IFMP WORKSHOP IN IONIAN UNIVERSITY, CORFU, GREECE

Friday 10/11/2017 11:40

RADIATION PHOBIA: FAKE NEWS AND ALTERNATIVE FACTS

David W. Townsend PhD

Director, Singapore Clinical Imaging Research Centre

For the past 50 years, the risks associated with exposure to ionizing radiation have been estimated based on the Linear No Threshold (LNT) model. This model assumes that there is a risk associated with any radiation exposure, however small, and that the risks of low-level exposure can be estimated by extrapolating to zero from high, often lethal, levels of radiation. There are, however, no reliable data for the risks from radiation levels associated with medical imaging, and specifically data to support the LNT model. The perception that all radiation causes cancer has been extensively hyped by the media creating radiation phobia and unnecessary concern among the population even though it is unsupported by scientific data. Such media reports have been endorsed by members of the medical imaging profession even though they can generally be dismissed as fake news. The evidence increasingly supports an alternative to the LNT model whereby low levels of radiation may even be beneficial (hormesis model). This presentation will summarise the data available to assess radiation risk and, by identifying a number of alternative facts, attempt to put into perspective the real concerns associated with medical imaging using ionizing radiation.

Radiation Phobia

Fake News and Alternative Facts

David W. Townsend

Clinical Imaging Research Centre
Singapore

Joint venture between Agency for Science, Technology And Research (A*STAR)
And National University of Singapore (NUS)

Lecture 4: 11:30 am Friday November 10th, 2017

A*STAR Biomedical Sciences Institutes

NUS National University of Singapore

Radiation Phobia

Oak Ridge National Laboratory 1947

Radiophobia is an obsessive fear of ionizing radiation, in particular, a fear of X-rays.

In the 1920s, the term was used to describe people who were afraid of radio broadcasting and receiving technology.

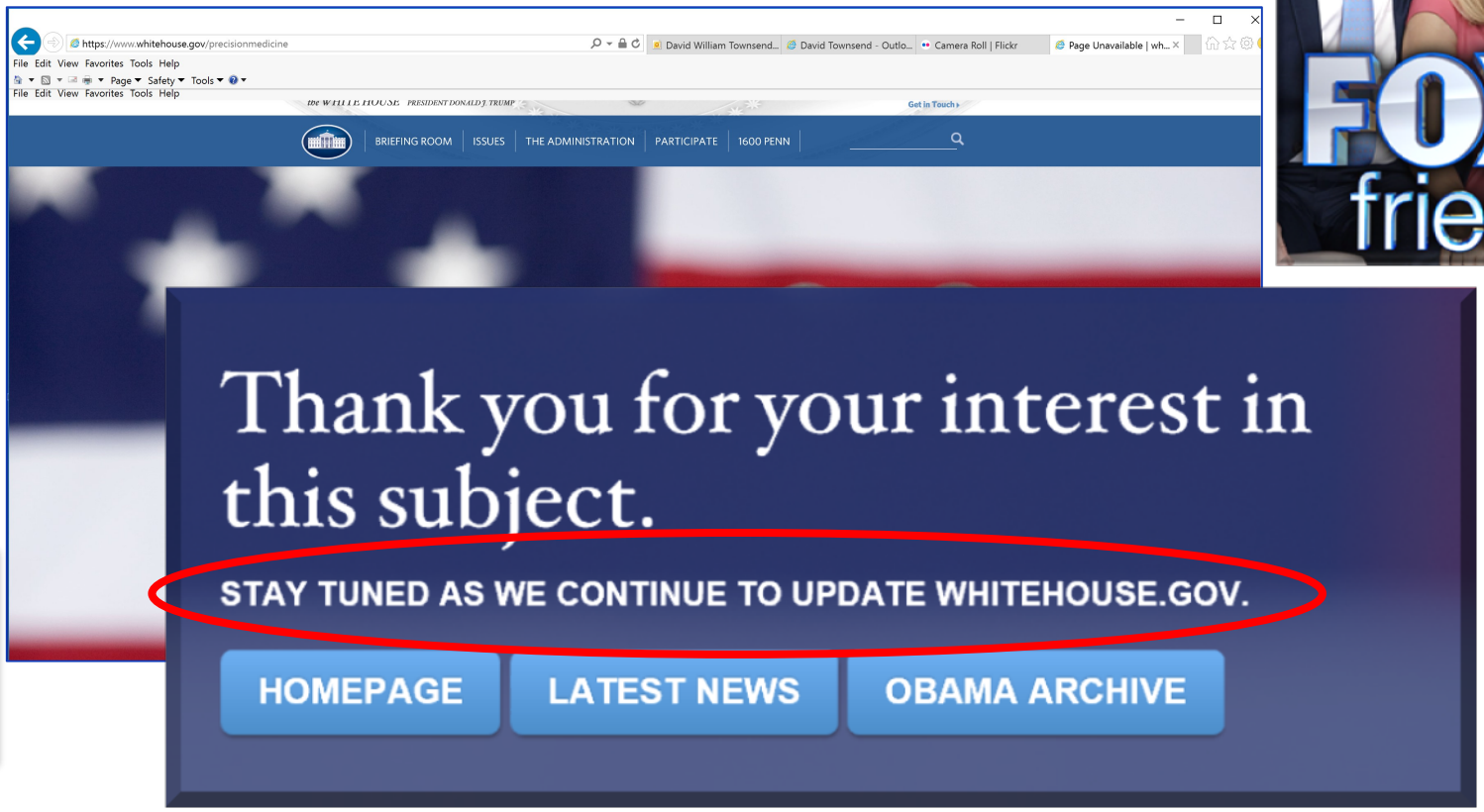
In 1931, radiophobia was referred to in *The Salt Lake Tribune* as a "fear of loudspeakers.

During the 1950s and 1960s, the Science Service associated the term with fear of gamma radiation and the medical use of x-rays.

Several American newspapers proposed that "radiophobia" could be attributed to the publication of information regarding the "genetic hazards" of exposure to ionising radiation by the National Academy of Sciences in 1956

Fake News....Defined as all news other than

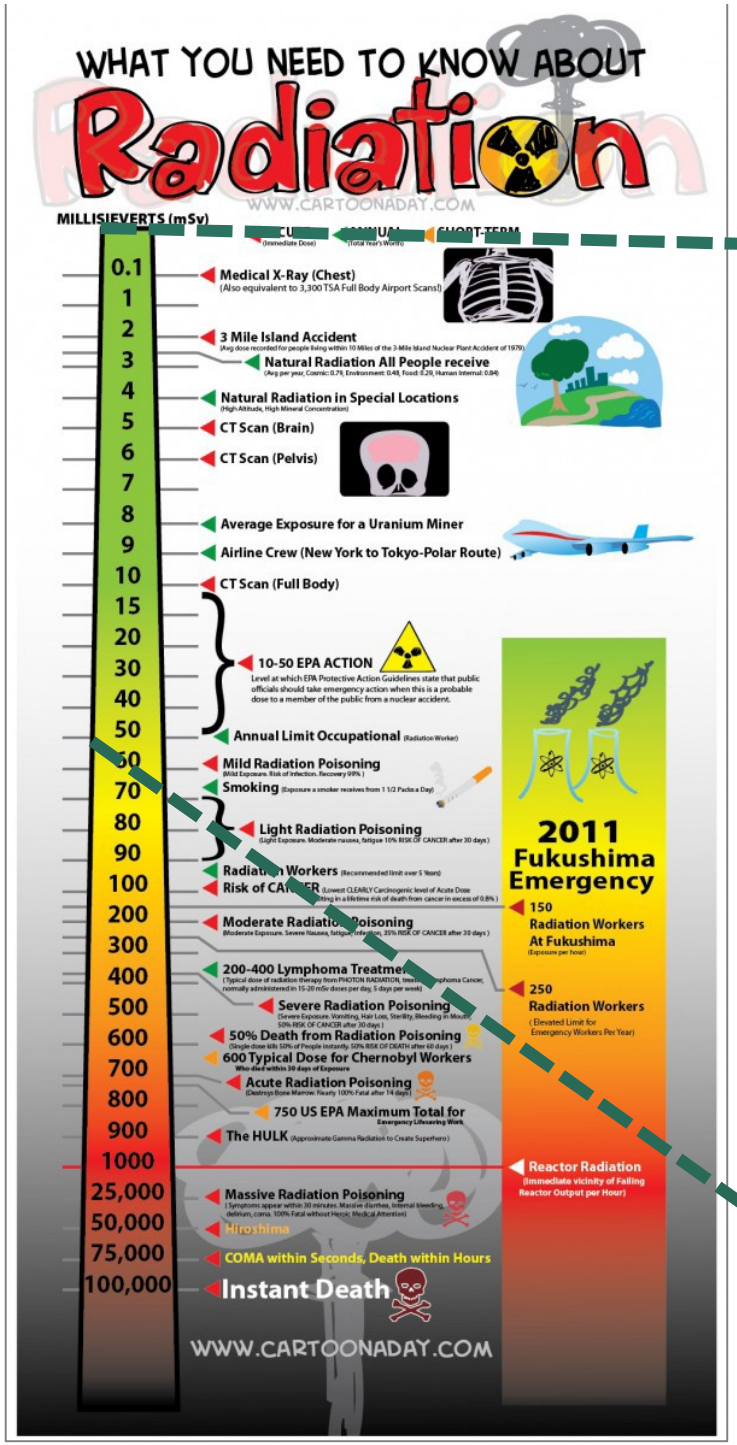
www.whitehouse.gov/precisionmedicine

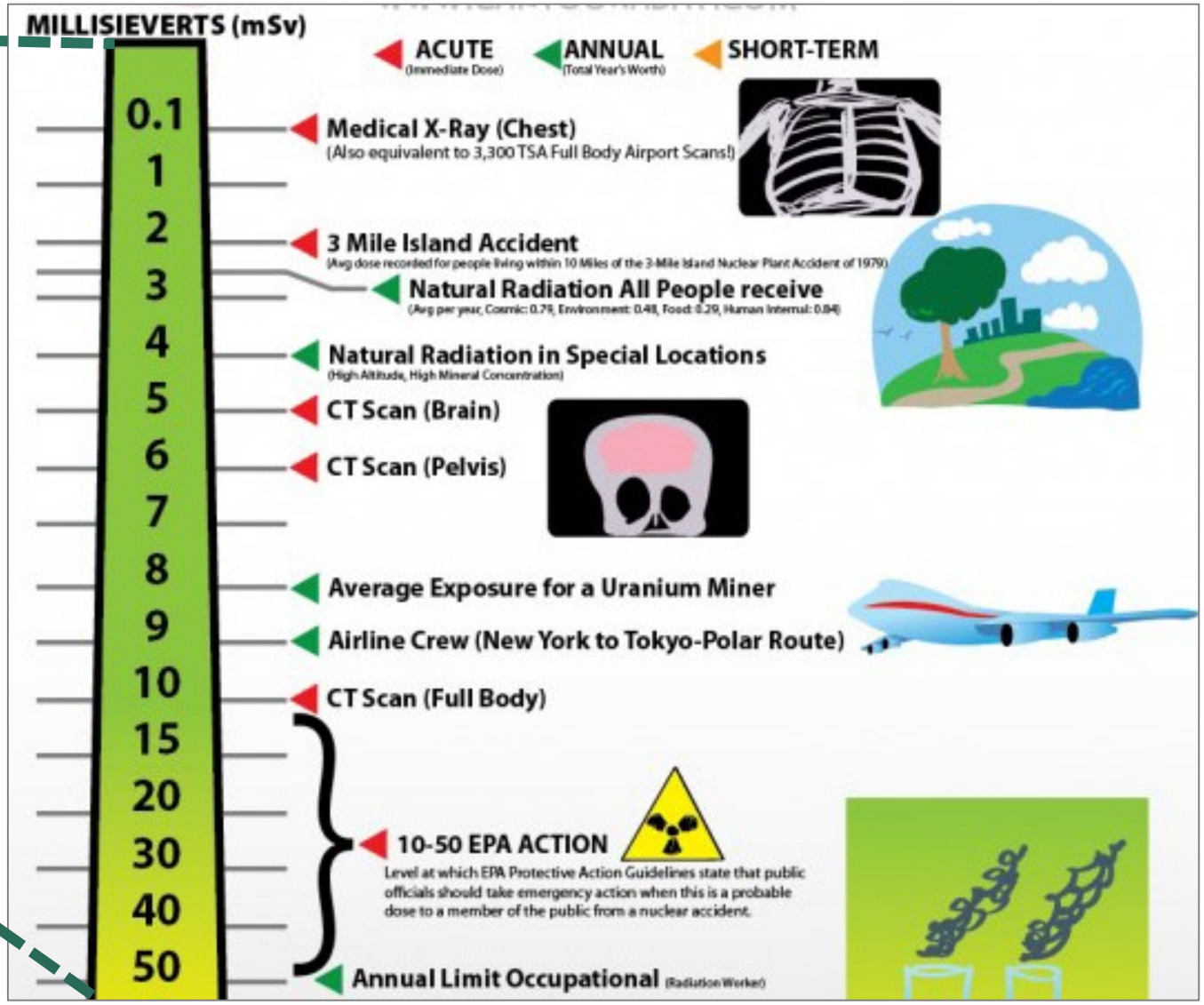


alternative fact <u>Definition</u>

Not a fact; a lie or a falsehood

Typical radiation doses





Radiation Units and Dose

Gray (Gy) = *amount of radiation absorbed in any material*

1 Gy = 1 J/kg 1 Gy = 100 rad

Sievert (Sv) = *estimates biological effect from the absorbed radiation*

1 Sv = 1 J/kg equivalent 1 Sv = 100 rem

Radiation type	Energy	w_R (Q factor)
x-rays, gamma rays, beta particles, muons		1
neutrons	< 10 keV	5
protons	> 2 MeV	2
alpha particles		20

Organ	Tissue weighting factor
Gonads	0.20
Colon	0.12
Breast	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Chest	0.05
Liver	0.05
Thyroid gland	0.05
Oesophagus	0.05
Skin	0.01
Bone surface	0.01

Absorbed dose — Energy "deposited" in a kilogram of a substance by radiation

Equivalent dose — Absorbed dose weighted for the effect of different radiation types (w_R)

Effective dose — Equivalent dose weighted for susceptibility to effect different tissues

Example:

Mammogram; 2 view x 2 breasts

Absorbed dose: 4 x 1 = 4 mSv

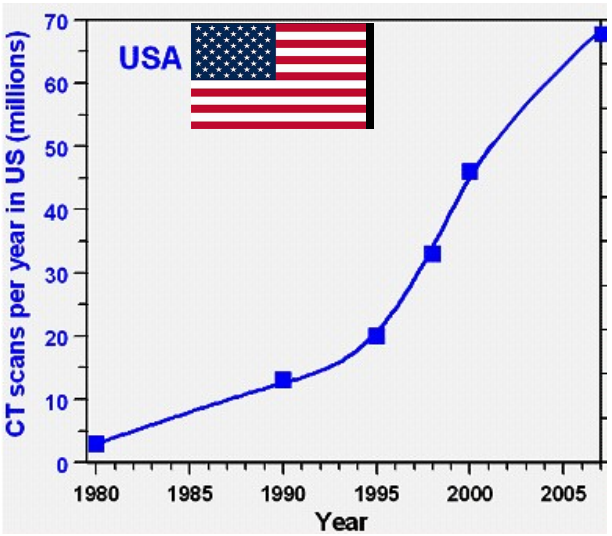
Effective dose: 4 x 0.12 ≈ 0.5 mSv

Mammogram exposure equivalent to whole-body dose of 0.5 mSv

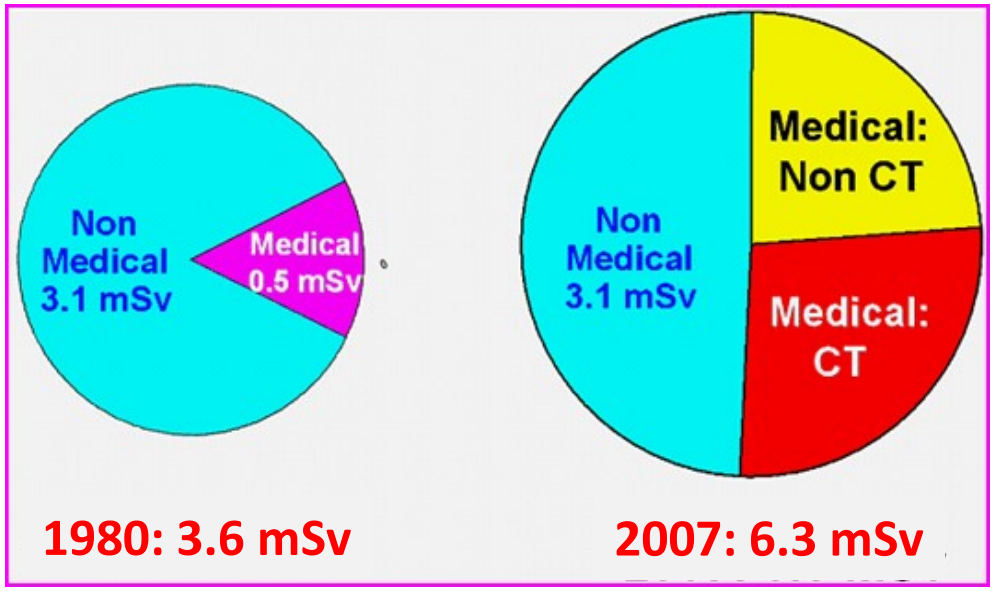
Benefit versus Risk

***** The benefit should be greater than the risk *****

Benefit:	Risk:
- to the health of the patient	- delayed health effect
- to the physician	- financial
- to the lawyers	- none



Growth in CT scans
1980 - 2007



Does this represent a significant increased risk?

Publicity on Radiation Risks

The New York Times

The Opinion Pages | OP-ED CONTRIBUTORS

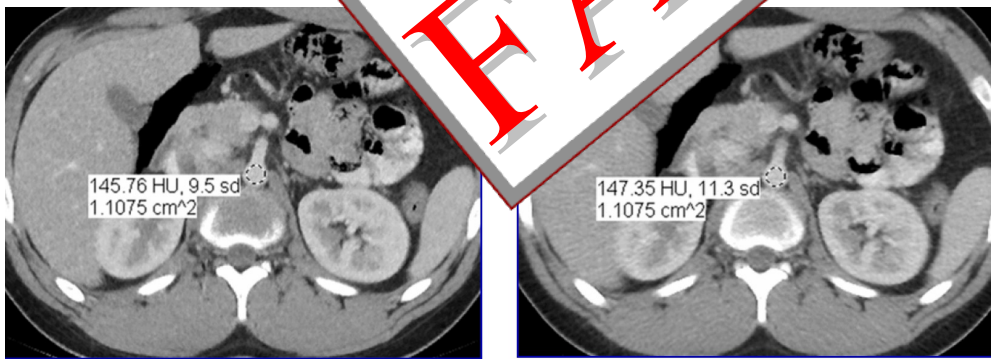
Cardio

We Are Giving Ourselves C

By RITA F. REDBERG and REBECCA SMITH-BINDMAN JAN. 30

DESPITE great strides in prevention a
rates remain stubbornly high and **eart**
disease as the leading cause o **States.**
Increasingly, we and man **ve that an**
important culprit may **practices: We**
are silently irradiati

FAKE NEWS



Radiation dose < 1 mSv

Publicity on Radiation Risks

abcNEWS / Health

HOT TOPICS: 'Law & Order' · Rob Simmons · U2 Bono

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MORE HEALTH: OnCall+ Sleep Center | OnCall+ Wellness Center | Health Conditions | Check Your Symptoms

Home > Health > Health

CT Scan Radiation May Lead to 29,000 Cancers, Researchers Warn

Popular Diagnostic Scans May Be Overused, Some Worry

REUTERS | EDITION: U.S. | News & Markets | Sectors & Industries | Analysis & Opinion

(Reuters) - Radi… scans done in 2007 will cause 29,000 cancers and … mericans, researchers said on Monday

By Julie Steenhuysen

CHICAGO | Mon Dec 14, 2009 4:30pm EST

…line

…ody scanners 'could …ou cancer', warns expert

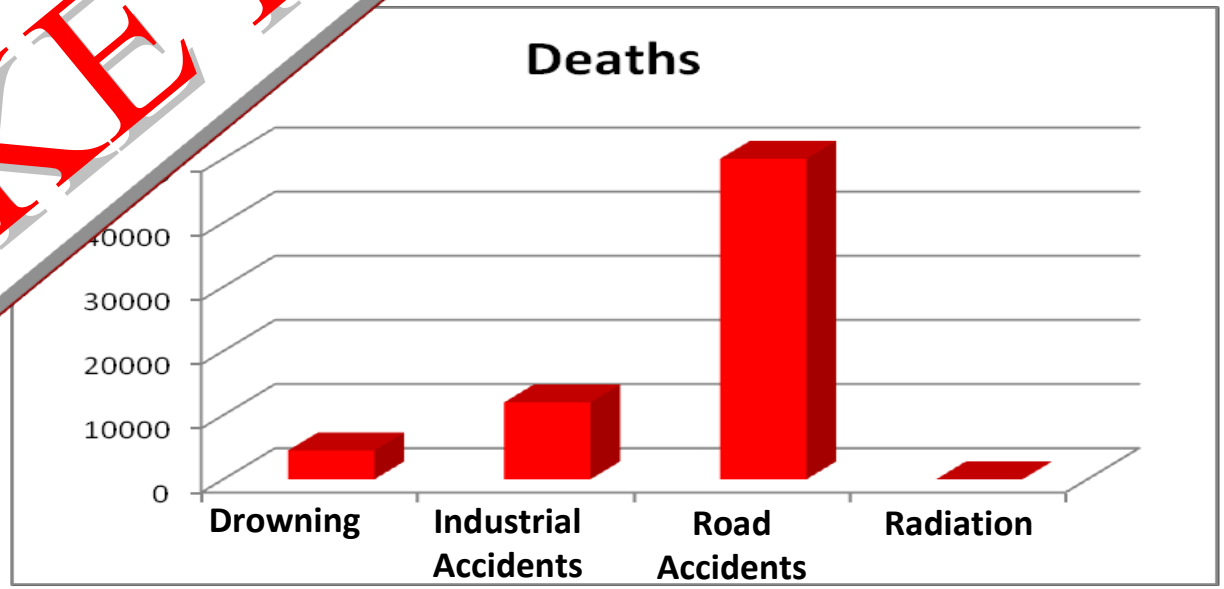
nature International weekly journal of science

We don't know enough about low-d… radiation risk

The long-term risks to health … radiation are still poorly kn… Brenner. A combination … exposed populations … needed.

David J Brenner

FAKE NEWS



The estimated dose to the lung or s… from a single full-body CT examination is 14–21 mGy, which corresponds to a dose region for which there is direct evidence of increased cancer mortality in atomic bomb survivors.

Where does the estimate of 29,000 cancers come from ?

It is based on Application of Linear No Threshold Hypothesis in BEIR VII Phase 2 Report

and

Risk estimates from radiation exposure for 57,000,000 CT scans (in 2007)

"Although cancer risks from CT scans have not been demonstrated directly, radiation is one of the most extensively studied carcinogens, and there is direct evidence from studies of the Japanese atomic bomb survivors, nuclear workers, and patients receiving multiple diagnostic x-rays that radiation doses of the magnitude delivered by several scans (50-100 mGy) can cause cancer".

Lifetime attributable risk (LAR)

TABLE 12D-1 Lifetime Attributable Risk of Cancer Incidence[a]

Cancer Site	Age at Exposure (years) 0	5	10	15	20	30	40	50	60	70	80
Males											
Stomach	76	65	55	46	40	28	27	25	20	14	7
Colon	336	285	241	204	173	125	122				30
Liver	61	50	43	36	30	22	21				3
Lung	314	261	216	180	149	105	104				34
Prostate	93	80	67	57	48	35	35				5
Bladder	209	177	150	127	108	79	79				23
Other	1123	672	503	394	312	198	172				23
Thyroid	115	76	50	33	21	9	3				0.0
All solid	2326	1667	1325	1076	881	602	564				126
Leukemia	237	149	120	105	96	84	84	84	82	73	48
All cancers	2563	1816	1445	1182	977	686	648	591	489	343	174
Females											
Stomach	101	85	72	61	52	36	35				11
Colon	220	187	158	134	114	82	79				23
Liver	28	23	20	16	14	10	10				2
Lung	733	608	504	417	346	242	240				77
Breast	1171	914	712	553	429	253	141				4
Uterus	50	42	36	30	26	18	16	13	9	5	2
Ovary	104	87	73	60	50	34	31	25	18	11	5
Bladder	212	180	152	129	109	79	78	74	64	47	24
Other	1339	719	523	409	323	207	181	148	109	68	30
Thyroid	634	419	275	178	113	41	14	4	1	0.3	0.0
All solid	4592	3265	2525	1988	1575	1002	824	678	529	358	177
Leukemia	185	112	86	76	71	63	62	62	57	51	37
All cancers	4777	3377	2611	2064	1646	1065	886				214

NOTE: Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.

100,000 women aged 30

Single dose of 100 mGy

Over their lifetime

1.065%

LAR is the <u>additional</u> cancer risk above baseline and is based on sex of patient, magnitude of the single dose and age at time of exposure to radiation.

Calculating Your Radiation Risk

FAQs

Why isn't there a study directly linking medical imaging and cancer?

There are no studies that *directly* link cancer to the low dose radiation used in current medical imaging. ✓

If I have cancer, can radiation from medical imaging make it worse?

Low dose exposure increases the risk of developing new cancer decades after exposure.

X

asrt American Society of Radiologic Technologists

PROTECH Medical

Politics on Radiation Risks 2015

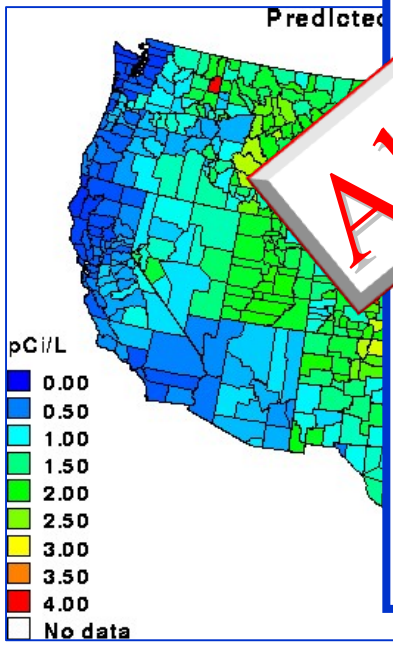
November 10, 2015

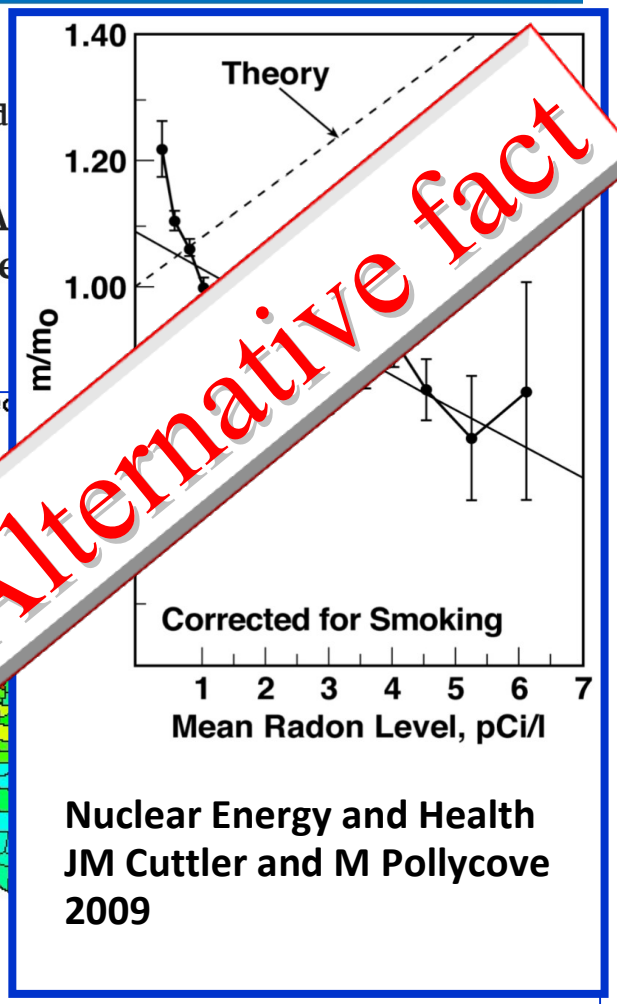
Environmental Topics | Laws & Regulations | About EPA | Search EPA.gov

News Releases

News Releases from Head
Administrator (AO)

EPA and Partners A
Prevent Lung Cance
Exposure

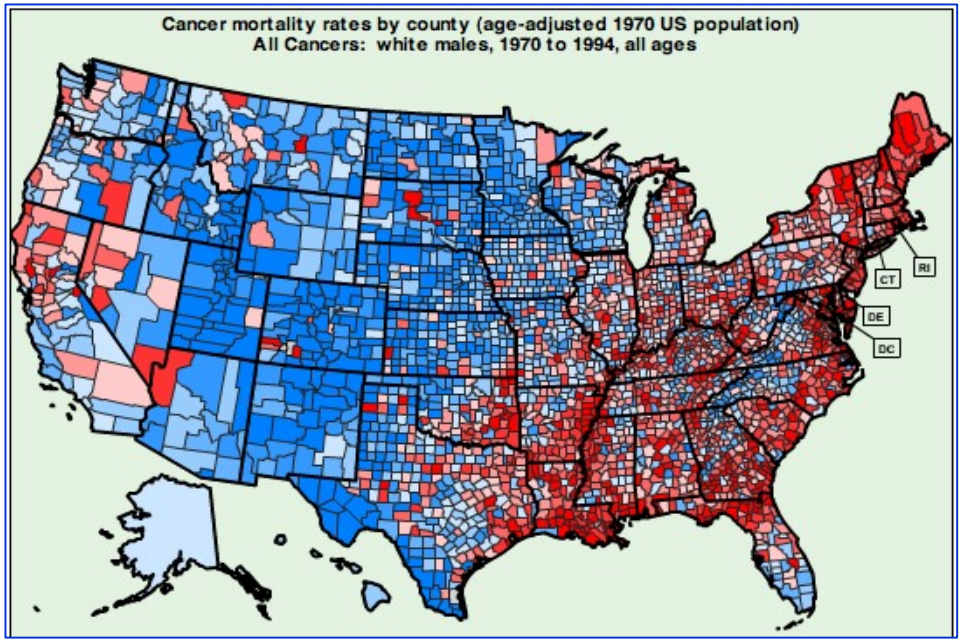




Radiation levels from radon

WASHINGTON - Today, the U.S. Environmental Protection Agency (EPA), American Lung Association, and other partners are announcing a strategy for preventing 3,200 lung cancer deaths annually by 2020 through radon exposure reduction strategies. **Exposure to radioactive radon gas is the second leading cause of lung cancer in America.**

^{220}Rn from ^{232}Th **^{222}Rn from ^{238}U**



Cancer mortality rates

Politics on Radiation Risks 2017

EPA United States Environmental Protection Agency

September 2017

Scott Pruitt

Scott Pruitt's EPA Says Maybe More Radiation Exposure Wouldn't Be So Harmful

Tom McKay
10/17/17 12:50am • Filed to: EPA

The updated version of the document which in 2007 said no levels of radiation exposure are safe now cites unnamed "radiation safety experts" as saying that "radiation exposures of 5–10 rem (5,000–10,000 mrem or 50–100 mSv) usually result in no harmful health effects, because radiation below these levels is a minor contributor to our overall cancer risk."

New EPA Radiation Exposure Guidance Comparisons			
Protective Action Guides	2007 PAG Guidance Document	2017 PAG Guidance Document	SDWA Maximum Contaminant Level Goals
How much radiation exposure is "safe"?	0 mrem[1]	10,000 mrem	0 mrem
Chest x-ray equivalent	0	5,000-10,000	0 mrem
Increased incidence of cancer	0	Every 86th person would get a cancer from that exposure	0

[1]U.S. Envtl. Prot. Agency, *Communicating Radiation Risk*, 16 (Sept. 2007) ("There is no known safe amount of radiation…the current body of scientific knowledge tells us this.") *available at:* https://www.epa.gov/radiation/pag-public-communication-resources.

From: Public Employees for Environmental Responsibility

Science on Radiation Risks

Low doses of radiation could harm cardiovasc health

July 15, 2017

SOMEWHAT FAKE NEWS

Ionizing radiation, such as x-r effect on the cardio-vascular system even at do recurrent CT imaging, a new study published nal Journal of Radiation Biology suggests.

It is known that populati ed to ionizing radiation in medical or environmental settings symptoms suggesting an increased risk of cardiovascular disease. However, this research study suggests that low exposure to doses of around 0.5 Gy (the equivalent of repeated CT scans) is associated with a significantly increased risk of cardiovascular damage, up to decades after exposure.

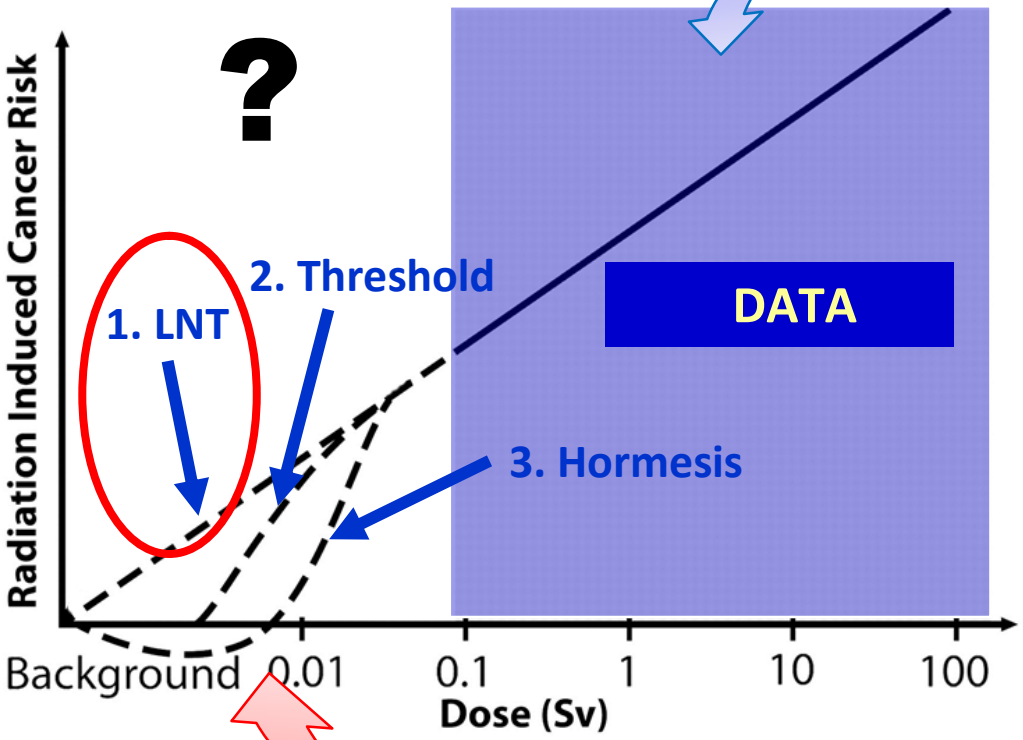
Dr Soile T Azimzadeh of Helmholtz Zentrum Münch esearch Center for Environmental He es studied how human coronary artery respond to a relatively low radiation dose of und several permanent alterations in the cells the potential to adversely affect their essential ns. Endothelial cells, which form the inner layer of od vessels, were found to produce reduced amounts of nitric oxide, an essential molecule in several physiological processes including vascular contraction. Previously, high dose radiation (16 Gy) has been shown to persistently reduce levels of nitric oxide in the serum of mice, but this is the first study to indicate impaired nitric oxide signaling at much lower doses.

Cells damaged by low-dose radiation also produced increased amounts of reactive oxygen species (ROS), which are formed as a natural byproduct of normal oxygen metabolism and play an important role in cell signaling. Increased ROS can damage DNA and proteins.

0.5 Gy ≡
- **5000 chest x-rays**
- **50 – 100 CT scans**
- **90,000,000 flight miles**

The BEIR Report: which data source and which model?

Biological Effects of Ionizing Radiation (BEIR) VII Phase 2 (2007)



Experimental data sources

A. Environmental radiation
B. Occupational radiation
C. Medical radiation
D. Atomic bomb survivors

Cancer Risk models at low dose

1. Linear No Threshold (LNT)
2. Threshold Model
3. Hormesis Model

A. Environmental Radiation Studies for BEIR VII

- Populations living near nuclear facilities

  "..no increased risk…with radiation exposure"

- Populations exposed to atomic bomb testing

  "..some studies (4 out of 10) show some effect"

- High natural background regions (China and India)

  "..did not find higher disease rates in geographical areas with high background levels.."

- Estimated cancer risk associated with the low level radiation exposure of **6.4 mSv / year**
- 20-year study in 125,079 subjects
- Excess Relative Risk:
  ERR/Sv = -0.10 (-0.67 to 0.69)
- **Conclusion:** mortality of all cancers in Yangjiang was generally lower than that in control group, but not significant statistically.

Tao et al, Zhonghua Yi Xue Za Zhi, 1999; 79: 487-492

Yangjiang, China, 1979-1995

A.(cont) Most radioactive place in the world: Ramsar, Iran

Background radiation: 100-260 mSv / year due to ^{226}Radium

No epidemiological evidence of adverse affects

Residents demonstrate a marked increase in DNA repair capacity

Proposal: to relocate the inhabitants (2000) to a lower radioactive area!

B. Occupational radiation studies for BEIR VII

US:	9 studies	Canada:	1 study
UK:	6 studies	France:	1 study

Combined study population > 500,000 subjects with 30 - 40 years of follow-up

Cumulative dose levels: 30 - 60 mSv

Healthy worker effect:

"….in most cases, rates for all causes and all cancer mortality in the workers were substantially lower than the reference populations."

Breast Cancer Mortality: Study of 67,979 women who worked with radiation in Nuclear Weapons facilities before 1980 (relative to women who were unmonitored in same facilities)

Expected mortality = 18,106 deaths; Observed mortality = 13,671 deaths

"Because of uncertainty in occupational risk estimates….., the BEIR VII committee has concluded that the occupational studies are not suitable for the projection of population-based risks."

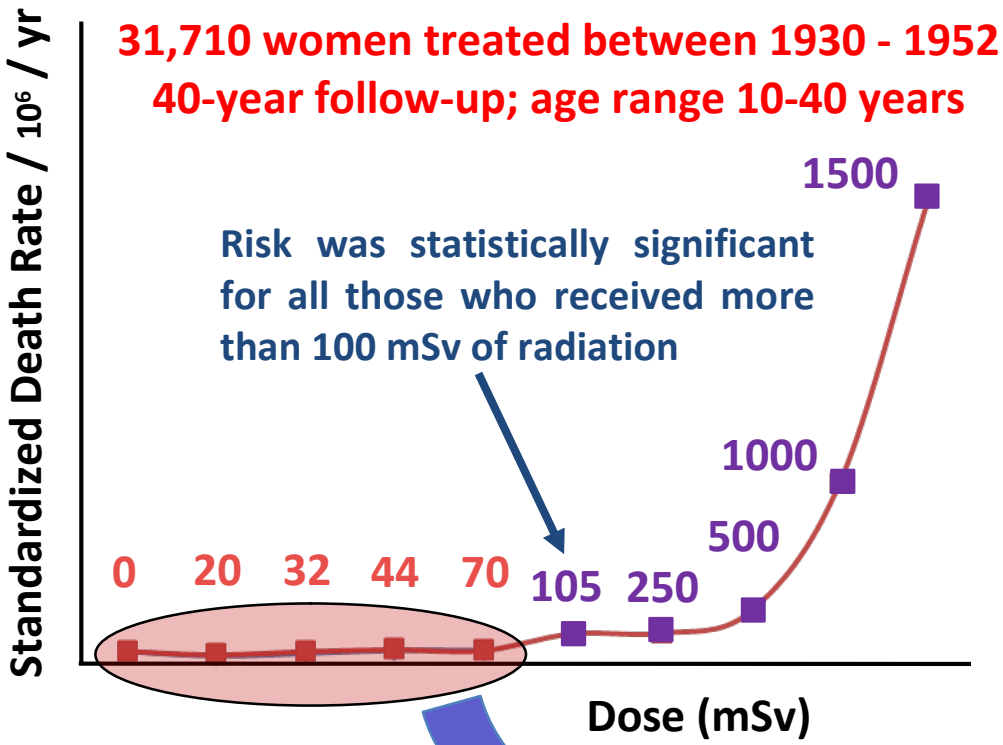
C. Medical Radiation Studies for BEIR VII

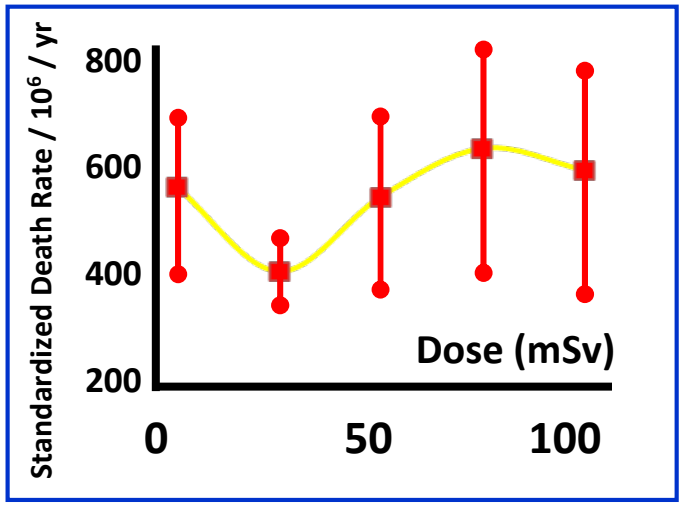
Focus is on therapeutic studies:

"…most of the information comes from studies of populations with medium to high doses"

Lung Cancer: 9 studies, 40,000 subjects average dose ~ 1 Gy

Breast cancer: 11 studies, 20,000 subjects average dose ~ 300 mGy





Mortality from Breast Cancer after irradiation during fluoroscopic examinations in patients being treated for Tuberculosis

D. Atomic bomb survivor studies for BEIR VII

120,000 survivors:

93,000 present at time of bombings
27,000 from locale, but absent at time of the bombing

Monitored over 60 years and includes both sexes and all ages of exposure; mean dose = 200 mSv

Dose range	**37,000**	**0 - 5 mSv**
	32,000	**5 - 100 mSv**
	17,000	**100 – 2000 mSv**

The probability that an A-bomb survivor will have a cancer caused by A-bomb radiation (excess lifetime risk) depends on the dose received, age at exposure, and sex.

The dose-response relationship appears to be linear, without any apparent threshold below which effects may not occur

This is the primary source of data for all LNT risk models used in BEIR VII

Linear No-threshold Model

- 1930: fruit fly irradiation at 814 mGy/min to delive 0 Gy total dose
- Experiments showed increased genetic mutati adiated group
- Müller received a Nobel Prize for this w e claimed data <u>supported</u> LNT model
- Müller stated that the LNT model w ed for doses <u>as low as</u> 4 Gy (CT: ~8 mGy)
- In 1946, Caspari established a se-response model (at low dose rate)
- All studies acquired at d 00 x average background radiation in US
- 1956: LNT model was acce s established scientific fact by BEAR I Committee

Alternative fact

Siegel et al. Am J Clin Oncol, 2015

RADIATION RESEARCH 171, 1–8 (2009)
0033-7587/09 $15.00

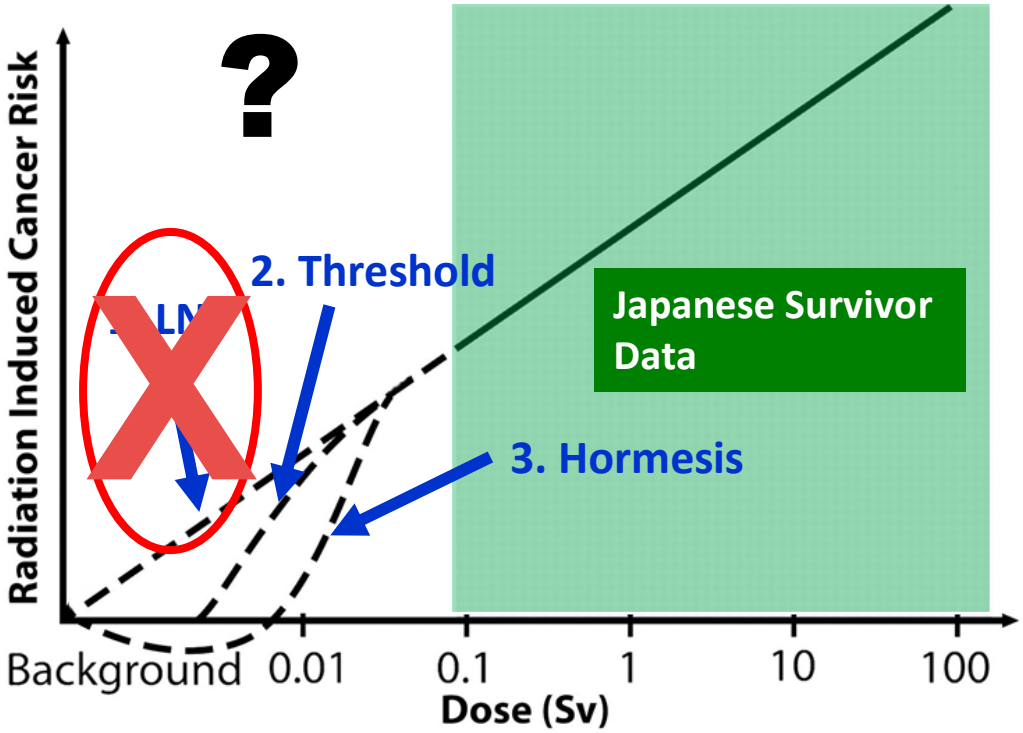
Reduction in Mutation Frequency by Very Low-Dose Gamma Irradiation of *Drosophila melanogaster* Germ Cells

Keiji Ogura,[a,b,1] Junji Magae,[a,b] Yasushi Kawakami[b] and Takao Koana[a,2]

[a] *Radiation Safety Research Center, Central Research Institute of Electric Power Industry, Iwado-Kita 2-11-1, Komae, Tokyo 201-8511, Japan; and*
[b] *Biotechnology Department, Institute of Research and Innovation, Takada 1201, Kashiwa, Chiba 277-0861, Japan*

The BEIR Report: so which theoretical model then?

Biological Effects of Ionizing Radiation (BEIR) VII Phase 2 (2007)



1. ~~Linear No Threshold (LNT) Model~~
2. Threshold Model ✓
3. Hormesis Model ✓

No evidence to support the LNT model at imaging doses while much evidence supports the hormesis model. Low dose radiation stimulates repair and removal of radiogenic damage in excess of the immediate damage and thus provides enhanced protection, resulting in a reduction of damage below spontaneous levels.

In a comparison of a cohort of 100,000 radiologists with psychiatrists, the radiologists had lower death rates from all causes than the unexposed psychiatrists. The two professions had similar risks of cancer mortality overall.

Conclusion on LNT model:

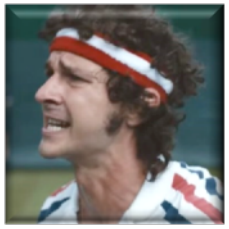
Note: fruit flies are extremely radio-resistant. A dose of 40 Gy resulted in a 10% mutation rate whereas the same dose applied to humans would have resulted in 100% death rate.

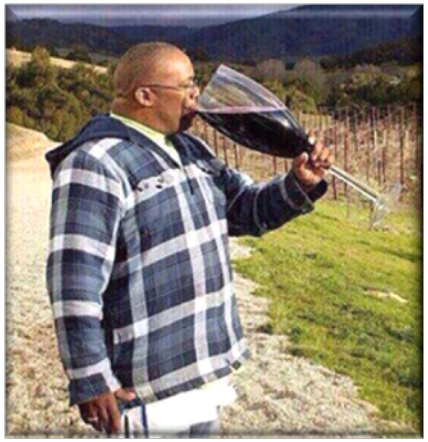
= a poor choice of animal model

- **The use of the Linear No Threshold Model to estimate risk due to medical imaging levels of radiation is not supported by <u>any scientific data</u> and should be <u>rejected.</u>**

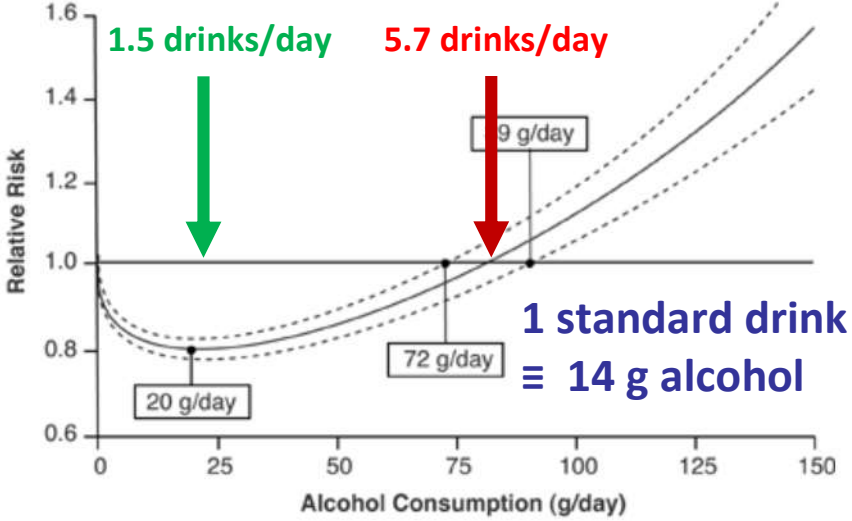
- **The LNT model ignores the biology of adaptive response to DNA damage that involves evolutionary-developed repair mechanisms, stimulated by low-level radiation.**

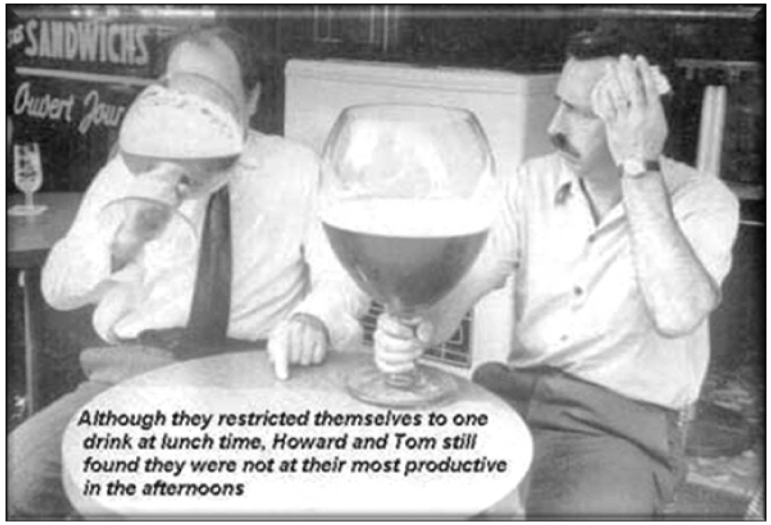
Hormesis? You can't be serious…..





One drink a day





Therapeutic Nuclear Medicine
Springer 2012 ISBN 978-3-540-36718-5

Hormesis by Low Dose Radiation Effects: Low-Dose Cancer Risk Modeling Must Recognize Up-Regulation of Protection

Ludwig E. Feinendegen, Myron Pollycove, and Ronald D. Neumann

"A little poison is good for you"

LNT ignores the spontaneous endogenous DNA damage rate that is repaired.

Single-strand breaks:

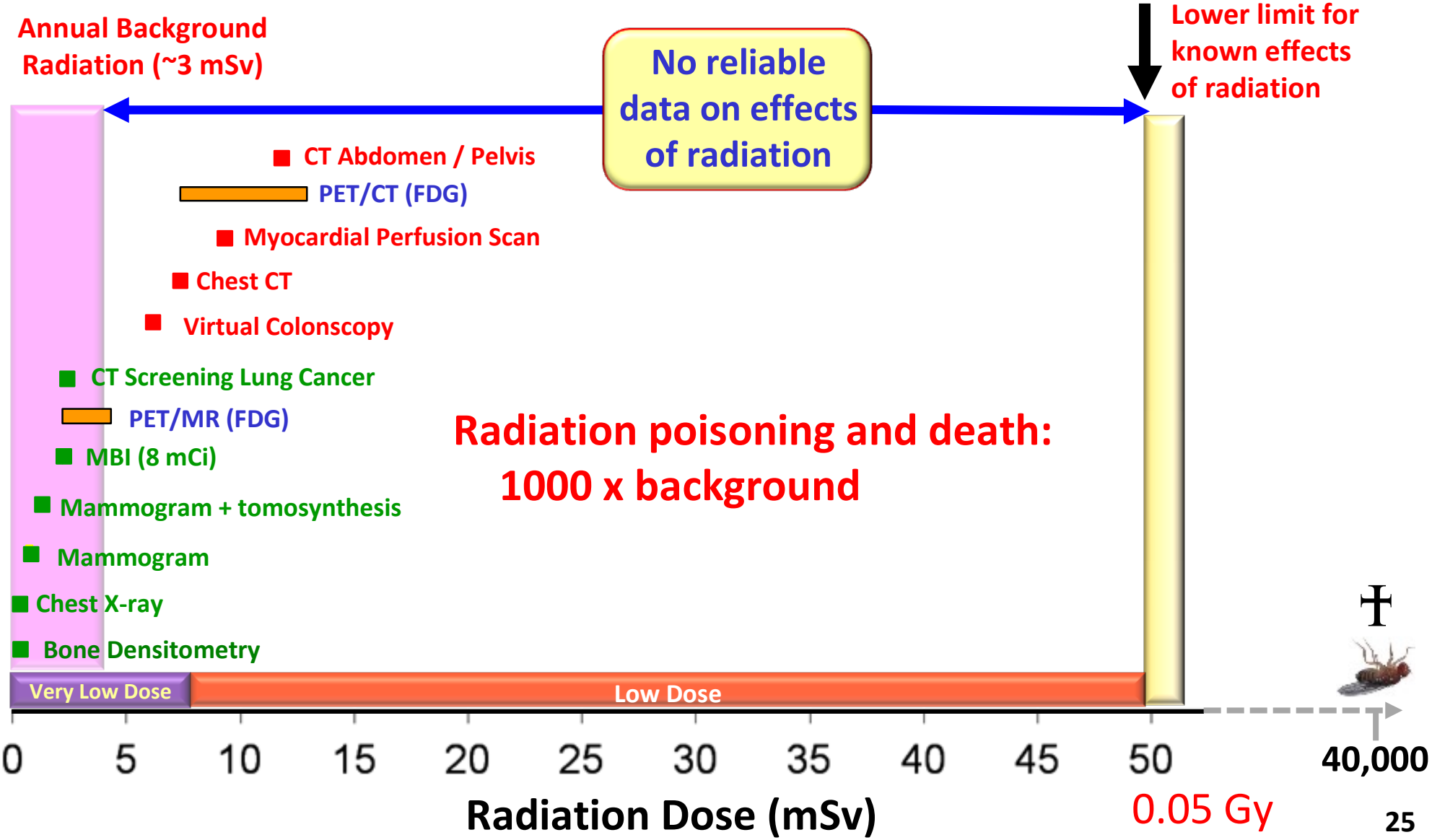
Endogenous rate > 10^6 x background radiation rate

Double-strand breaks:

Endogenous rate > 10^3 x background radiation rate

Low dose radiation up-regulates adaptive protection systems and the effect may last more than a year

Radiation doses for clinical imaging procedures



Disassociation of major organizations

The following organizations have clearly stated that the use of the LNT Hypothesis to

Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged.

These predictions are harmful because they lead to sensationalistic articles in the public media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.

AAPM (2011) Position statement on radiation risks from medical imaging procedures. Policy Number PP 25-A, 2011.

Question: So what needs to be done?

Educate the public and regulators on the real risks of radiation:

Subjecting Radiologic Imaging to the Linear No-Threshold Hypothesis: A Non Sequitur of Non-Trivial Proportion

J Nucl Med 2017; 58:1–6
DOI: 10.2967/jnumed.116.180182

Jeffry A. Siegel[1], Charles W. Pennington[2], and Bill Sacks[3]

[1]Nuclear Physics Enterprises, Marlton, New Jersey; [2]NAC International (retired), Norcross, Georgia, and executive nuclear energy consultant, Alpharetta, Georgia; and [3]U.S. Food and Drug Administration (retired), Green Valley, Arizona

Does Imaging Technology Cause Cancer? Debunking the Linear No-Threshold Model of Radiation Carcinogenesis

Technology in Cancer Research & Treatment
2016, Vol. 15(2) 249–256

DOI: 10.1177/1533034615578011
tct.sagepub.com
SAGE

Jeffry A. Siegel, PhD[1] and James S. Welsh, MS, MD, FACRO[2]

Dose Optimization to Minimize Radiation Risk for Children Undergoing CT and Nuclear Medicine Imaging Is Misguided and Detrimental

J Nucl Med 2017; 58:865–868
DOI: 10.2967/jnumed.117.195263

Jeffry A. Siegel[1], Bill Sacks[2], Charles W. Pennington[3], and James S. Welsh[4]

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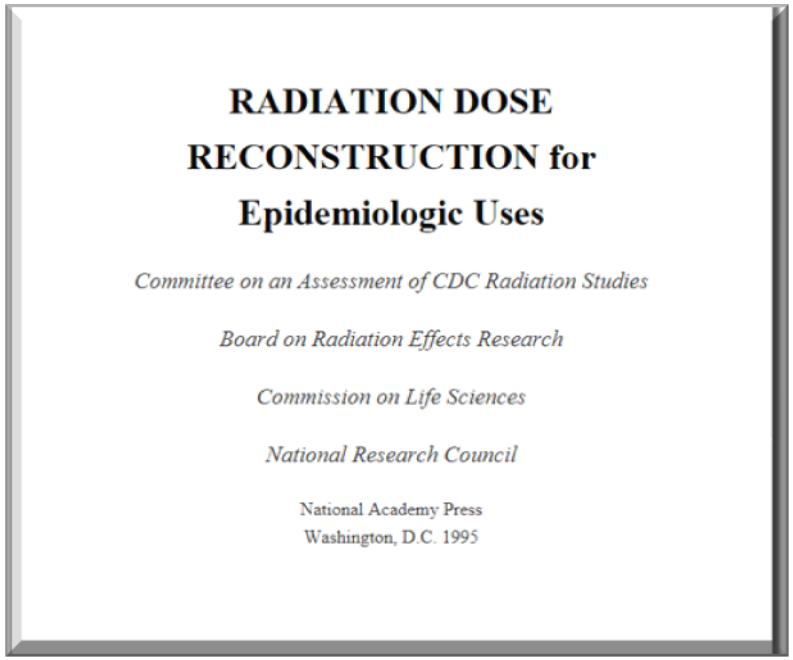
"Studies demonstrate that children are not more radiosensitive than adults in the radiologic imaging dose range rendering dose reduction for children unjustifiable and counter-productive."

Note the sample size required to identify an effect


RADIATION DOSE
RECONSTRUCTION for
Epidemiologic Uses

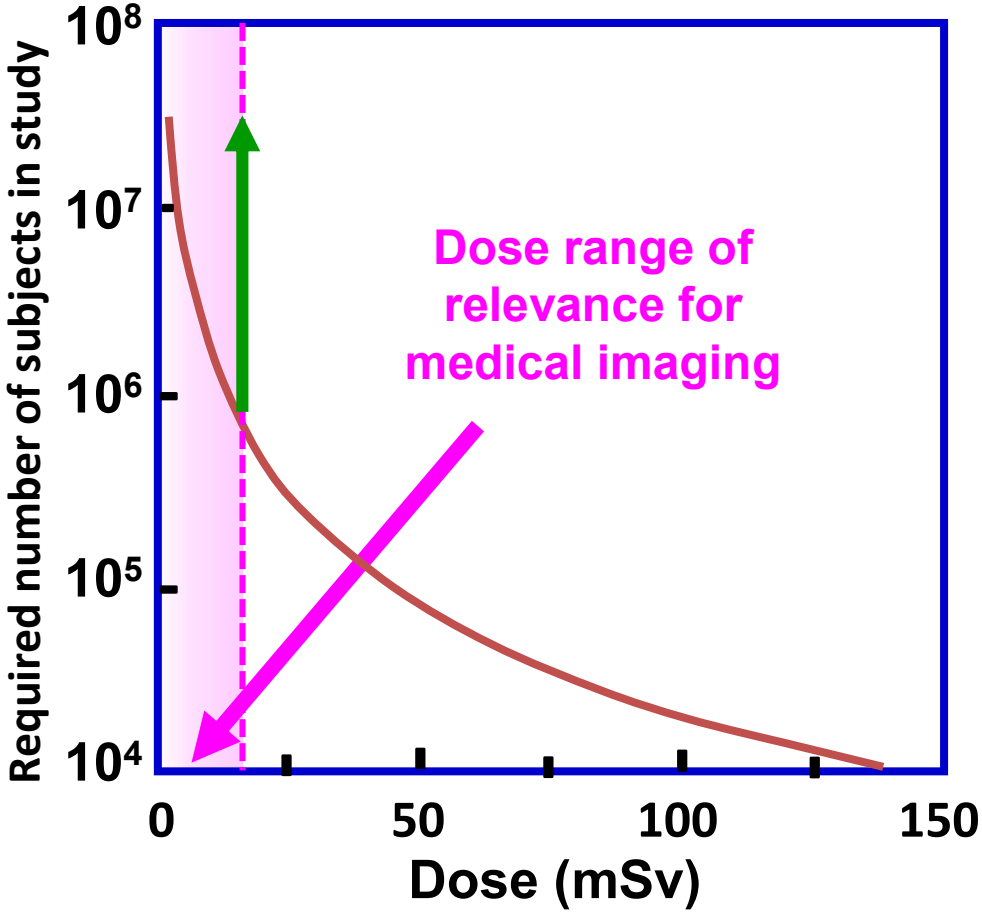
Committee on an Assessment of CDC Radiation Studies

Board on Radiation Effects Research

Commission on Life Sciences

National Research Council

National Academy Press
Washington, D.C. 1995



Example: To detect an increase in cancer from an exposure of 12 mSv would require a study of ~7,000,000 subjects.

Lifetime risk: 50% (from CR UK)

Sample size required to detect a significant increase in cancer mortality

Assumes lifetime follow-up

National Research Council (1995) *Radiation Dose Reconstruction for Epidemiologic Uses* (Natl. Acad. Press, Washington, DC).

John Roderick Cameron
1922 - 2005

"In 1970 I realized that there was negligible risk from x-rays but many radiographs had poor image quality so that the risk from a false negative was significant."

John Cameron

Image Wisely: personalize the radiation dose

Image Appropriately

Take home message(s):

The LNT model is unsupported by data and should be abandoned

We still <u>need</u> to reduce radiation dose from imaging procedures:

- **Not necessarily because it causes cancer**
- **But because people *<u>fear</u>* it will cause cancer**
- **And where does this fear come from?**

  - <u>inappropriate use of the BEIR risk models</u>

Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy.

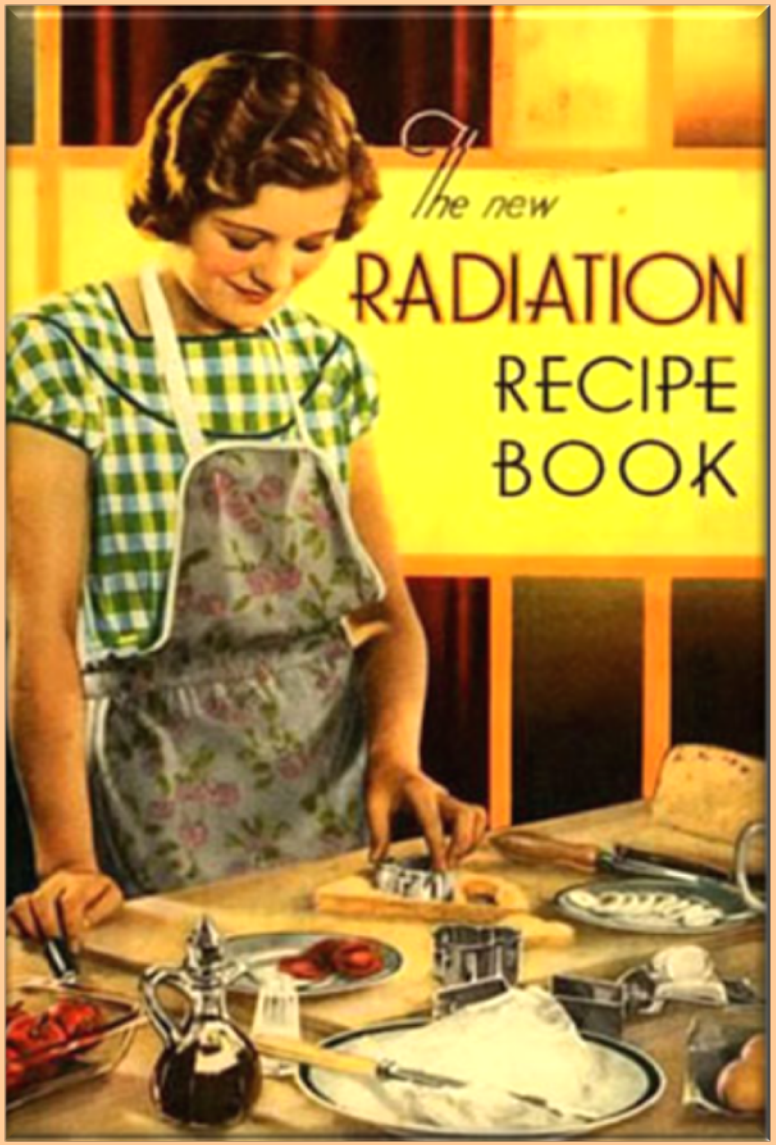
Paracelsus
1493-1541

Consequences: Negative impact on patient care:

- **Patients declining needed exams or procedures**
- **Physicians ordering alternate exams, which may be less accurate, more expensive, or require anesthesia**

For further information, you should consult the:

RADIATION RECIPE BOOK



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