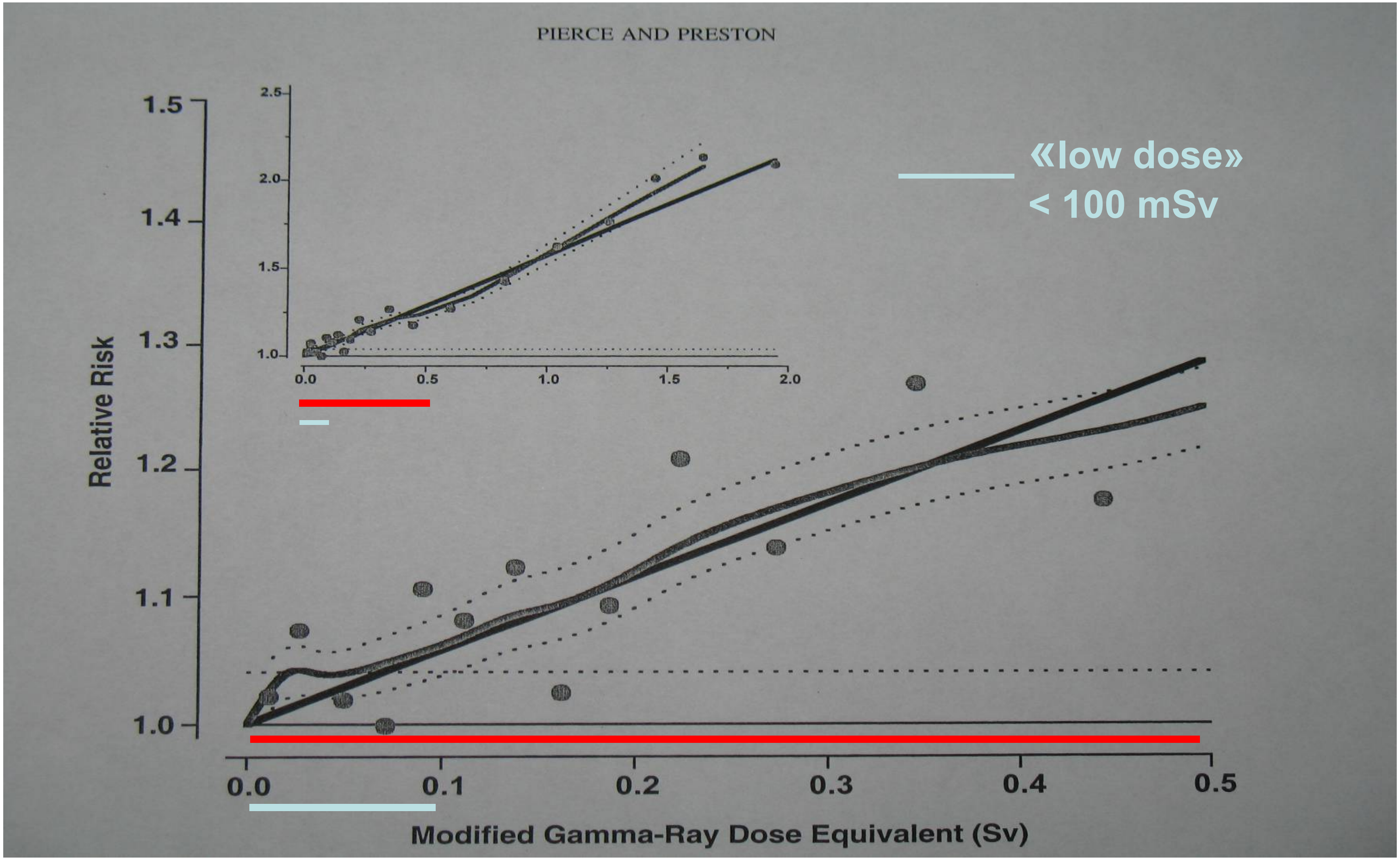
- Significant noncancer death risk demonstrated

- Risk calculations based on the «***collective effective irradiation dose***»:

  individual dose x number of individuals

Radiation-Related Cancer Risks at Low Doses among ***Atomic Bomb Survivors***; D.A.Pierce, D.L.Preston Radiation Res. 154, 178-186 (2000)

→ No threshold – every dose of ionising radiation is harmful



Low dose ionising radiation (LDIR): ***stochastic*** effects

- „low dose“: < 100 mSv as opposed to „high dose“: > 100 mSv
  … questionable, arbitrary classification „low dose“ suggesting „low risk“. But: ***Both low and high doses can kill !***

- Effects of LDIR in human tissues are ***stochastic*** =
  - by chance
  - no immediate health effects

- ***LNT: Linear-no-threshold model…***
  - high level of exposure → high probability of pathology, *and* low level of exposure → low probability of pathology,
  - no dose of ionising radiation without risk («no threshold»)

The ***LSS risk factor calculations must be considered outdated,*** ***because…***

- Japanese 1945 A-bomb survivors:
  - short exposure to high energy gamma-radiation – not comparable to chronic alpha-, beta-, gamma-irradiation or x-rays
  - low dose radiation range not covered (→ extrapolations are subject to never ending controversies)

- No dosimetry (only dose estimates)

- Studies of RERF began in 1950 only (→ teratogenic, genetic effects and cancers with short latency periods missed)

- Selection bias: many early, traumatic casualties → „survival of the fittest“

- Social aspects: japanese A-bomb-survivors were ostracised… → medical family history unreliable

Difficulties of studies on ionising radiation health effects I: Lack of straight forward proof (principle of cause and effect), no smoking colts, no IR tags on cancer

Difficulties of studies on ionising radiation induced health effects II.

- ***Indirect proof*** with ***epidemiological studies*** → even in big studies: some uncertainty: statistical association or causality?

- However ***epidemiological studies*** (*not laboratory research*) based mainly on temporal and geographical criteria ***give strongest information***

- ***Long disease induction time periods*** (…several decades) seen between radiation and following diseases → challenging logistical aspects of scientific work

… and many other difficulties as confounders like smoking, drinking, social problems, migration; insufficient radiation dose information; selection bias and statistical fallacies (lack of statistical power in small populations)

- Results of LSS-Study
  - still important *and*
  - must be continously updated,

- but for medical risk-factor calculations
  → **we need new, modern studies**

…and there are many of them

Modern studies on health effects of low dose ionising radiation: References 5. – 18.

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Studies with statistically significant health effects associated to ionising radiation
Criteria: solid cancer / leukemia / non-cancer disease / cardiovascular disease (Ref. 4. – 18.)

Setting / Criteria	A-Bomb victims	Nuclear workers	Nuclear workers	Children living near NPP	Children living near NPP	Chernobyl victims	Indoor radon exposure	Diagnostic CT-exposure in childhood	Diagnostic CT-exposure in childhood	Children, natural background	Children natural background
1st Author; Study	Pierce; Kotaro; Life Span LSS	Cardis; Vrijheid; 15 countries	Richardson; Leraud; Gillies; INWORKS	Kaatsch; KiKK	Körblein Metanalysis	Several authors cited by IPPNW.de	Darby; collabor. 13 case ctrl studies	Pearce	Mathews	Kendall	Spycher
Year of Publication	2000; 2012	2005; 2007	2015; 2015; 2017	2008	2012	2016	2005	2012	2013	2013	2015
Journal(s); Ref. No	Rad Res 4; 5	BMJ; Rad Res 6; 7	BMJ; Lancet hem; Rad Res; 8; 9; 10	Intl J Cancer; 11	Intl J Cancer 12	IPPNW.de 13	BMJ 14	Lancet 15	BMJ 16	Leukemia 17	Environ Health Perspectives 18
Persons (N) Cases/ Controls	120 000	407 391	308 927	593 / 1766			7 148 / 14 208	> 176 000 74 B / 135 L	10.9 Mio 680 000	27 447 / 36 793	2 093 660 1782
Country/ Continent	Japan	US, EU, Can, Aus, s Korea, Jpn	F, UK, US	Germany	GB, F, D, CH	EU, UDSSR	9 European countries	England Wales Scotland	Australia	Great Britain	Switzerland
Solid Cancer I Incidence / D Death	+ (D) 0.43 / Gy (EAR)	+ (D) 0.97 / Sv (ERR)	+ (D) 0.48 / Gy (EAR)			+	+ (D, lung) 0.084 / 100Bq / m3	+ (I, brain) 0,023 / mGy	+ (I) brain 0.021 / mGy + non-brain 0.027 / mSv		+ (I, brain) 1.04 / mSv (HR)
Leukemia I Incidence / D Death	+ (D) 3.1 / Gy (ERR)		+ (D) 2.96 / Gy (ERR)	+ (I)	+ (I)	+		+ (I) 0.036 / mGy (ERR)	+ (I) 0.039 / mGy (ERR)	+ (I) 0.12 / mSv (ERR)	+ (I) 1.04 / mSv (HR)
Non Cancer disease I / D	+ (D)		+ (D) 0.19 / Sv (EER)			+					
Cardio-vasc. Disease I / D	+ (D)		+ (D) 0.22 / Sv (ERR)			+					
Dose response	YES (x 2)	YES	Yes (x 4)	[Yes]	[YES]		YES	YES (x 2)	YES (x 3)	YES	YES (x 2)
Low dose ionising radiation	(+) (extrapol.)	19.4 mSv. (mean)	20.9mGy 25.2mSv	[surrogate marker: dist. from NPP]	[surrogate marker: dist. from NPP]	Yes	+/- 100 Bq / m3	50-60 mGy	4.5 mSv	0.8mGy / y (controls)	1mSv / y (Mean)

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Studies with statistically significant health effects associated to ionising radiation

How to read this table ? I.

Horizontal lines - «criteria» referring to:

- **publication(s), reference (s)**
- **study population**
- **Pathology (incidence / mortality)**
  - **cancer**
  - **leukemia**
  - **non-cancer disease**
  - **cardiovascular disease**
- **exposure**
  - **is there a dose response ?**
  - **is there an exposure to *low* doses of ionising radiation ?**

1st Author, Study
Year of Publication
Journal, Ref. No
Persons (N) Cases Controls
Country/ Continent
Solid Cancer I Incidence / D Death
Leukaemia I Incidence / D Death
Non Cancer disease I / D
Cardio-vasc. Disease I / D
Dose response
Low dose ionizing radiation

Studies with statistically significant health effects associated to ionising radiation

How to read this table ? II.

Colour-code for «setting»

Yellow:
Japanese A-bomb victims (LSS-study)

Blue / Green:
NPP-exposure «regular operation»

Orangebrown:
NPP-exposure «catastrophy»
(Chernobyl / Fukushima)

Pink / Purple:
Radon / medical diagnostics /
natural background exposure

Studies with statistically significant health effects associated to ionizing radiation
Criteria: solid cancer / leukaemia / non-cancer disease / cardiovascular disease

Setting / Criteria	A-Bomb victims	Nuclear workers	Nuclear workers	Children living near NPP	Children living near NPP	Chernobyl victims	Radon exposure	Diagnostic CT-exposure in childhood	Diagnostic CT-exposure in childhood	Children, natural background	Children Natural background
1st Author, Study											
Year of Publication											
Journal, Ref. No											
Persons (N) Cases Controls											
Country/ Continent											
Solid Cancer I Incidence / D Death											
Leukaemia I Incidence / D Death											
Non Cancer disease I / D											
Cardio-vasc. Disease I / D											
Dose response											
Low dose ionizing radiation											

Summary: Studies with statistically significant health effects associated to ionising radiation

1. +/- 10 studies since 2005 showing a statistically significant association of exposure to low dose and a ***dose-response*** of ionising radiation and mortality / incidence due to severe health effects (solid cancer and leukemia or non-malignant diseases such as cardiovascular diseases)

2. **N.B.: Dose-response is a strong argument for causality**

3. Health effects observed already with doses of ***a few mSv***

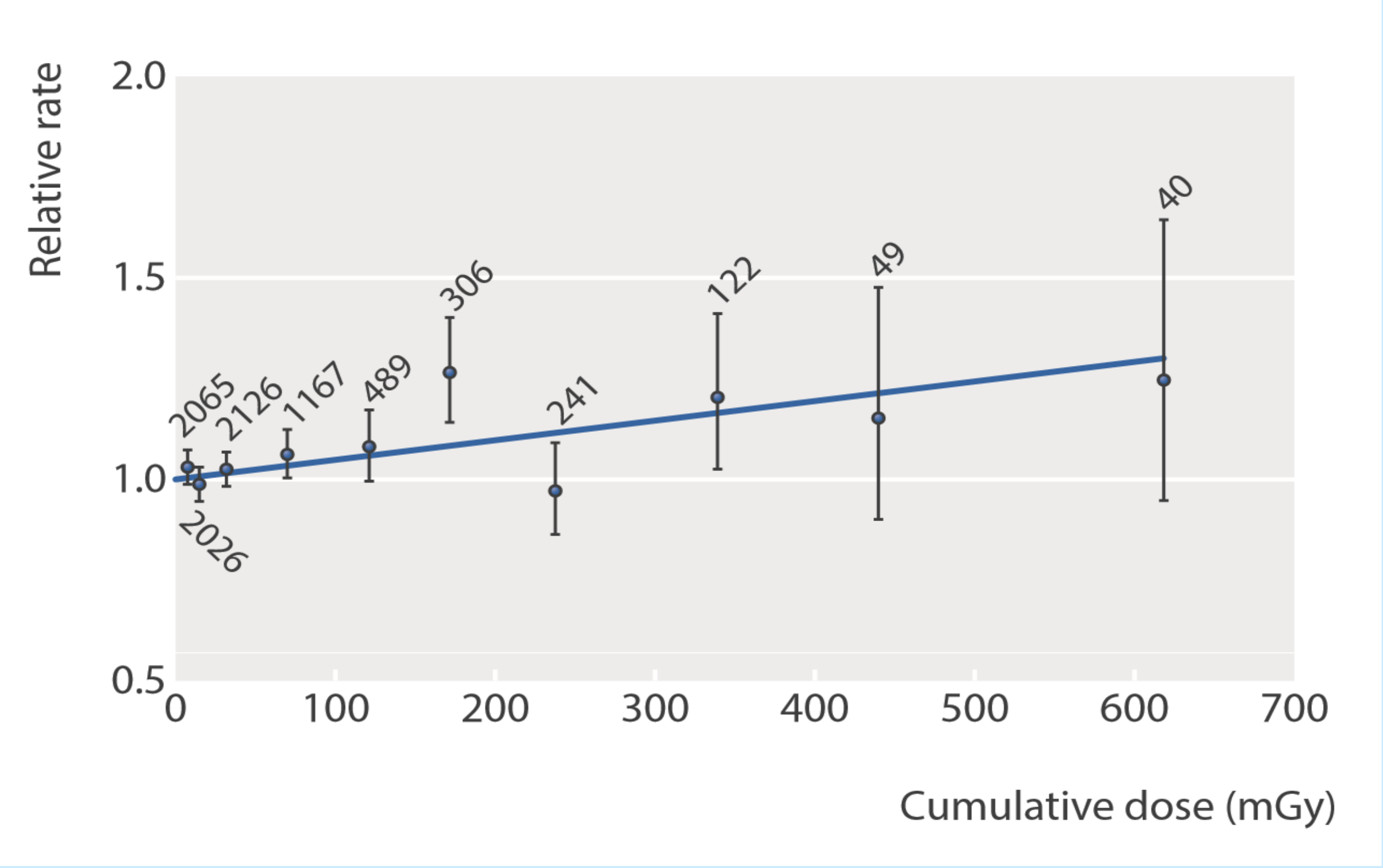
4. Studies published in peer reviewed journals (see references)

INWORKS-Study: Richardson B. et al., BMJ 2015 (Ref.8) Solid cancer deaths in nuclear workers (USA, GB, F)

- 308’297 workers, 22% (66’632) known deaths by the end of follow up of 8.2 million person years.
- among them 17’957 deaths due to solid cancers.
- Average colon dose **20.9 mGray (mGy;** median 4.1 mGy).

- Results :
  - estimated rate of mortality from all cancers (non-leukaemia) **48% per Gy** (90% confidence interval 20% to 79%), lagged by 10 years
  - results suggesting a linear increase in the rate of cancer with increasing radiation exposure

Relative rate of mortality due to all cancers (other than leukaemia) by categories of cumulative colon dose, lagged 10 years, in INWORKS
vertical lines = 90% confidence interval
(Richardson B. , BMJ 2015; Ref. 8)



INWORKS Study: Gillies M., Rad Research 2017 (Ref.9) Mortality from Circulatory Diseases and other Non-Cancer Outcomes among Nuclear Workers (USA,GB,F)

- 308’297 nuclear workers
- average cumulative equivalent dose **25.2 mSv.**
- Statistically significant excess of circulatory deaths due to:
  - **cerebrovascular disease,** ERR/Sv = 0.50; 90% CI: 0.12, 0.94) *and*
  - **ischemic heart disease,** ERR/Sv = 0.18; 90% CI: 0.004, 0.36).

(ERR = excess relative risk per Sievert)

Conclusion:

- **Estimates of associations between radiation dose and *non-cancer mortality* comparable with those observed in atomic bomb survivor studies**

- *“The findings of this study could be interpreted as providing further evidence that non-cancer disease risks may be increased by external radiation exposure, particularly for ischemic heart disease and cerebrovascular disease.”*

Radon: A recognized severe health risk by low dose ionising radiation

- Radon – a naturally occurring noble gas – and its decay products emit Alpha-radiation
- Mean effective dose / person / year: 1.1 mSv (Germany)
- A statistically significant dose response effect of low dose ionizing radiation from indoor radon exposure and lung cancer has been demonstrated (Darby et al. 2005; Ref. 14)
- The risk factor is 8.4 % / 100 Bq / m3 .
- In Europe, 9 % of lung cancer deaths and 2% of all cancer deaths are attributed to ionizing radiation due to indoor radon.
- In Switzerland, every year +/- 240 persons die of radon induced cancer
- The international community started in 2005 to understand low dose ionising irradiation by indoor radon as being a severe health risk
- Building legislation has implemented standards which aim at lowering radon exposure for inhabitants

The Swiss BAG warns (2006):

«Radon causes lung cancer»

BAG Switzerland:

Bundesamt für Gesundheit = Swiss Federal Office of Public Health

«Legal informations for estate agents and construction experts»

The Swiss BAG warns (2006):

«Radon *causes* lung cancer»

BAG Switzerland:

Bundesamt für Gesundheit = Swiss Federal Office of Public Health

«*Legal* informations for estate agents and construction experts»

Document 103 (2007) of ICRP (International Commission for Radiological Protection) – presently forming the basis of internationally radiation protection standards

- «Collective effective dose is not intended as a tool for epidemiological risk assessment, and it is inadequate to use it in risk projections. The aggregation of very low individual doses over extended time periods is inappropriate, and in particular, the calculation of the number of cancer deaths based on collective effective doses from trivial individual doses should be avoided» (Ref. 19)

This wording is scientifically inappropriate in 2017

Conclusions:

- Modern scientific studies confirm the linear no threshold model (LNT) and support the validity of epidemiological risk calculations for severe health effects due to ionising radiation doses far below 100mSv (i.e. «low dose ionising radiation» ; Ref. 20).

- The LNT forms the basis for ***radiation protection*** of the public exposed to low dose ionising radiation, e.g. after nuclear accidents.

- The risk factor (EAR = Excess Absolute Risk) for ***cancer death*** due to ionising radiation has to be adapted from 5.5% / Sv to → 20% / Sv. (Ref.1).

- Significant increase of mortality related to ***non-cancer deaths*** (e.g. cardiovascular) due to low dose ionising radiation in the order of cancer-related mortality has been observed. This must be officially acknowleged.

→ ICRP 103 (2007) must be revised

Command of the hour: ***IIRP = «integrative ionising radiation protection»***

Apart from already established radiation protection standards *(as for nuclear industry workers, medical exposure, building law in view of radon exposure)*
for all situations, where populations are exposed to low doses of ionsing radiation,

e.g.

- uranium mining,

- exposure to fallout from A-bomb tests and in A-bomb survivors

- exposure to depleted uranium

- regular and accidental exposure by nuclear power plants,

- exposure with NPP decommissioning and nuclear waste management

- etc.

the *medical principle of prevention* in view of the unalienable Human Right of Health should be respected.


FILA

Abstract

C. Knüsli "Ionizing Radiation: Medical Risks – New Aspects“

- Since its detection ionising radiation [IR] has been recognised as a major human health risk inducing a broad variety of biological cellular changes. Characteristically, high IR doses are associated with deterministic whereas lower IR doses are related to stochastic effects respectively. Biological research establishing reliable biomarkers in low dose IR is still limited in contrast to higher dose and dose-rate IR. Radioprotection concepts have been developed and respective measures were widely implemented in the medical fields and in occupational exposure in the nuclear industry. According to the current recommendations of the International Commission on Radiological Protection (ICRP publication 103; 2007) the risk for lethal cancer disease in adults amounts to 5.5%/Sievert. Carcinogenicity is the hallmark of IR, however lethal IR impact of noncancer – e.g. cardiovascular – diseases has been shown to be in the same order as death to radioinduced malignancy. Modern epidemiological studies on nuclear workers, on populations exposed to fallout from nuclear power plant accidents, on natural background irradiation as well as radiodiagnostic studies confirm the dose response relationship of low dose IR and its detrimental health impacts. These studies corroborate the Linear No Threshold [LNT] concept and underline the usefulness of collective dose calculations. The latter allow extrapolations of health risks in large populations exposed to low doses of ionising radiation. Current scientifically based understanding calls for acceptance of risk estimations at doses as low as 1 mSv and below and therefore asks for a revision of the ICRP-recommendations which are outdated one decade after their effective date.