LNT, Radiation Hormesis and the Red Forest: Why LNT Is Wrong and Radiation Hormesis is Real

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Disclosure

- None
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- First Attendance Verification Code: 4067
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Objectives

- Individuals attending this presentation will be able to:

- 1. State the definition of the Linear No-Threshold Hypothesis (LNT) and describe its features.
- 2. Discuss the evidence that refutes LNT.
- 3. Discuss the evidence supporting radiation hormesis.

Linear No-Threshold Hypothesis (LNT) – What is it?

- The Linear-No Threshold Hypothesis (LNT) states that any ionizing radiation exposure carries some risk of future development of cancer, with no threshold, and that the risk increases linearly with dose.
- LNT specifically refers to exposures of less than 10 rem (100 mSv).
- Everyone agrees that high dose exposure results in a linear risk of carcinogenesis - at high doses, risk increases linearly relative to dose, without a threshold.
- Even at high doses, ionizing radiation is a weak carcinogen and a weak mutagen.

Linear No-Threshold Hypothesis (LNT) – Features

- LNT - risk from radiation exposure extends down to zero. There is no safe exposure.
- LNT - Radiation damage is linearly related to exposure.
- LNT ignores evolutionary biology
- LNT assume radiation damage and therefore cancer risk is cumulative throughout life.
- LNT assumes dose rate does not matter.
- LNT assumes a single mutation will lead to cancer.
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LNT is Wrong

- Linear No-Threshold hypothesis (LNT) is wrong on every point.

1. LNT claims cancer risk extends down to zero. But there has never been evidence to show increased risk below 100 mSv (10 rem) and probably 200 mSv (20 rem). **However, uncertainties in this range are very large.**

2. Whether or not low-dose damage is linearly proportional to dose, the defense response is nonlinear. DNA repair involves >150 genes, antioxidant production, apoptosis, bystander effects, and immune system response.

3. LNT excludes evolutionary biology. There are different responses to high-dose vs. low-dose exposure. Mechanisms active at low-dose are impaired or overwhelmed at high-dose.

LNT is Wrong

4. LNT assumes radiation damage and associated cancer risk accumulate throughout life. – **Not true**, as this ignores repair of DNA damage as well as cellular turnover and elimination (apoptosis, etc.).Repair mechanisms also repair DNA damage from other causes at the same time, so the DNA is actually in better condition than before.

5. LNT assumes radiation induced-risk is independent of dose rate. **Not true** – radiation therapy is based on different responses due to different dose rates.

6. LNT assumes a single mutation will lead to cancer. – **Not true**. Development of malignancy requires multiple mutations and deficiencies of the body's defense mechanisms as well as immune system failure.

7. No evidence of harm with higher radiation background rates, up to at least 260 mSv/yr (26 rem/yr). Bkgd rate in US averages 300-360 mrem/yr. There have been substantial advances in radiation biology in the last 16 years (since BEIR VII).

DNA Repair

- Nobel Prize in 2015 for chemistry was awarded for elucidating methods of DNA repair
- 3 intracellular DNA repair mechanisms:
- 1. Base excision repair
- 2. Nucleotide excision repair
- 3. Mismatch repair
- These mechanisms are utilized in repair from radiation-induced DNA damage as well.

LNT is Wrong: Several Recent Articles

- The good rays: let them shine! Hoiland-Carlsen, EJNMMI, 2019;46:271-275
- Linear No-Threshold Model of Low-Dose Radiogenic Cancer: A Failed Fiction. Pennington and Siegel, Dose Response, 2019, Jan-Mar:1-10
- A critical evaluation of the NCRP Commentary 27 endorsement of the LNT model of radiation effects. Ulsh, Env Res, 2018;167:472-487
- Are We Approaching the End of the LNT Era? Doss, JNM, 2018;59:1786-1793
- **A Critical Assessment of the Linear No-Threshold Hypothesis**: Its Validity and Applicability for Use in Risk Assessment and Radiation Protection. Siegel, Brooks, Fisher, Zanzonico, Doss, O'Connor, Silberstein, Welsh and **Greenspan**. Clin Nucl Med 2019 Jul;44(7):521-525. Epub April 2019
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LNT is Wrong

- A Critical Assessment of the Linear No-Threshold Hypothesis: Its Validity and Applicability for Use in Risk Assessment and Radiation Protection. Siegel, Brooks, Fisher, Zanzonico, Doss, O'Connor, Silberstein, Welsh and **Greenspan**. Clin Nucl Med 2019 Jul;44(7):521-525. Epub April 2019
- ABSTRACT - SNMMI convened a task group to examine the evidence for the risk of carcinogenesis from low-dose radiation exposure and to assess evidence in the scientific literature related to the overall validity of the LNT hypothesis and its applicability for use in risk assessment and radiation protection.
- In the low-dose (<10 rem) and dose-rate region, the group concluded that the LNT hypothesis is invalid, as it is not supported by the available scientific evidence and, instead, is actually refuted by published epidemiology and radiation biology.

LNT is Wrong

- Medical imaging does not produce iatrogenic cancer risk from radiation exposure. Credible evidence of imaging-related low-dose (<100 mGy [10 rem]) carcinogenic risk is non-existent.
- Ref: Siegel, Sacks and Greenspan JNM 60(6):18N, 2019

- Interestingly, there is a consensus of ICRP, NCRP, and BEIR VII, leading advisory agencies on radiation protection, that LNT cannot be used for risk assessment, i.e., LNT cannot predict future cancer risk.
- International Council of Radiation Protection (ICRP)
- National Council on Radiation Protection and Measurements (NCRP)

Radiation Hormesis => LNT is False

- **Hormesis** – definition: a substance that is toxic in large amounts can be beneficial in small amounts.
- **Radiation hormesis**: a small amount of radiation is beneficial.
- A huge amount of evidence supports radiation hormesis - improvement in mortality rates and decreased cancer incidence from low-dose radiation exposure.
- If radiation hormesis is true, and extensive evidence suggests that it is, LNT **MUST** be false.

LNT is False – Radiation Hormesis

- Radiation hormesis is real and is well-supported by evidence
- Evidence - improvement in mortality rates and in decreased cancer incidence
- Many substances – drugs (e.g., aspirin), vitamins (especially Vitamins A & D), trace metals (e.g. Tl), are beneficial at low levels but toxic at high levels
- Atom bomb survivors – exposures at 0.5-1.5 Sv (50-150 rem) – have less nonmalignant disease; Leukemia – hormesis with threshold of 500 mSv (50 rem)
- Cancer risk is below baseline at approx. 0.15 Gy (15 rad) weighted colon dose
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Evidence for Radiation Hormesis

- 1. Low-dose radiation has a cancer therapeutic effect.
- References:

- Chaffey et al. 1976 Total body irradiation as treatment for lymphosarcoma
- Mendenhall et al. 1989 Total body irradiation for stage II-IV NHL: 10 yr follow-up
- Pollycove M. Radiobiological basis of low-dose irradiation in prevention and therapy of cancer. Dose Response 5:26-38, 2006

Evidence for Radiation Hormesis

- 2. Second cancers per kg of tissue were lower in volumes exposed to low-dose radiation compared to no radiation exposure in radiation therapy patients.

- Reference:
- Tubiana et al. A new method of assessing the dose-carcinogenic effect relationship in patients exposed to ionizing radiation. A concise presentation of preliminary data. Health Physics 100 (3):296-299, 2011

Evidence for Radiation Hormesis

- 3. Radiation workers had reduced cancer mortality rates compared to non-radiation workers in the Nuclear Shipyard Worker Study
- References:
- Boice et al. 2011 Updated mortality analysis of radiation workers at Rocketdyne (Atomics Intl.), 1948-2008. Radiation Research 176:244-58, 2011
- Sponsler and Cameron. Nuclear shipyard worker study (1980-1988): a large cohort exposed to low-dose-rate gamma radiation. Int J Low Radiat. 1:463-478, 2005
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Evidence for Radiation Hormesis

- 4. Taiwan apartment residents exposed to low-dose radiation from radioactive contamination in building materials had lower cancer rates.
- References:
- Hwang et al. Cancer risks in a population with prolonged low dose-rate gamma radiation exposure in radiocontaminated buildings, 1983-2002. Int J Radiat Biol, 82(12):849-858, 2006
- Hwang et al. Estimates of relative risks for cancers in a population after prolonged low-dose-rate radiation exposure: a follow-up assessment from 1983-2005. Radiation Res, 170(2):143-148, 2008

Evidence for Radiation Hormesis

- 4. Taiwan apt residents – lower cancer rates
- Hsieh et al. 30 years follow-up and increased risks of breast cancer and leukaemia after long-term low-dose-rate radiation exposure. Br J Cancer, 117(12):1883-1887, 2017
- Doss M. Comment on “30 years follow-up and increased risks of breast cancer and leukaemia after long-term low-dose-rate radiation exposure Br J Cancer, 118(5):e9, 2018
-

Evidence for Radiation Hormesis

- 5. Low-dose irradiation to the total body or half body improved survival of non-Hodgkin lymphoma radiation therapy patients.
- References:
- Sakamoto Radiobiological basis for cancer therapy by total or half-body irradiation. Nonlinearity Biol Toxicol Med, 2(4):293-316, Oct 2004
- Pollycove M. Radiobiological basis of low-dose irradiation in prevention and therapy of cancer, Dose Response, 5(1):26-38, 2006
-

Evidence for Radiation Hormesis

- 6. Radiologists who were exposed to low-dose radiation had lower cancer mortality rates than physicians not exposed to low-dose radiation.
- References:

- Berrington et al. 100 years of observation on British radiologists: mortality from cancer and other causes 1897-1997. Br J Radiol 74:507-519, 2001
- Linet et al. Historical review of occupational exposures and cancer risks in medical radiation workers. Radiat Res 174:793-808, 2010
- Linet et al. Mortality in U.S. Physicians Likely to Perform Fluoroscopy-guided Interventional Procedures Compared with Psychiatrists, 1979-2008. Radiology 284:482-494, 2017

Evidence for Radiation Hormesis

- 7. Lung cancer rates decrease with increasing residential radon levels.
- References:

- Cohen, B.L. Test of the linear-no threshold theory of radiation carcinogenesis for inhaled radon decay products. Health Physics, 68(2):157-174, 1995
- Bogen and Cullen. Residential Radon in U.S. Counties V Lung Cancer in Women Who Predominantly Never Smoked. Environmental Geochemistry and Health 24(3):229-247, 2002
- Thompson. Epidemiological Evidence for Possible Radiation Hormesis from Radon Exposure: A Case-Control Study Conducted in Worcester, MA. Dose Response 9(1):59-75, 2011

LNT is Wrong – Radiation Hormesis

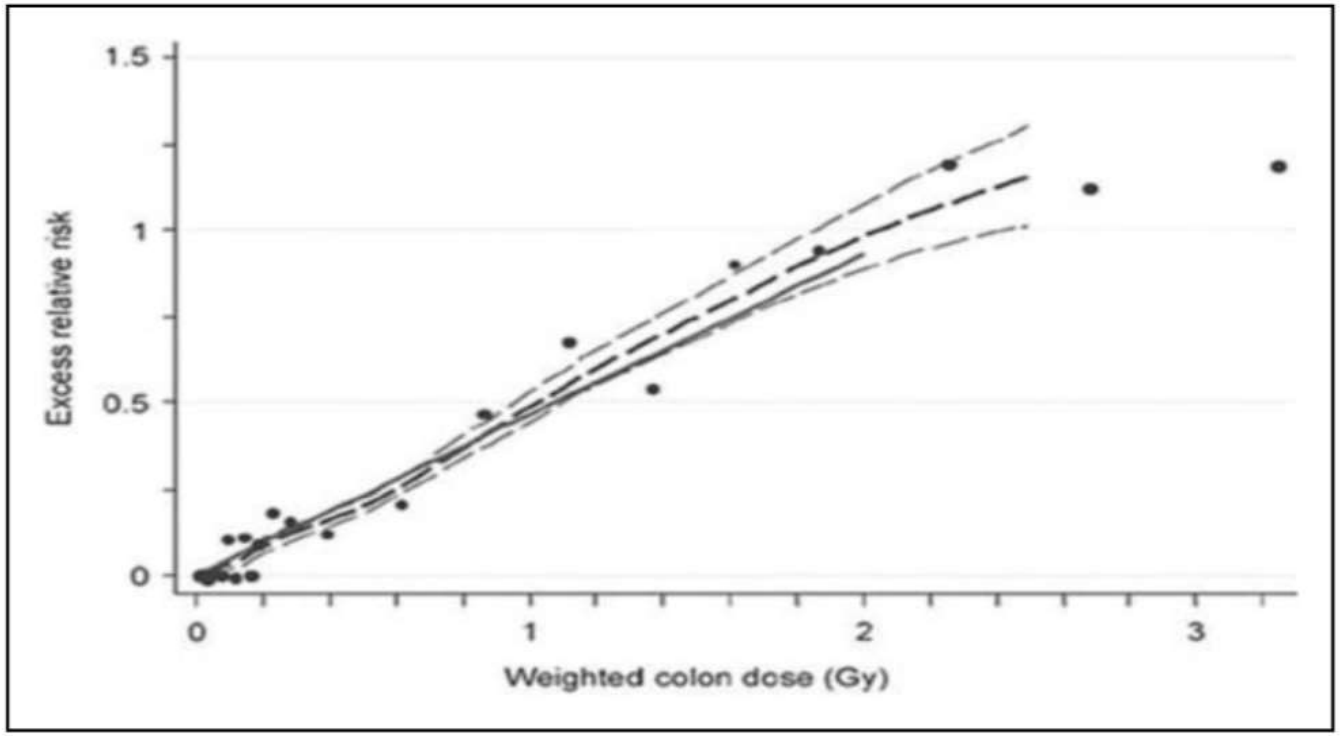


Figure 1. LSS solid cancer incidence, excess relative risk (ERR) by radiation dose, 1958 to 1998, using DS86 dosimetry system.[8] Note that doses <0.1 Gy appear to have ERRs <0. LSS indicates Life Span Study.

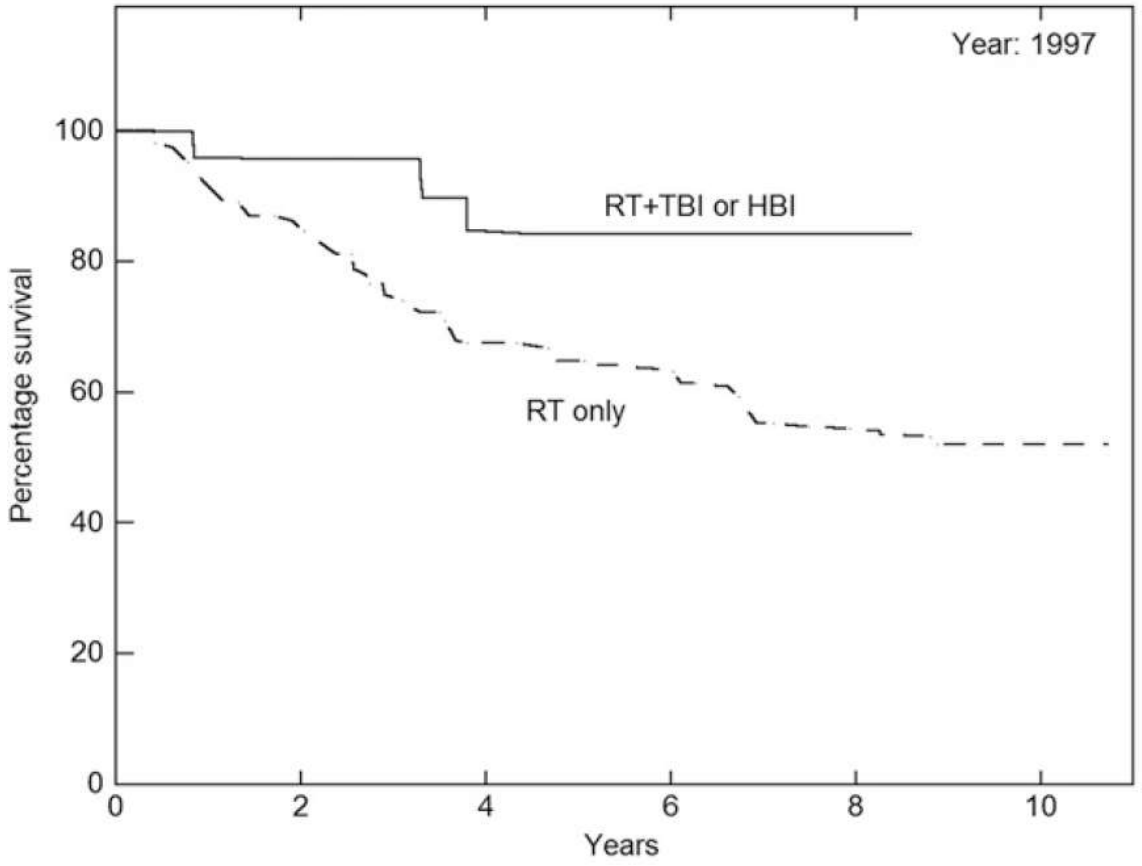
Ref: Pennington and Siegel, 2019

Improved Survival of British radiologists

- Since 1936, cancer rates among British radiologists dropped below those in the general public, and radiologists registered after 1955 had a 32% lower ($p<0.001$) mortality rate for all-cause deaths than that of all physicians, a 36% lower ($p<0.001$) mortality rate for noncancer deaths than other physicians, and a 29% lower (p=NS) mortality rate than that of all male physicians. During most of this time, the exposure limit for occupational workers was 50 mSv/yr (5000 mrem/yr).

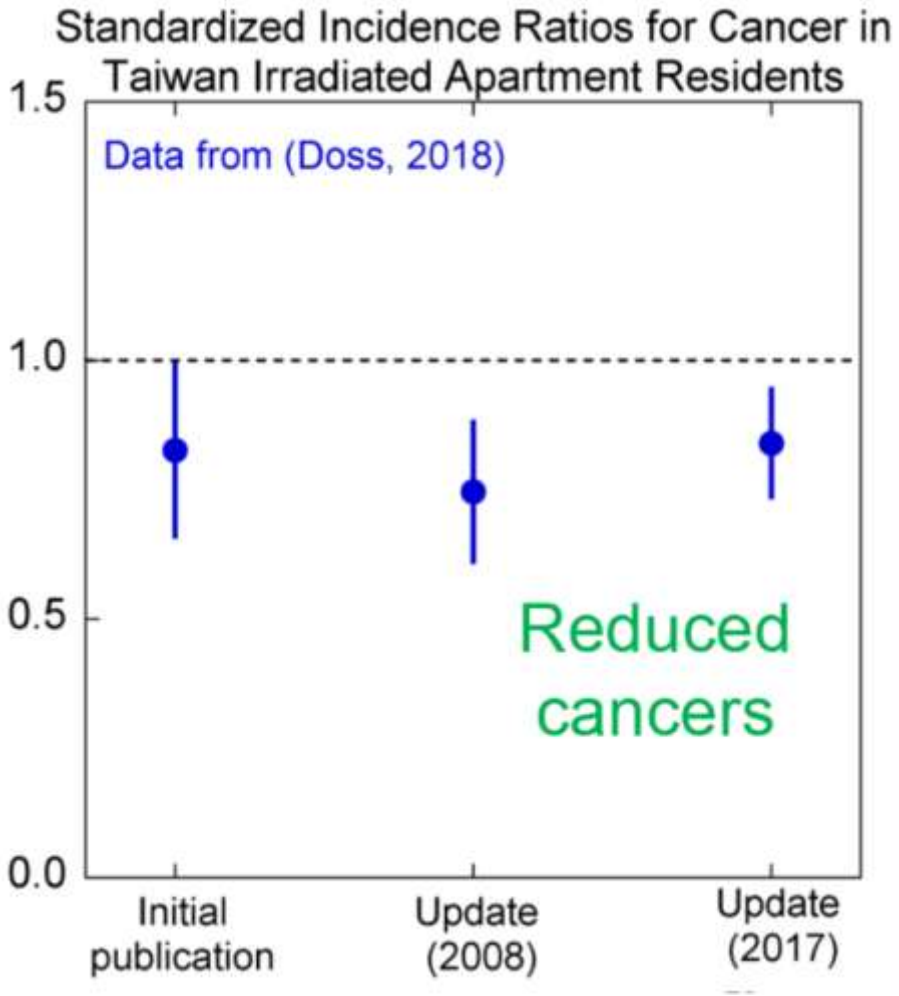
Ref: Cameron JR. Radiation increased the longevity of British radiologists. Br J Radiol. 2002;75:637-639

Improved survival of patients treated with RT with interspersed low-dose RT



- Survival of NHL patients having radiation therapy (RT) to tumor compared with patients having interspersed low-dose total body (TBI) or half-body (HBI) between radiation treatments to tumor.
- Ref: Sakamoto K. Fundamental and clinical studies on cancer control with total and upper half body irradiation. J JASTRO 1997;9:161-175.

LNT is Wrong – Radiation Hormesis



- Over 7200 Taiwan apt dwellers exposed to 48 mSv (4.8 rem [4800 mrem]) had fewer cancers than unexposed controls (hormesis in the low-dose range).
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- Courtesy of Mohan Doss, PhD
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Threshold – Radiation Hormesis

- Fluoroscopy of Canadian TB patients with doses of 50-300 mGy (5-30 rad) – 1/3 less breast cancer

- Fluoroscopy of Massachusetts TB patients (mean dose 0.61-1.12 Gy [61-112 rem]) had markedly less mortality from lung cancer, compared to unexposed controls. However, breast cancer was increased (mean dose 0.54-0.96 Gy [540-960 mGy, 54-96 rem])

- Ref: Davis, et al, Cancer Research 49: 6130-6136, 1989

Radiation Hormesis

- Protracted exposure of low-level radiation <2 Gy (200 rem) does not increase risk of lung cancer.
- The natural incidence of lung cancer is actually reduced.
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-

Ref: Rossi, Zaider, Radiat Environ Biophys 1997 Jun;36(2):85-88

Radiation Hormesis

- Nuclear power workers (over 400,000, 154 facilities, 15 countries) decreased risk of malignancy
- Mayak incident – individuals with exposures of 0.04, 0.12 and 0.5 Sv (4, 12 and 50 rem) – less cancer than individuals not exposed.
  At 0.5 mSv (50 rem) cancer mortality was 29% less than controls.

Radiation Hormesis

- Radiation hormesis is real
- Chronic exposure to low dose ionizing radiation induces DNA damage response, accumulated DNA damage only occurred in more highly exposed subjects; => suggestive of radiation hormesis.
- Ref: Gaetani et al. Occup Environ Med 2018 doi: 10.1136/oemed-2018-105094
- Derived standardized mortality rates for cancer and circulatory disease in French nuclear works are <1, suggestive of hormetic effects/adaptive response
- Ref: Scott B Dose Response 2018 Apr-Jun; 16(2): 1559325818778702 online 2018 May 28. doi: 10.1177/ 1559325818778702

Case for a Threshold

- Thresholds
- **Everything** has a threshold – drugs, vitamins, trace metals, other chemicals
- Radiation is a natural entity of the environment, why should radiation be different?
- Low dose radiation is beneficial, and high dose is harmful, therefore, there **must** exist a threshold between them.

Case for a Threshold

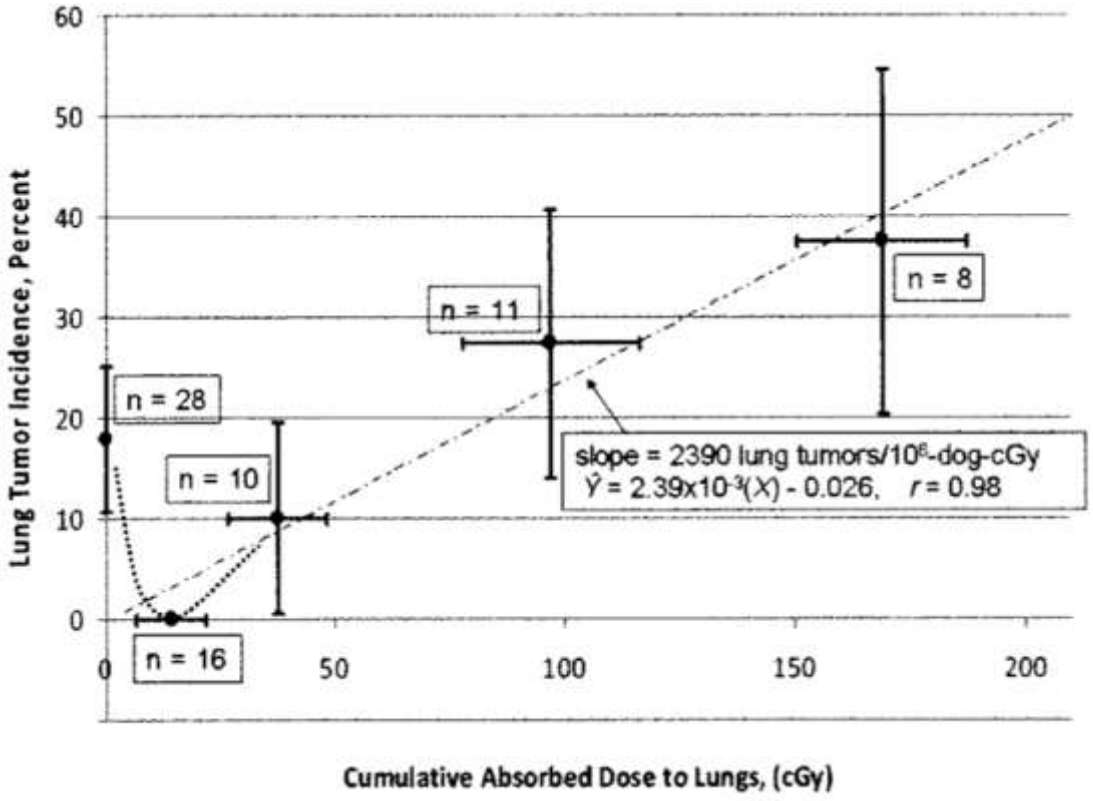
- Known thresholds for deterministic effects

Cumulative dose	Gy	Rad
Pancytopenia	20	2000
Sterility, men (temporary)	15	1500
Sterility, women	6	600
Cataracts	7.5	750

Ref: Sanders 2017

Case for a Threshold and Radiation Hormesis

- Non-human data –
- Beagle dogs that inhaled plutonium dioxide – threshold of lung adenocarcinomas of approximately 150 - 400 mSv (15-40 rem)



- Reference: Fisher and Weller, Health Phys. 99(3):357-362, 2010
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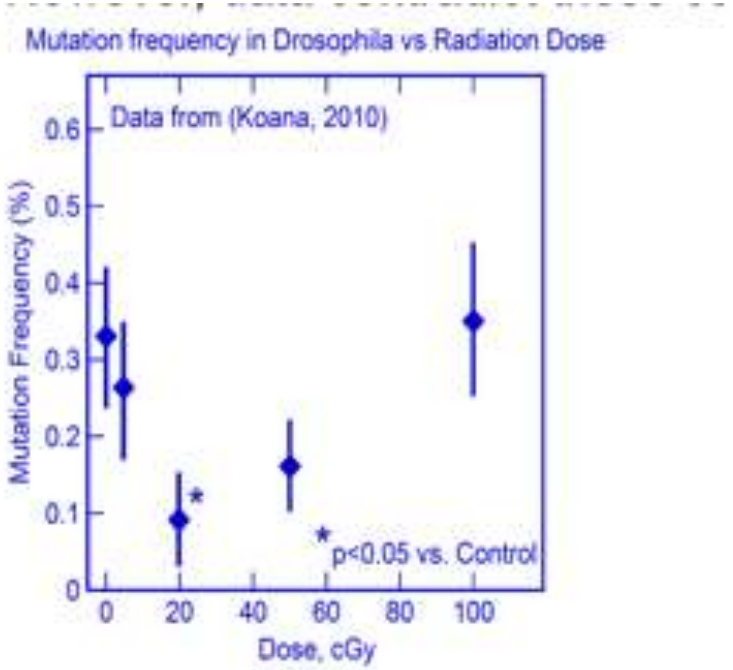
Case for a Threshold and Radiation Hormesis

- Mutations in fruit flies – threshold of 500 mGy (50 rad).
- Mutation rate similar to unexposed fruit flies.



Mutations decrease for low radiation doses

- Courtesy of Mohan Doss, PhD
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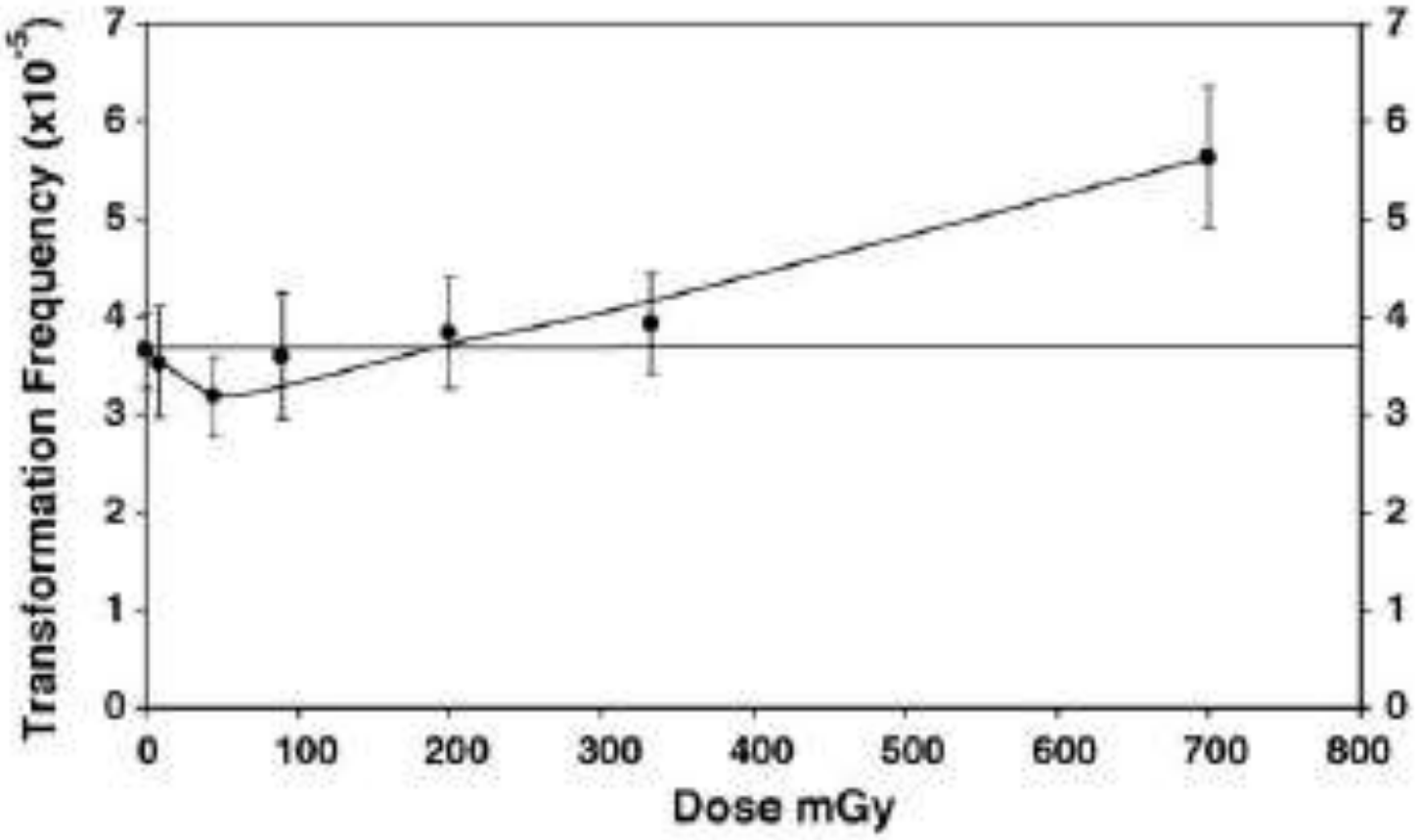
Case for a Threshold

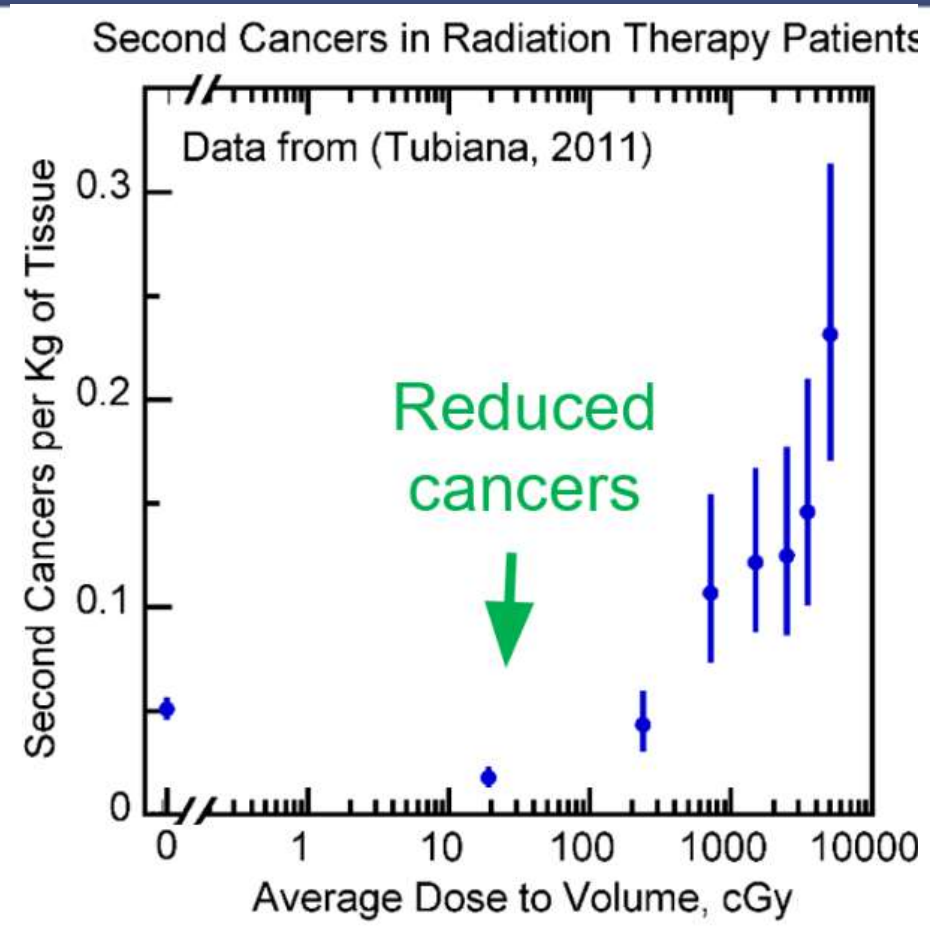
- Thresholds for carcinogenesis
- Transformation of human fibroblasts – threshold of approximately 20 rem
- Secondary cancers following radiation therapy – latent period minimum approximately 5-8 years, threshold at least 2-2.5 Gy (200-250 rem)

Neoplastic transformation of human fibroblasts dips below bkgd frequency at low doses

Ref: Ko et al, 2006



Case for a Threshold

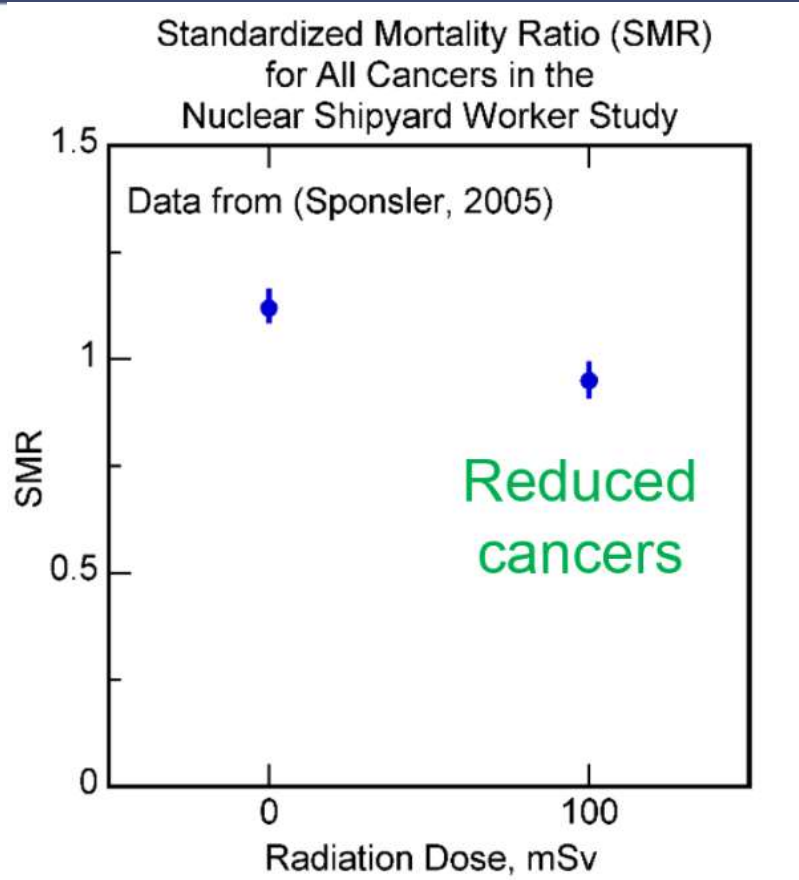


- Courtesy of Mohan Doss, PhD

Case for a Threshold/Radiation Hormesis

- Thresholds for carcinogenesis
- Nuclear power workers – no increase in mortality
- Nuclear shipyard workers – 8 mSv (800 mrem) – 24% lower mortality
- Plutonium workers (Manhattan Project) – decreased cancer incidence and mortality

Case for a Threshold/Radiation Hormesis

- 

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Courtesy of Mohan Doss, PhD

Case for a Threshold

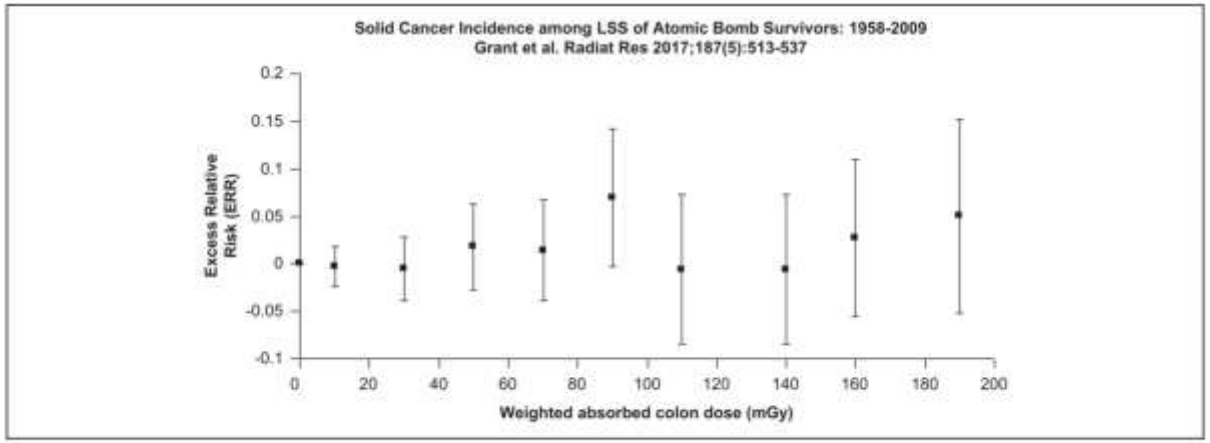

Figure 3. LSS data derived from Grant's reported data in Appendix Table E1.[10] ERR values are shown with 95% confidence intervals, indicating large uncertainties. LSS indicates Life Span Study; ERR, excess relative risk.

- Ref: Pennington and Siegel, 2019
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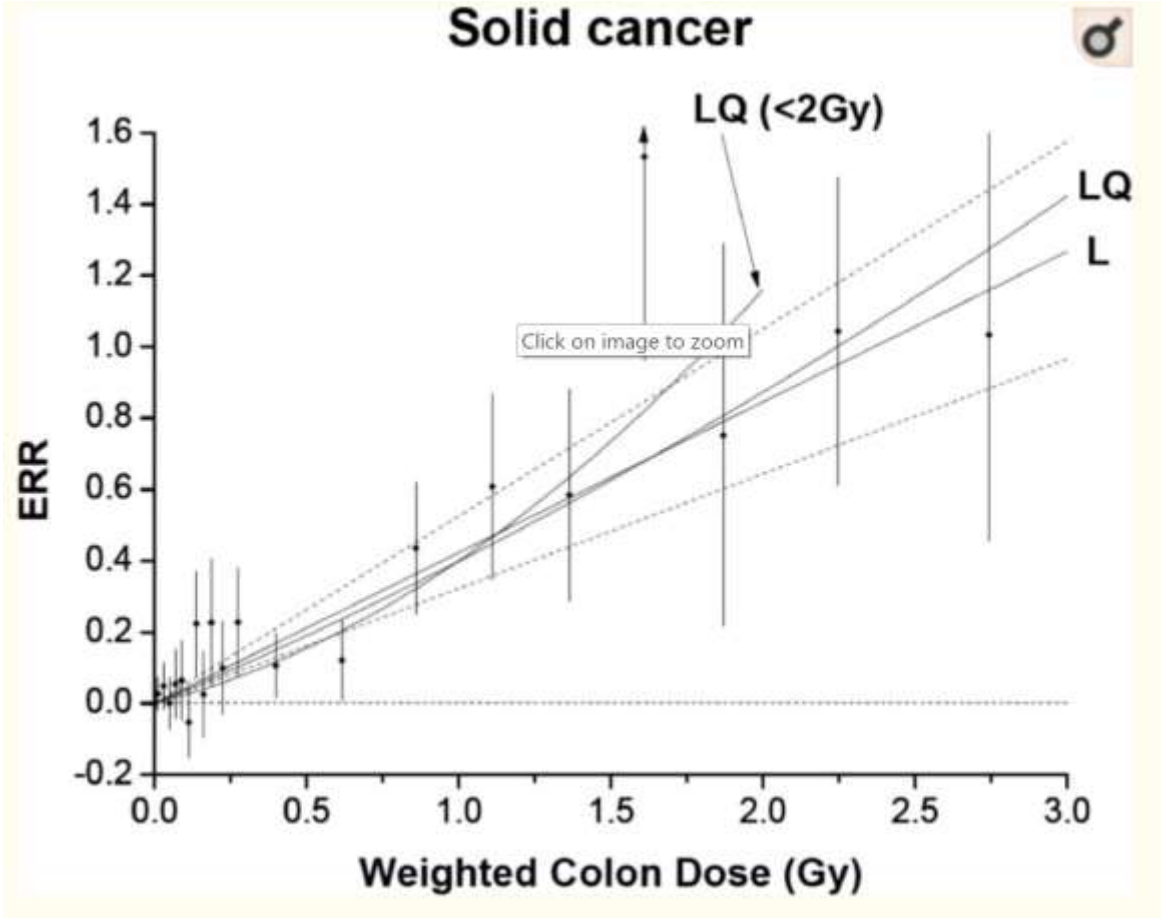
- Atom bomb survivor data – threshold of up to approximately 700 mSv (70 rem)
- Ref: Doss Dose Response 2013 Nov; 11(4):495-512

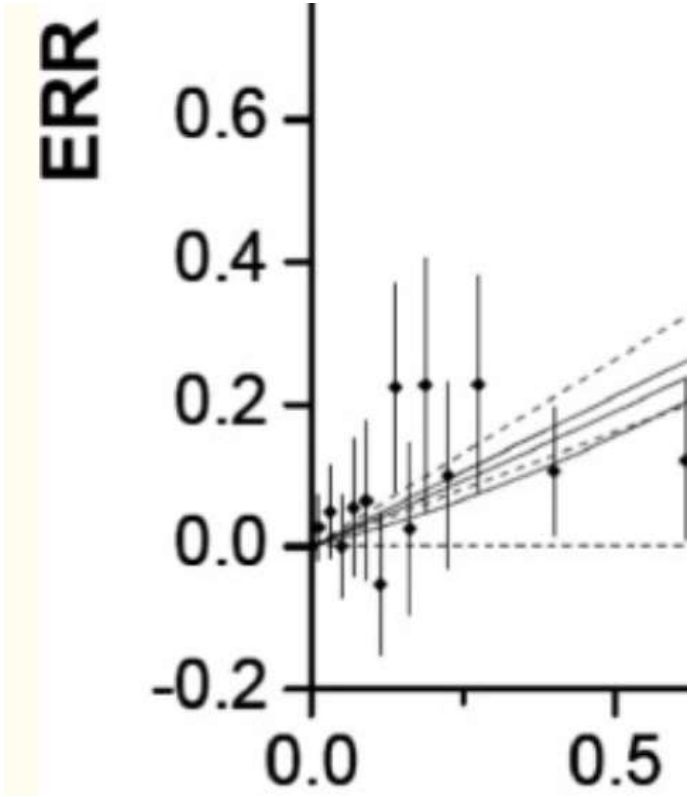
- Atom bomb survivors – threshold for solid cancers approximately 200 mSv (20 rem)
- Ref: Ozasa, 2012, 2013

Case for a Threshold



- Ref: Ozasa et al, 2012, 2013

Case for a Threshold



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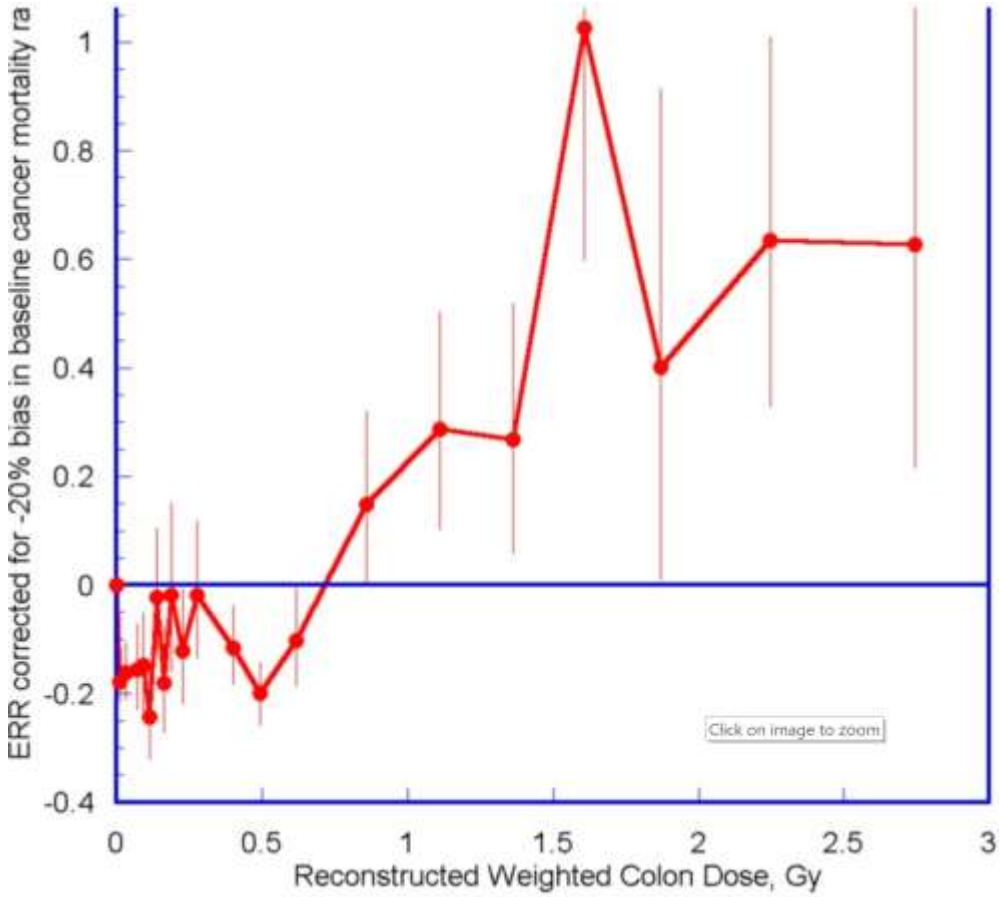
Ref: Ozasa et al, 2012, 2013 41

ERR for all solid cancer mortality in atom bomb survivors



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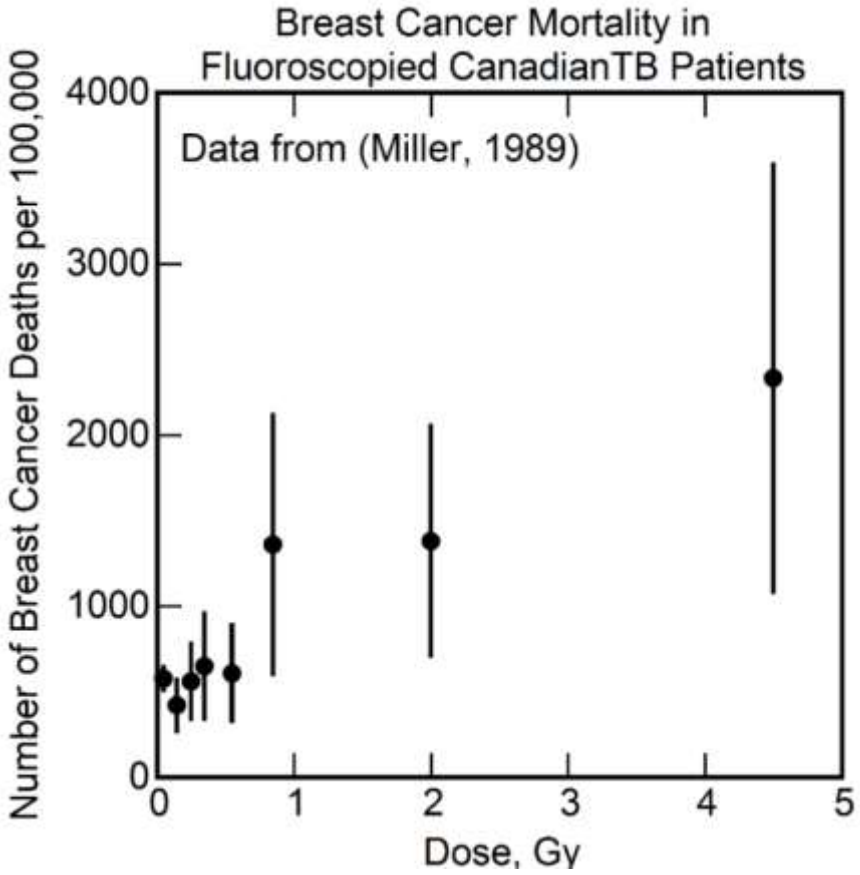
Case for a Threshold

- People who live in high background areas – no increase in cancer rate. In some areas, rates are lower, in others, they are similar.
- Fluoroscopy of Canadian TB patients – no increase in breast cancer below 550 mGy (55 rem)
- Hyperthyroid patients treated with I-131 – no increased risk of thyroid cancer, other solid malignancies, or leukemia.
  Ref: Saenger, et al, JAMA, 1968; 205(12): 855-862

Case for a Threshold



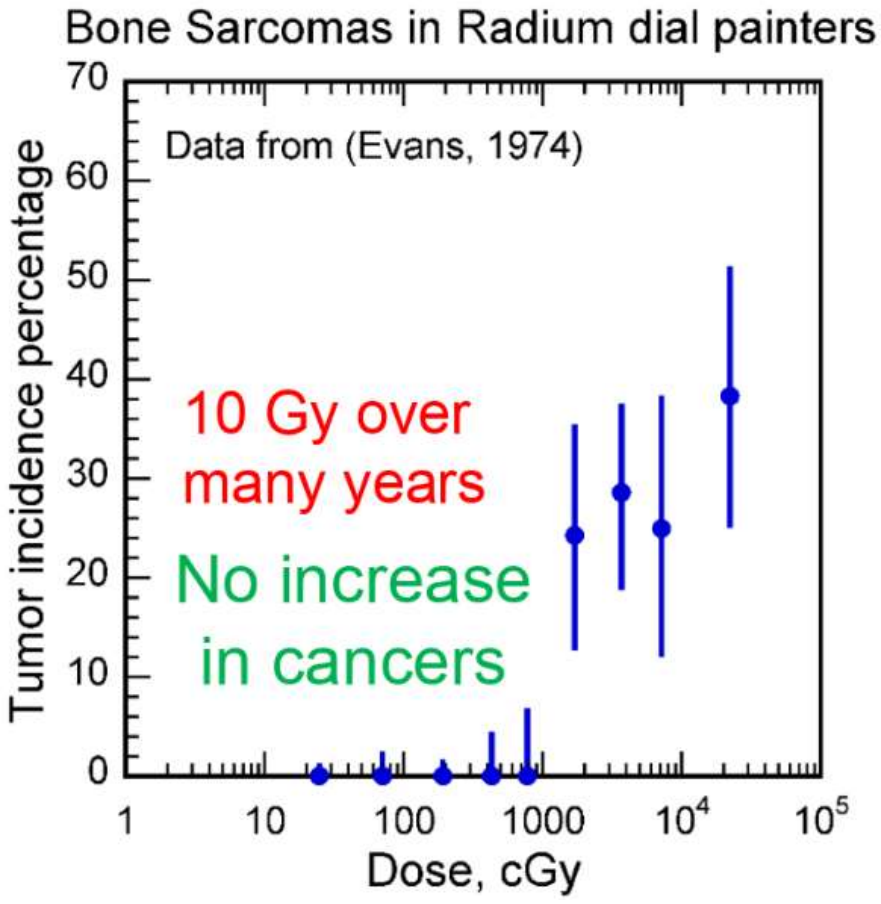
- Courtesy of Mohan Doss, PhD

Case for a Threshold

- Thyroid cancer patients treated with I-131 – no increase in solid tumors, slightly increased risk of leukemia above total administered activity of 600 mCi (22.2 GBq).
- Dose to thyroid tumors may range from 300,000 – 800,000 rem and more, depending on uptake and mass of the tumor.

Case for a Threshold

- Radium dial painters – no increased risk of osteogenic sarcoma below 10 Gy (1000 rad).



- Courtesy of Mohan Doss, PhD

Red Forest

- What is the Red Forest?
- The Red Forest is the area (10 km2 [4 sq miles]) surrounding the Chernobyl Nuclear Power Plant. As a result of the nuclear “accident”, the pine tree needles turned a ginger-brown color (I presume similar to what happens in autumn when the days get shorter and colder) before the trees died due to the high radiation exposure.
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The Red Forest

- Long-term impact on animal and plant life is uncertain.
- However, it is a fertile habitat for many animals and plants. Animal life thrives, in part due to decreased human impact.
- Is this an example of radiation hormesis?

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Conclusions (1):

- **LNT is not a valid hypothesis to estimate future cancer risk.**
- Behavior of ionizing radiation as a toxic substance is similar to other toxic substances.
- Low dose radiation is beneficial, and high dose is harmful, therefore a threshold between them **must** exist.
- Given that all of the previous evidence is true, **LNT must be false**.
- The LNT model cannot explain evidence of benefit (negative slope [= risk below baseline]) or the evidence of a threshold. **LNT is therefore invalid.**

Conclusions (2):

- Thresholds for development of carcinogenesis are identified.
- Thresholds for deterministic effects are known.
- Different tumors exhibit different thresholds.
- Range of thresholds in humans: approx. 0.15-0.70 Sv (15-70 rem)
- It appears reasonable that all low-dose radiation effects have a threshold.
- Radiation hormesis in humans is real.
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Conclusions (3):

- Radiation hormesis in humans is real:
- Lower limit – approx. 0.15 Sv (15 rem), some evidence as low as 4-5 rem (which is within the low-dose range).
- Upper limit – range of approx. 0.70 - 2 Sv (70 - 200 rem).
- Well-supported by evidence.
- Low-level radiation produces:
- Decreased cancer risk, cancer therapeutic effect.
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Conclusions (4):

- Is LNT valid in the low-dose range? – **NO!**
- Is linear extrapolation from high-dose to low-dose reasonable? **NO**, this obscures important data in the low-dose range. And repair mechanisms effective at low dose are impaired or overwhelmed at high dose.
- Is there a threshold below which there is no harm? **Yes**. There is a range below which no increased risk can be demonstrated, however, uncertainties in this range are very large.
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IMPORTANCE (1)

- **Why is this important?**
- LNT is used as a basis for radiation protection regulations.
- LNT should **NOT** be used for risk assessment (esp. individual risk assessment), even regulatory and advisory bodies (NRC, NCRP, ICRP) agree, but this is often misunderstood and misused.
- Use in risk management (radiation protection) causes misguided policies and actions (e.g., evacuation at Fukushima, which caused over 2,000 real deaths [compared to expected deaths from LNT of 96 - in 20-30 years!]).
- Use in risk management causes markedly increased costs due to increased shielding or adequate remediation or cleanup, which likely are of questionable benefit.

IMPORTANCE (2)

- **Why is this important?**
- Use of LNT promotes radiophobia, not only in patients, but also doctors, including radiologists and some NM physicians. Some patients avoid exams for themselves and children and doctors order less useful exams.
- **Focusing on potential risks due to LNT promotes overlooking the vastly greater benefits of medical imaging, which include a more accurate and/or rapid diagnosis, evaluation of extent of disease, allowing more accurate therapy, saving lives, improved quality of life, avoidance of unnecessary surgeries, reduced hospital stays, and reduced costs.**

The Appalling History of the LNT Hypothesis (1)

- LNT model is based on a fear-driven process full of errors, lies, deceptions and distortions.
- Hermann Muller lied during his Nobel Prize acceptance speech (1946). Muller initially thought that he induced mutations in the drosophila genome, but later discovered that that was not true. However, he understood the power and social utility of the Nobel Prize and decided to deceive the audience. He acknowledged 10 years after receiving the Noble prize that he had not produced mutations, but instead produced big holes in the chromosomes.
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The Appalling History of the LNT Hypothesis (2)

- Caspari study 1946 – low chronic radiation dose rate- no radiation induced mutations. Results supported a threshold dose-response model and discredited the LNT model.
- Muller convinced Curt Stern, Caspari's supervisor, to suppress the results to save the LNT and single hit model.
- National Academy of Sciences – supported a claim that all radiation-induced damage was cumulative, non-repairable and irreversible, and therefore supports the LNT dose response model, at any level of exposure [**we now know that all of this is wrong!**]
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The Appalling History of the LNT Hypothesis (3)

- In 1955, Neel presented a 10-year study on occurrence of birth defects in offspring of adults exposed to radiation to the Genetics Panel of the NAS. Result – they followed 75,000 offspring. No evidence of radiation related genetic effects.
- However, Muller stood up and challenged the results. NAS backed down.
- NAS based their recommendations on improperly designed and flawed fruit fly studies rather than major human epidemiological investigations.
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The Appalling History of the LNT Hypothesis (4)

- William L. Russell, 1956, Oak Ridge – large study on effects of radiation on lifespan and cancer incidence in mice. High expectation that radiation would decrease lifespan and increase incidence of cancer and leukemia.
- Results: no treatment effects! Russell suppressed the findings for 34 yrs!
- Edward B. Lewis – claimed that exposure to ionizing radiation could induce leukemia in multiple populations, including radiologists, patients with ankylosing spondylitis, children irradiated for an enlarged thymus, and survivors of the atomic bomb explosions in Japan. He concluded the LNT model was best. There were many flaws, especially in mixing high and low doses. The paper was apparently not peer-reviewed before publication!. This work has been discredited.

The Appalling History of the LNT Hypothesis (5)

- A second cover-up by William Russell
- Late 1950s – unexpected discovery that mouse spermatogonia and oocytes could repair DNA damage from low radiation dose rates.
- Exposures at low dose rates that did not overwhelm the repair capacity could repair induced damage. This suggests a threshold.
- Russell showed that radiation damage did not have to accumulate, could be repaired, and a threshold model was realistic.
- Russell had hidden gene cluster mutations that would have clearly shown the validity of a threshold model.

The Appalling History of the LNT Hypothesis (6)

- US NAS and Science Journal – promoted a fraudulent LNT model.
- 1. Muller's Nobel prize paper – no peer review! No mutations produced.
- 2. Failure of the Stern and Uphoff studies – flawed design.
- 3. BEAR Genetics Panel – publication with data falsification
- 4. Edward B. Lewis radiation and leukemia paper- profound deficiencies.

Future of Cancer Risk Assessment

- Science has discovered that the human genome is very susceptible to mutational damage. However, the human genome has evolved an amazing robust, redundant and high capacity process to repair damage.
- The LNT single hit hypothesis failed to account for repair.
- Our metabolism induces millions of mutations per day, of which 99.99999% are repaired.
- Our metabolism induces 200 million times more genetic damage events per cell per day than that induced by background radiation.
- Repair mechanisms evolved to repair damage from our own metabolism.
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Future of Cancer Risk Assessment

- Muller-led fear-driven process, all doses of ionizing radiation were harmful, and even a single ionization could cause harm. This idea was applied to chemical carcinogens as well as ionizing radiation.
- The experts were wrong at the start, but they convinced others that they were right. It was done in large part to get continued funding.
- This incorrect model was passed on to regulatory agencies, such as EPA and NRC without correction or updates and used for governmental environmental and occupational health standards.
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Future of Cancer Risk Assessment

- The path forward –
- First – recognize biological reality - humans are evolutionary survivors. Damage is repaired automatically, incorporated into cells by evolutionary processes.
- Extending life span is improved by being exposed to a wide range of low-level stresses daily.
- Environmental regulation must be science-based, not fear-driven.

Future of Cancer Risk Assessment

- Continued reliance on LNT for cancer risk assessment is detrimental for many reasons:
- 1. It provides grossly distorted cancer risk estimates for risk management decisions, which lead to poor policy and resource decisions.
- 2. Illusionary public health protection, a profound waste of limited resources for no benefit, and diverting resources from where they could be properly used.
- 3. Long history of adversely affecting technical innovations and in medical practice, adversely affects patient options and success.

Future of Cancer Risk Assessment

- Conclusion: Falsification of research and suppression of key scientific findings contributed to establishing the LNT model in place of the threshold dose-response model for hereditary and cancer risk assessment.
- This troubling history was hidden from regulatory agencies and these agencies accepted it uncritically.
- This uncritical acceptance of a dishonest foundation for cancer risk assessment is a failure in their public service mission. This misguided cancer risk assessment has provided improper guidance of its philosophies, policies and practices, which continues to the present.
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