Doctors for Disaster Preparedness

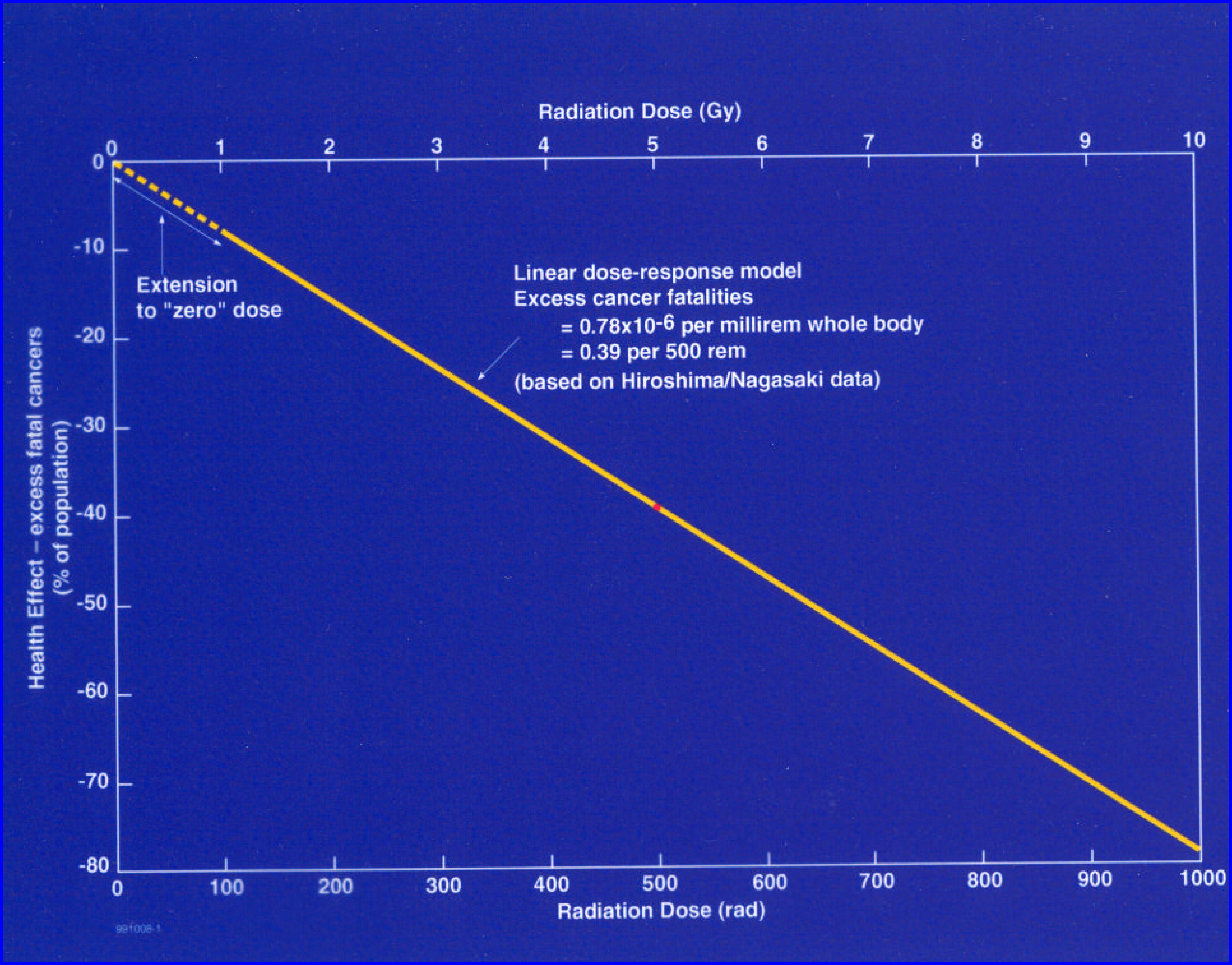
20th Annual Meeting

Colorado Springs, July 27-28, 2002

Radiation Hormesis in Medicine
Low Dose Irradiation Therapy

J.M. Cuttler

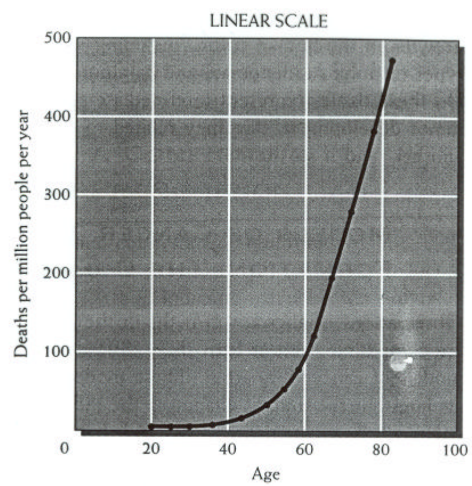
Cuttler & Associates Inc.

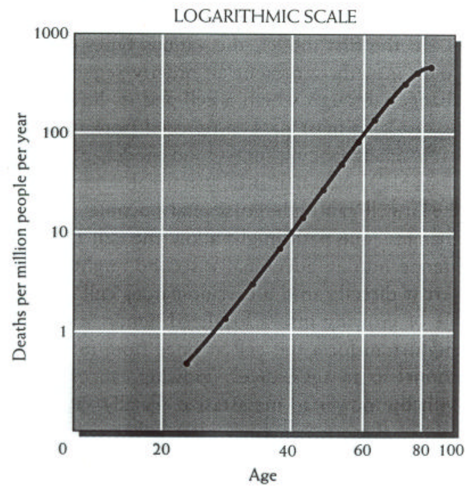


Radiation Dose (Gy)
0
1
2
3
4
5
6
7
8
9
10
0
-10
-20
-30
-40
-50
-60
-70
-80
Health Effect – excess fatal cancers
(% of population)
Extension
to "zero" dose
Linear dose-response model
Excess cancer fatalities
= 0.78x10-6 per millirem whole body
= 0.39 per 500 rem
(based on Hiroshima/Nagasaki data)
0
100
200
300
400
500
600
700
800
900
1000
Radiation Dose (rad)
991008-1

ı 1000 times higher
l boy. Some statisti-
sk increases approxi-
f of elapsed time (t^5),
n of *five* distinct
the progression to-
ıch occurring with
er year. Whether
n a defined order or
is not made clear by

t colon cancer is a
ve lived long enough
complex succession of
tically by curves plot-
nce each event is a
ears to occur, the
des, an entire adult
of us will die from
equence of events can
unusual exposure to
e of a cancer suscepti-
peeds up or leapfrogs
e steps, greatly in-
f developing cancer
.
-dependent cancer
any other adult tu-
carcinogenesis. But no
e nature of the mile-
malignancy. To learn
he biology of cancer
ths. Can the multiple
be described in con-
opping points on the
nalignancy? Are there
neither fully normal





Actual annual U.S. death rate from colon cancer in relation to age, 1986.

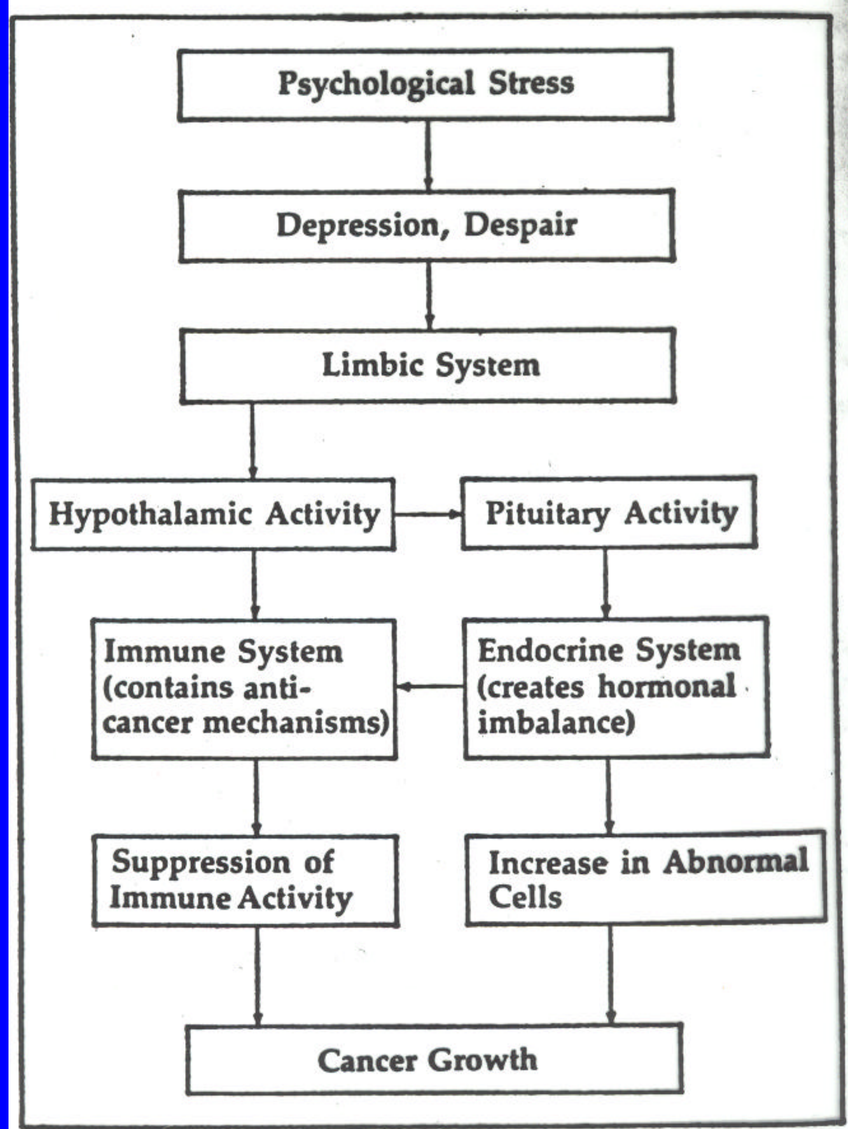


Figure 1. A Mind/Body Model of Cancer Development.

Studies of the Mortality of Atomic Bomb Survivors
Report 12, Part 1

by Donald Pierce et al, Radiation Research **146**, 1-27 (1996)

Table II, Observed and expected deaths for solid cancers, 1950-90

Dose Sv	Dose rem	Subjects	(1) Observed deaths	(2) Expected background	(1) – (2) Excess deaths	$\sqrt{(1) + (2)}$ Standard deviation
0	0	36,459	3013	3055	-42	78
0.005 - 0.1	0.5 - 10	32,849	2795	2710	85	74
0.1 - 0.2	10 - 20	5,467	504	486	18	31
0.2 - 0.5	20 - 50	6,308	632	555	77	34
0.5 - 1.0	50 - 100	3,202	336	263	73	24
1.0 - 2.0	100 - 200	1,608	215	131	84	19
> 2.0	> 200	679	83	44	39	11
Totals:		86,572	7578	7244	334	

Linear no-threshold (LNT) hypothesis

- LNT hypothesis assumes all radiation doses are harmful in linear proportion to dose, down to zero dose
- The LNT theory is employed to calculate the number of “excess” cancer deaths from minute fractions of background radiation
- There is no human data to support this use
- There are many data that contradict LNT hypothesis, i.e., less cancer mortality after low radiation dose

Recent discoveries

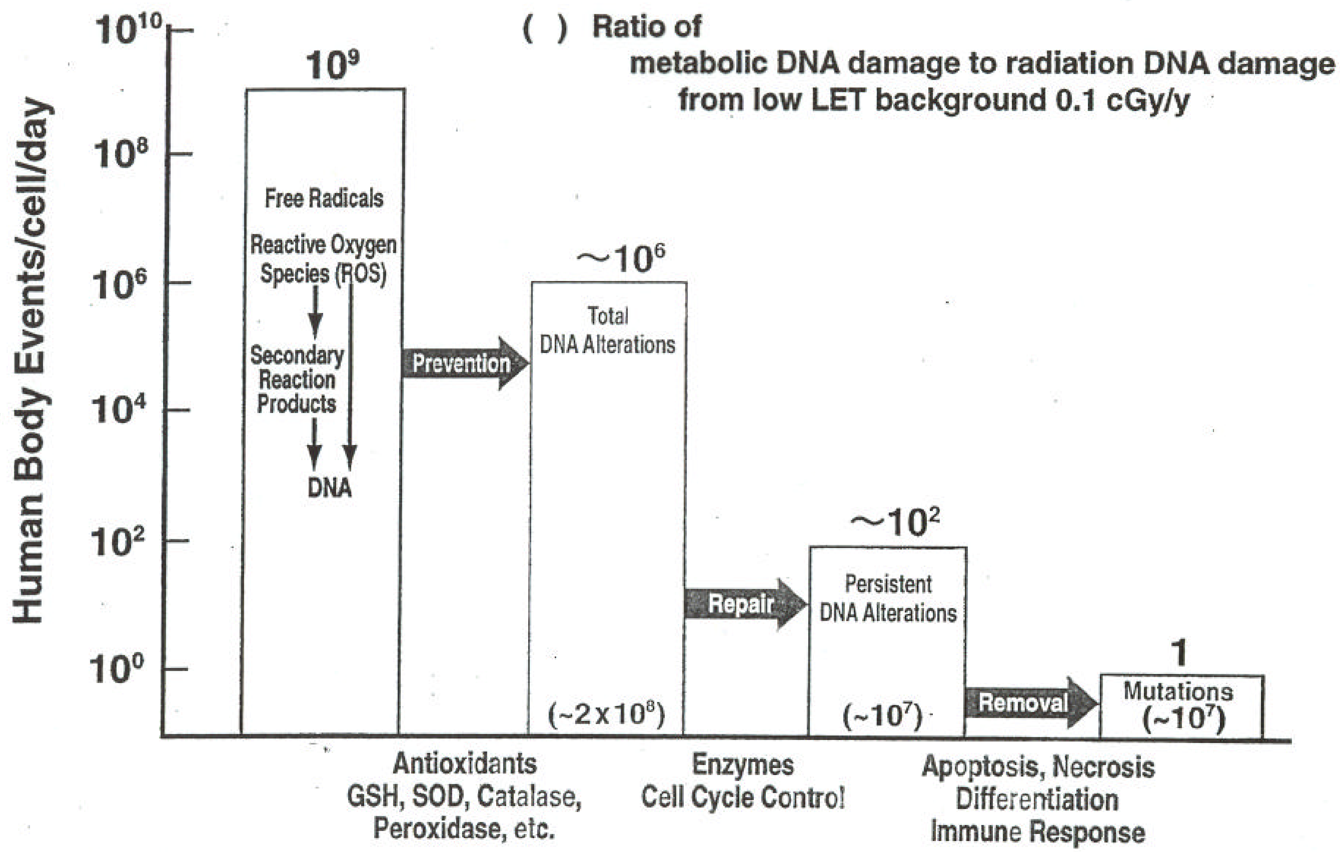
- An enormous rate of oxidative damage is occurring naturally to our cells
- Our survival until old age depends on our very capable damage control biosystem that prevents, repairs or removes almost all of the DNA alterations
- Those DNA alterations which are not eliminated by our biosystem are residual mutations
- A very small fraction of these residual mutations eventually becomes cancers as a result of creation of special genes that enable cancers to grow and spread

Radiation's direct effect on cells is negligible

- The rate of DNA mutations caused directly by background radiation is ~10 million times less than the rate caused by the natural oxidative damage
- Our common exposure to chemicals has a far greater adverse effect on cells than low-level radiation

Indirect effect is very important

- Radiation has a very significant effect on our damage-control biosystem
- High doses of radiation decrease biosystem activity, causing higher than normal cancer mortality
- Low doses of radiation stimulate biosystem activity, causing lower than normal cancer mortality
- The predictions of this hormesis model have been confirmed by many observations



The antimutagenic DNA damage-control biosystem.

Pollycove M and Feinendegen LE.

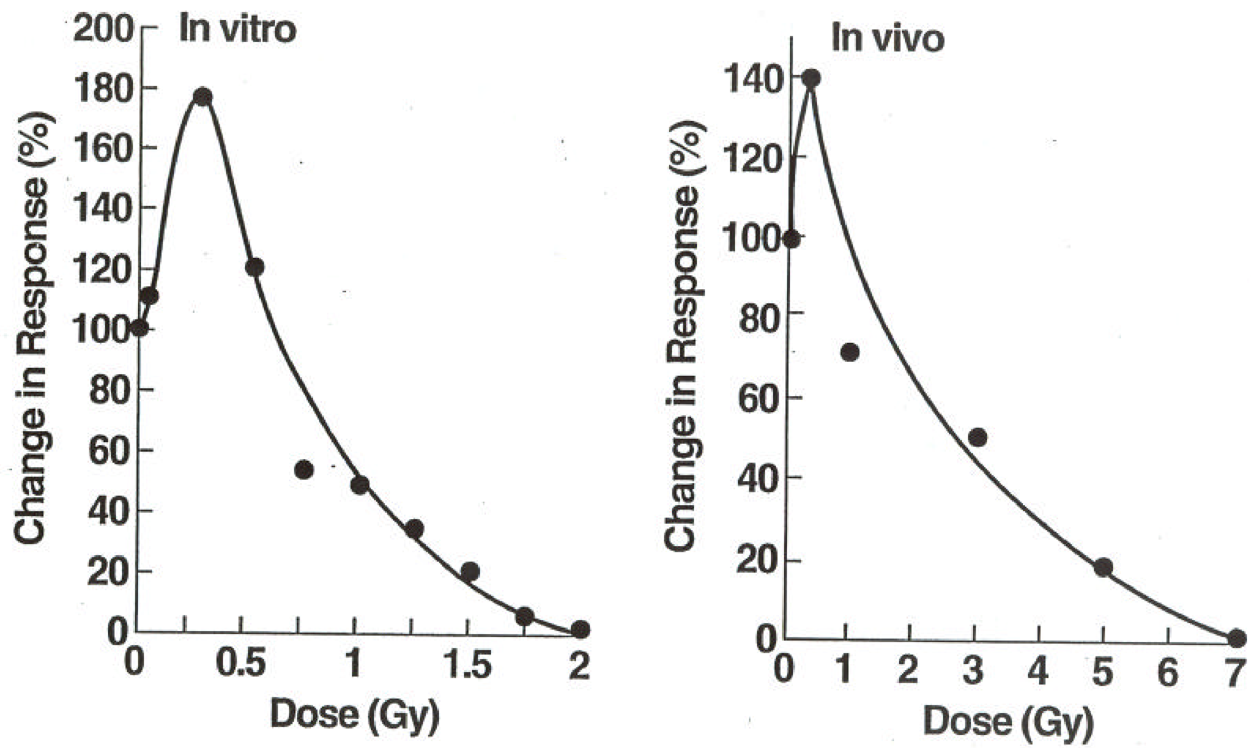


Figure 7. Immune system response to radiation. Mouse splenic cells primed with antigenic sheep red blood cells. Makinodan T, James SJ, 1990.

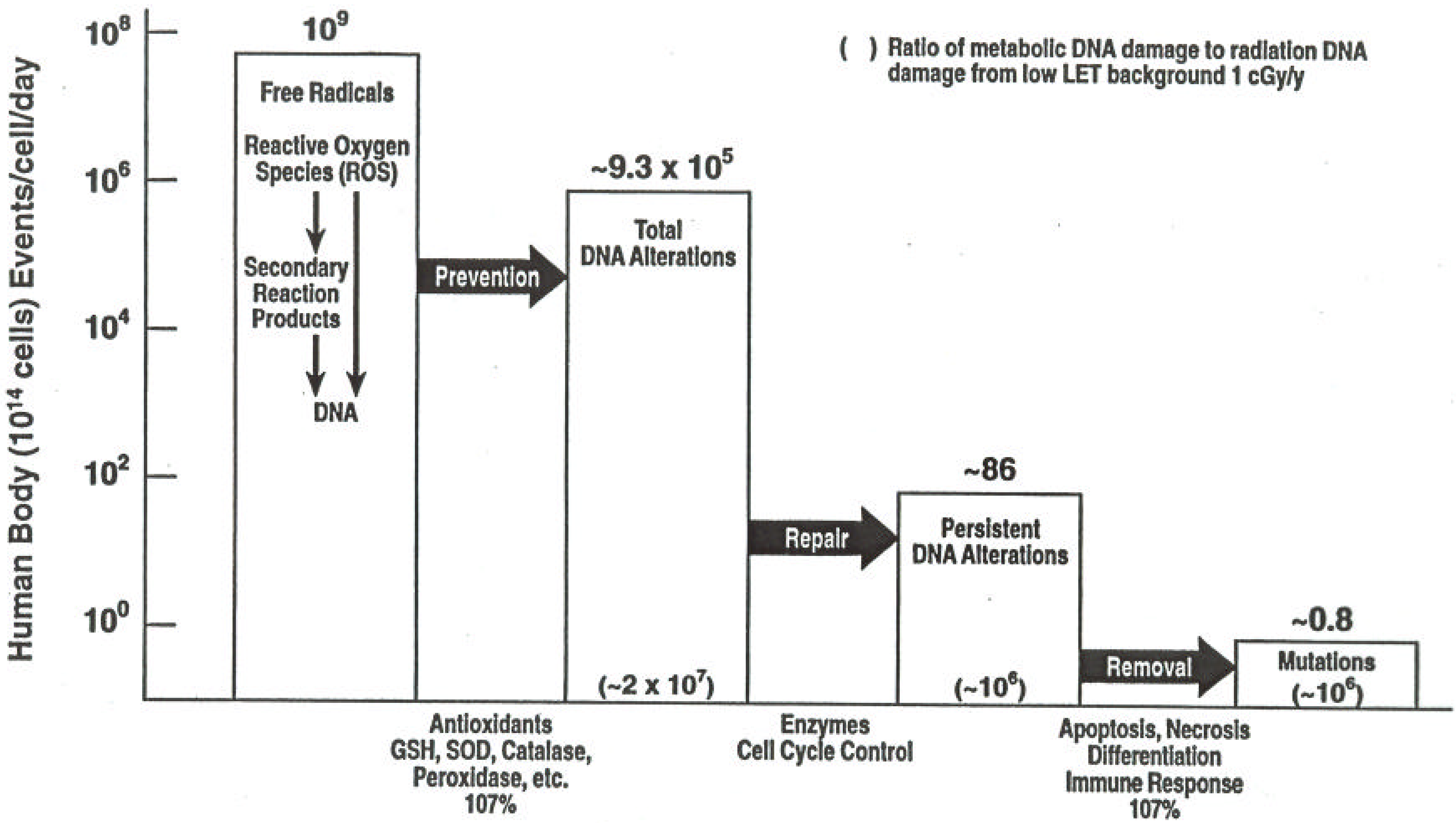


Figure 10. The antimutagenic DNA damage-control biosystem response to high background radiation = 120% Estimates based on data in literature. Pollycove M and Feinendegen LE.

Hormesis:

adaptive response of biological organisms to low levels of stress or damage, leading to a

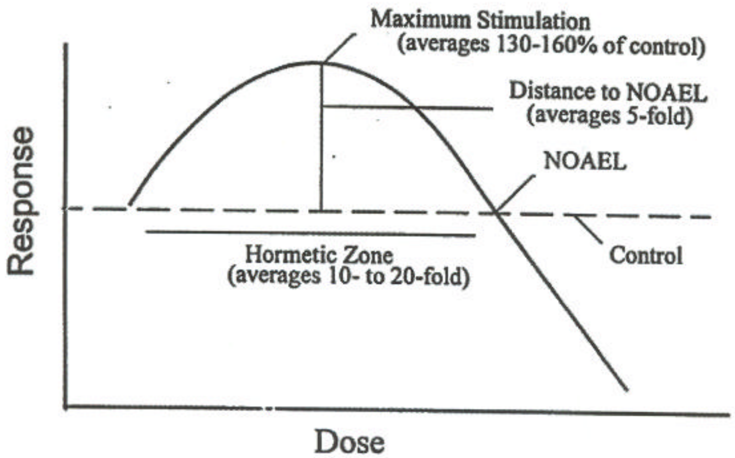
modest <u>over</u>compensation to the disruption, and

resulting in <u>improved</u> fitness

BELLE Newsletter, Vol. 8, No. 2, December 1999

RADIATION HORMESIS: Origins, History, Scientific Foundations

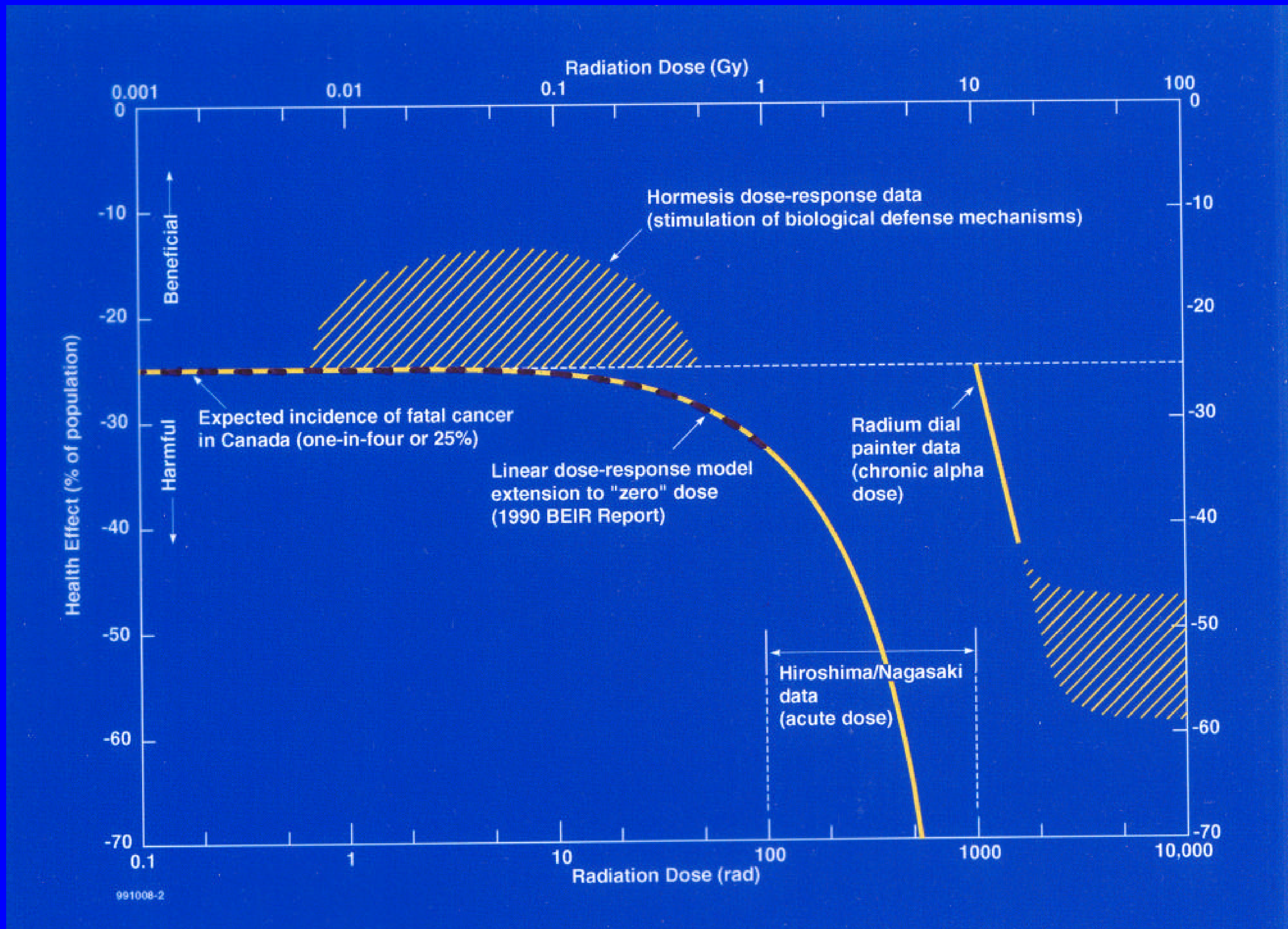
- **Radiation Hormesis: Its Historical Foundations as a Biological Hypothesis**
  Edward J. Calabrese and Linda A. Baldwin
- **Radiation Hormesis: The Demise of a Legitimate Hypothesis**
  Edward J. Calabrese and Linda A. Baldwin
- **Tales of Two Similar Hypotheses: The Rise and Fall of Chemical and Radiation Hormesis**
  Edward J. Calabrese and Linda A. Baldwin



Dose-response curve depicting characteristics of the chemical hormetic zone

Abbreviations:

NOAEL = no observed adverse effect level
LOAEL = lowest observed adverse effect level
ZEP = zero equivalent point



Radiation Dose (Gy)
0.001
0.01
0.1
1
10
100
0
-10
-20
-30
-40
-50
-60
-70
Beneficial
Harmful
Health Effect (% of population)
Hormesis dose-response data
(stimulation of biological defense mechanisms)
Expected incidence of fatal cancer
in Canada (one-in-four or 25%)
Linear dose-response model
extension to "zero" dose
(1990 BEIR Report)
Radium dial
painter data
(chronic alpha
dose)
Hiroshima/Nagasaki
data
(acute dose)
0.1
1
10
100
1000
10,000
Radiation Dose (rad)
991008-2

Lauriston S. Taylor Lectures in Radiation Protection and Measurements

Lecture No. 16

Dose and Risk in Diagnostic Radiology: How Big? How Little?

by Edward W. Webster

Presented April 1, 1992
Issued September 1, 1992

National Council on Radiation Protection and Measurements
7910 WOODMONT AVENUE/BETHESDA, MD. 20814

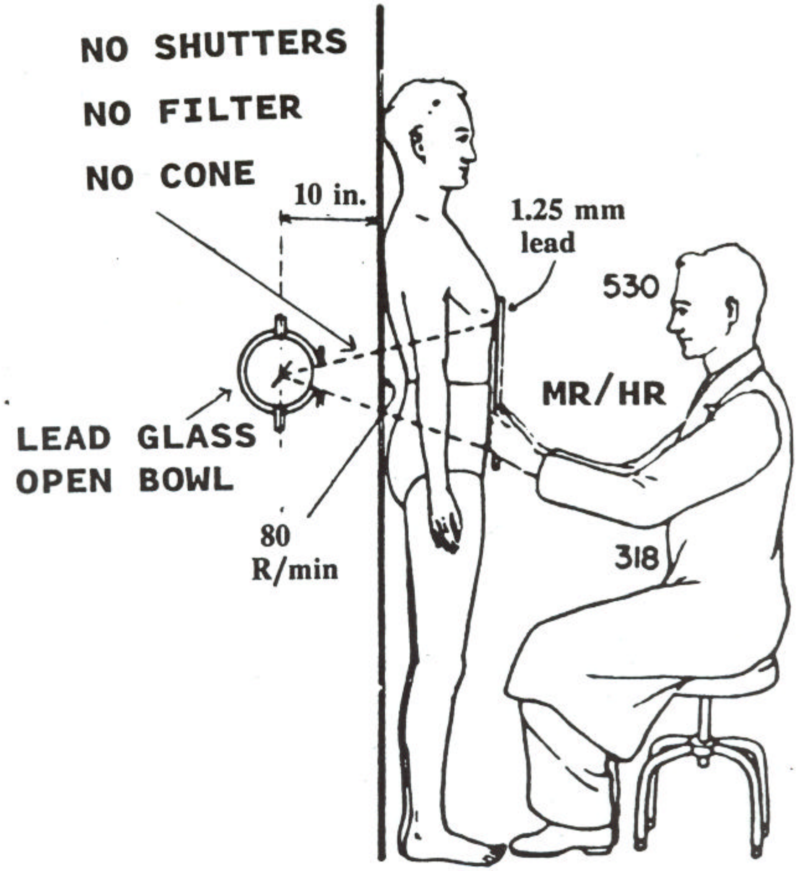


Figure 1 Exposure to patients and personnel from a non-protective fluoroscope in use circa. 1930. [Based on C. B. Braestrup in Radiation Hazard Symposium, Am. J. Roentgenol. 78 (1957) (3)].

with dose and between 0.7 and 7 per million per year per rad, with a best value of 2 per million. That estimate remains almost unchanged today, 35 years later! In 1958 A. M. Brues

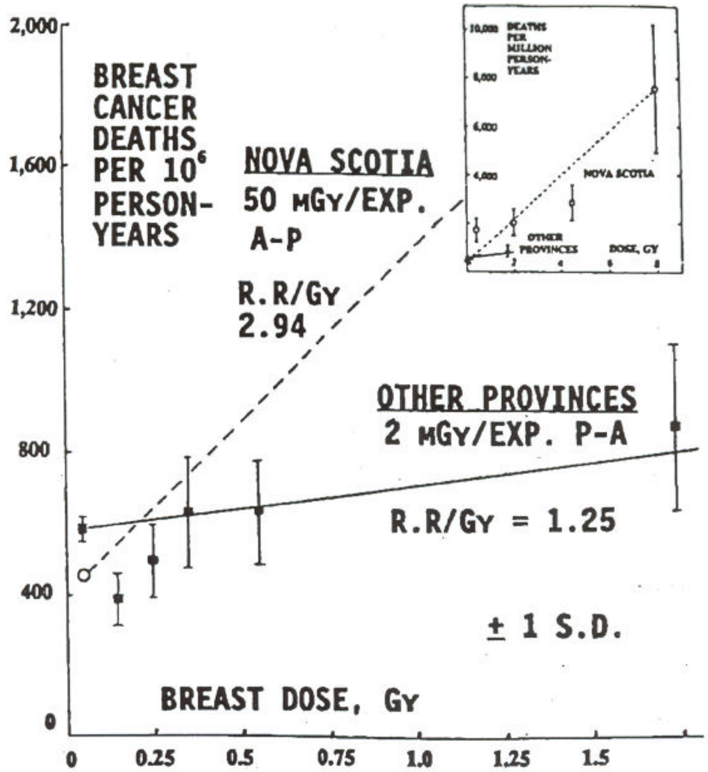


Figure 12 Dose responses in Canadian study of breast cancer mortality in women following multiple fluoroscopic chest exposures during treatment for tuberculosis. The significantly different dose response curves for women in Nova Scotia and those in the other provinces are plotted from data in Miller et al (1989) (42). The error bars show the standard deviation of the mortality rates in each dose group. [Data points for Nova Scotia are shown on a wider dose scale in the upper right insert.]

largely based on the linear dose responses and the similarity of relative risk for the A-bomb survivors with single acute dose and the Massachusetts patients (e.g. 1.9/Gy in Japan with RBE = 20, and 1.7/Gy in Massachusetts, both for mortality studies) (41,43). It is however of considerable interest

Canadian breast cancer fluoroscopy study

The authors predicted lifetime <u>excess</u> risk of death from breast cancer after a single exposure at age 30

- 60 per million women for 1 cGy (1 rad)
- 900 per million women for 15 cGy

But their data show that 15 cGy would <u>prevent</u> 7000 deaths per million women

Radiation treatment for hyperthyroidism

- University of Birmingham study of 7414 adult patients treated in Birmingham UK between 1950 and 1991
- Published in The Lancet, Vol. 353, June 19, 1999, pg 2111
- Mean cumulative dose 308 MBq of Iodine-131
- Corresponds to 50,000 rem to thyroid, 28 rem to whole body
- 638 cancers diagnosed vs 761 expected (age/sex/period)
- Standardized incidence ratio: 0.83 (95% CI: 0.77 to 0.90)
- 448 cancer deaths vs 499 expected
- Standard mortality ratio: 0.90 (95% CI: 0.92 to 0.98)
- "Decrease in overall cancer and mortality rates is reassuring"

Science vs the LNT hypothesis

"The great tragedy of science is the slaying of a beautiful hypothesis by an ugly fact."

T.H. Huxley (1825-1895)

Collected Essays 1893-1894

Biogenesis and Abiogenesis

The linear no-threshold (LNT) hypothesis of radiation carcinogenesis seems to be an important exception to this fundamental requirement of science. Why?

Intense disagreement continues among scientists and analysts regarding:

- validity of the LNT model
- reality of beneficial health effects of radiation

Controversy due to political, social, economic issues

- cloud objective research and thinking
- increase resistance to change of established paradigms

Extensive research already done over past century

- disagreement <u>not</u> resolved by more scientific data
- scientists often do <u>not</u> look for beneficial effects
- do <u>not</u> design experiments to find beneficial effects

Scientific societies now challenge LNT scare

- 1995 French Academy of Sciences
- 1996 Health Physics Society
- 1997 Council of Scientific Societies
- 1998 International Nuclear Societies Council
- 1998 U.S. Dept of Energy funds new research on health effects of low dose radiation
- 1999 American Nuclear Society

Low dose irradiation therapy – what is it?

- total or half-body irradiation (TBI or HBI) with X-rays to stimulate the patients natural defense mechanisms against diseases
- TBI or HBI increases cancer fighting activity
- 10 or 15 cGy doses @ 5 cGy/minute
- 30 cGy/week for 5 weeks = 150 cGy total
- booster therapy after 6 months, if needed

10r 3x/wk x 5 wks = 150r
15r 2x/wk x 5 wks = 150r

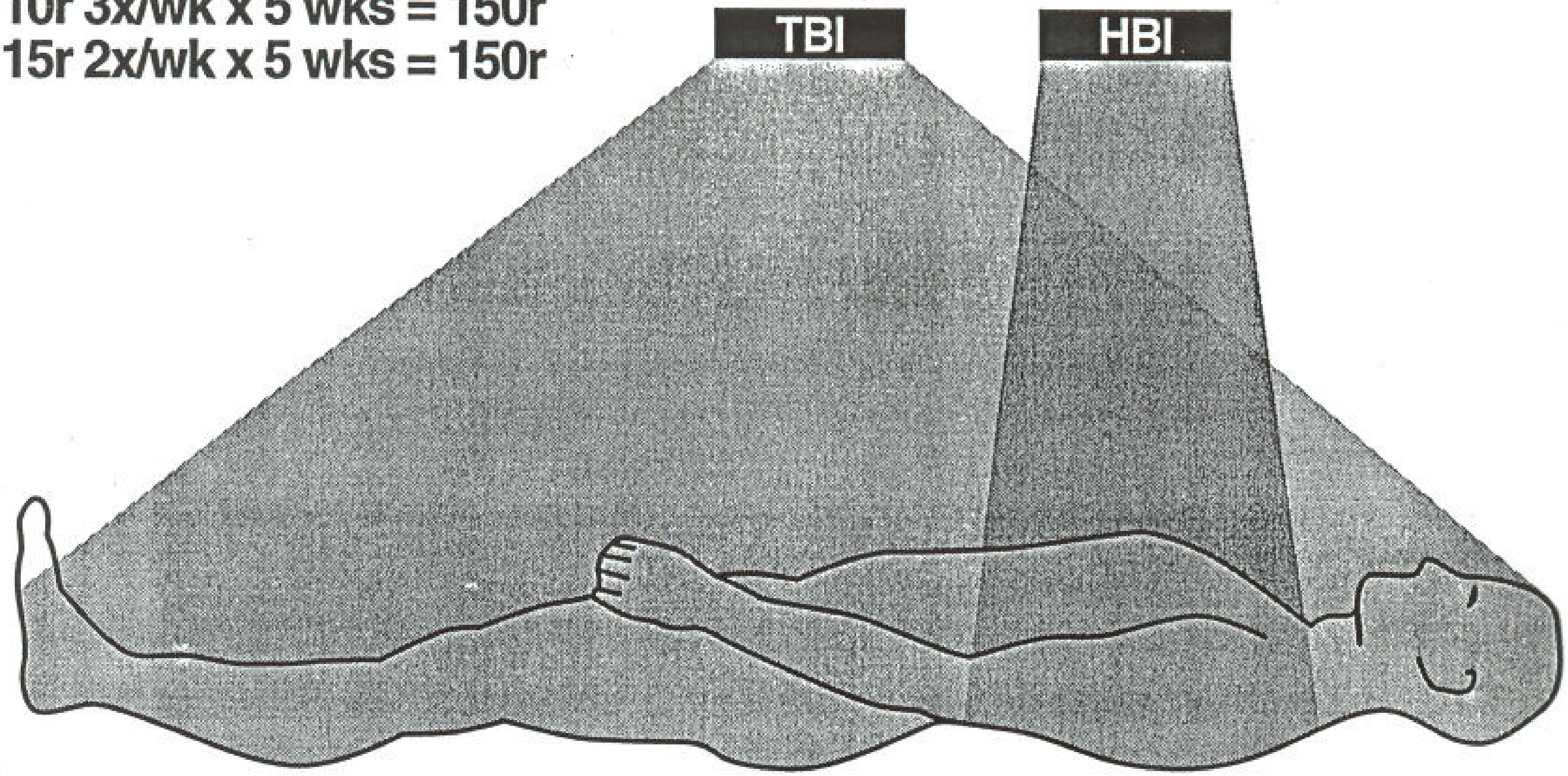


Figure 18. Treatment of patients with Non-Hodgkins Lymphoma with half (HBI) or total (TBI) body irradiation. Adapted from Sakamoto, et. al. J Jpn Soc Ther Radiol Oncol 9:161-175, 1997

Were clinical trials done on cancer?

- 1970s Harvard University for non-Hodgkins lymphoma (NHL)
- 1986-94 Institute Bergonie, France for NHL
- 1990s Tohuku University (Sakamoto) NHL
- have >20 abstracts for trials in Europe, Japan
- thousands of papers on human treatments for curing many other diseases

EORTC
European Organization for Research and Treatment of Cancer
International Association under Belgian Law

EORTC Lymphoma Cooperative Group

A phase III randomized study on low-dose total body irradiation and involved field radiotherapy in patients with localized, stages I and II, low grade non-Hodgkin's lymphoma

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Dates :

Outline approved	January 26, 1999
Current draft	13 September, 1999
Final version, PRC-NTC approval	

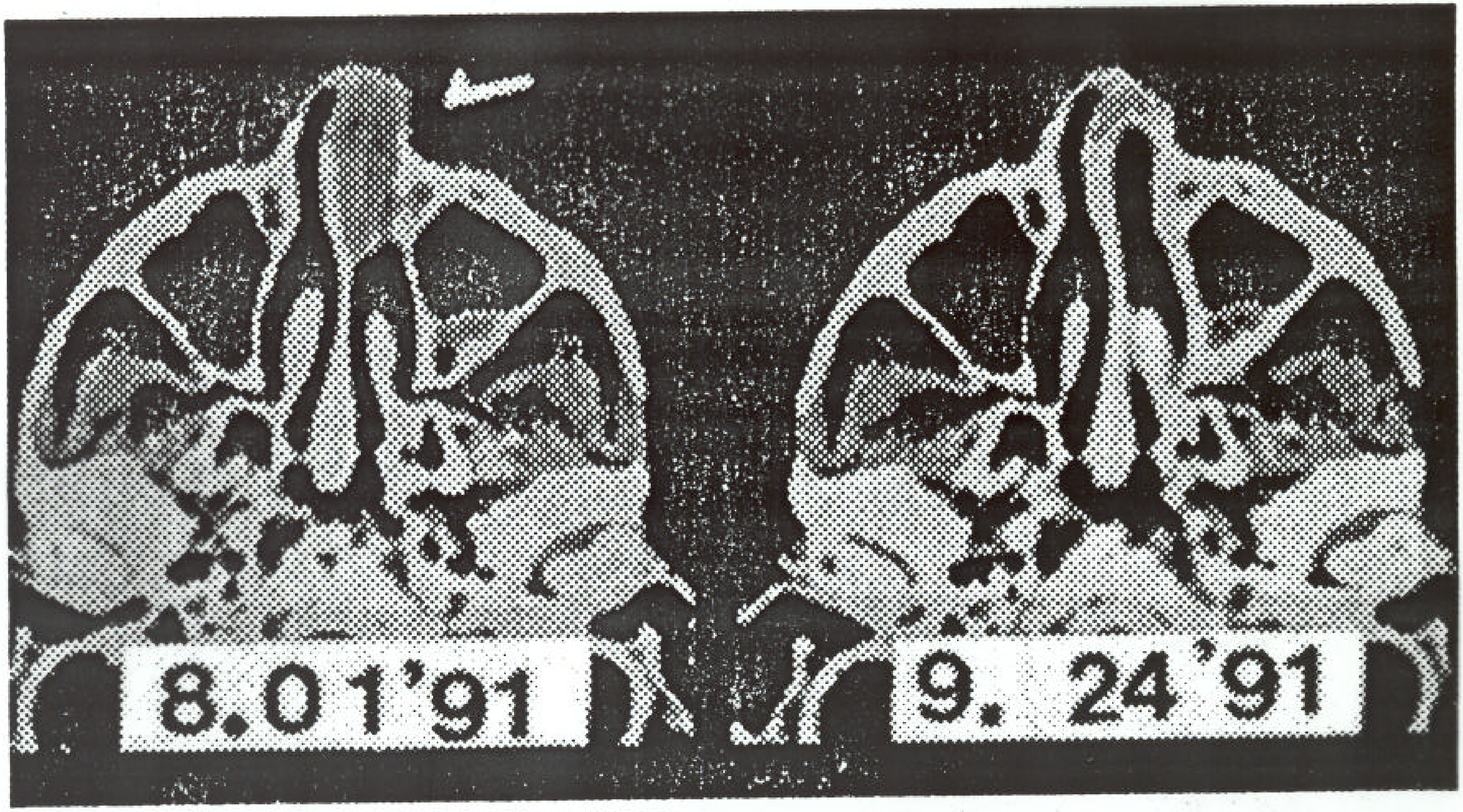
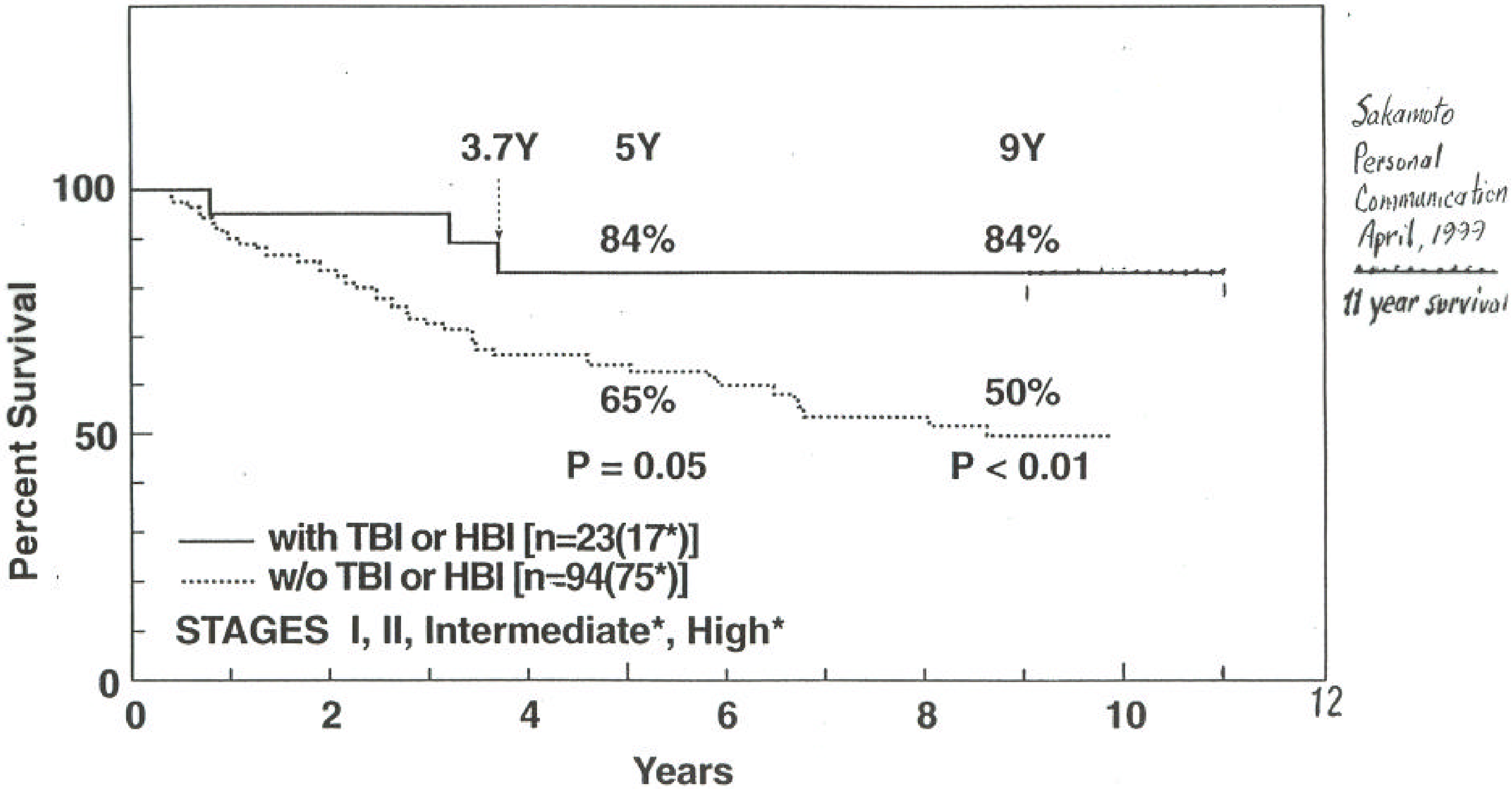


Figure 15. CT (computerized tomographic) scan of upper nasal cavity before and after half body irradiation (HBI). Nasal tumor, though outside HBI field, disappeared after low-dose HBI.
Takai et al. In: Low Dose Irradiation and Biological Defense Mechanisms (Sugahara, Sagan, Aoyama, eds). Amsterdam, Elsevier Science Publishers, 1992:115-116.

COMPARISON OF LOW-DOSE IRRADIATION OF HALF BODY (HBI) OR TOTAL BODY (TBI) OF PATIENTS WITH NON-HODGKIN'S LYMPHOMA

4 year survival: TBI-HBI 84%	Chemotherapy 66%	(79% of TBI-HBI Survival)
9 year survival: TBI-HBI 84%	Chemotherapy 50%	(60% of TBI-HBI Survival)



Patients in both groups received chemotherapy and localized tumor high-dose radiation.
Adapted from Sakamoto, et. al. J Jpn Soc Ther Radiol Oncol 9:161-175, 1997

Figure 20. Adapted from Sakamoto, et. al. J Jpn Soc Ther Radiol Oncol 9:161-175, 1997

AMERICAN, FRENCH AND JAPANESE SC

Photo courtesy of Jerry Cuttler

(From left) AECL's Jerry Cuttler is seen here with visiting professors Maurice Tubiana, French Academy of Sciences, Myron Pollycove, U.S. Nuclear Regulatory Commission, and Kiyohiko Sakamoto, director, Tohoku Radiological Science Center.

By Jerry Cuttler

Following the Canadian participation in the June conference of the World Council of Nuclear Workers (see Contact, August

The original 1965 estimate of the H-N dose included the effect of neutrons. In 1985, the dose was reestimated and the effect of neutrons

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Professeur Maurice TUBIANA
Vice-Président de l'Académie Nationale de Médecine
Membre de l'Académie des Sciences
Président du Centre Antoine Béclère
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Mr. Jerry M. Cuttler
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MT/mh

May 7, 2001

Dear Mr. Cuttler,

Thank you very much for your e-mail. I read with much interest your article. When will it be published? Is it possible to quote it?

Please find enclosed an article published in January 2000 in the journal *Radiation Environ. Biophys*. I hope that it will interest you. I have another article in preparation for the WONUC conference in June 2001 in Dublin.

It was good to hear from you. I remember with much pleasure my visit to Toronto and Ottawa.

With best wishes.

Yours sincerely,

pp Mary Hutting

Professor M. Tubiana

Encl.

Canadian Nuclear Society Bulletin, Vol. 21, No. 2, pp. 45, Aug 2000

Application of Low Doses of Radiation for Curing Cancer

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Abstract

Successful clinical trials of low dose irradiation therapy for curing cancer were carried out in the USA in the 1970s and, more recently, in Japan and France. A cure of colon cancer and a case study of the successful control of a cancer of the blood following this low-dose therapy are reported. The prompt, beneficial response of the patient's blood data to the radiation exposures supports the notion of radiation hormesis in humans. Widespread application of low dose therapy would help many cancer patients and could help to correct misconceptions and resolve the controversy about the biological effects of low doses of ionizing radiation.

LDI therapy - Johns Hopkins Medical Institute

- US Navy Captain Edward J. Bauser, age 81
- Waldenstrom's Macroglobulinemia in 1992
- Jan-Jun 98 chemo, IgM 4000 to 1600 mg/dL
- Sep-Oct 99 LDI, IgM 4000 to 1600 mg/dL
- <u>no</u> symptomatic adverse effects from LDI
- Mar 2000, IgM returned to 2800 mg/dL
- Apr-May received booster LDI therapy

Table 1. Diagnostic data regarding treatment of Edward J. Bauser for Waldenstrom's Macroglobulinemia[8]

Date	IgM mg/dL	PVIS Plasma viscosity	PLTS Platelet count x1000/mL	HgB Hemo-globin g/dL	T Help cells/mm^3	TH/TS Ratio of helper to suppresser	CD4 cells/mm^3	NK Natural killer cells per mm^3	WBC White blood cells per mm^3	RBC Red blood cells x10^6 per mm^3	PCV packed cell volume	Spleen volume cm^3
Normal	40-300	1	100-400	14-17	variable	changes in life		changes in life	4k to 10k			
Chemo												
1998 Jan	4080	3.3	300	9.9								
1998 Jun	1605	1.8	100	12.4								
TBI												
1999 Aug 31	4170		335	11.1	43.1	1.32	637 43.0		7680	3.75	34.1	
1999 Sep 07	3870	2.9										100.4
1999 Sep 16			301	10.8	48.3	1.43	659 48.3	16	7050	3.63	32.6	
1999 Sep 23	4040	3.1	301	11.2	54.5	1.67	808 54.5	14	5280	3.74	33.7	
1999 Sep 30			199	10.8	52.6	1.62	745 52.6		5450	3.59	32.8	
1999 Oct 07			95	10.8	54.1	1.71	589 ----		3600	3.61		
1999 Oct 11	2530	2.2	74	10.8	55.9	1.65	654 55.9	9	3930	3.53	32.5	72.4
1999 Oct 19	1770	1.9	73	11.1					2200	3.47		
1999 Oct 27			69	10.9					2200	3.41		
1999 Nov 03	1630	1.8	134	11.9					2500	3.57		
1999 Nov 10			174	10.6					2600	3.11		
1999 Nov 17			171	10.9					3600	3.33		
1999 Nov 18			178	11.4					3600	3.38		
1999 Dec 01	1794		266	12.1					5400	3.61		
1999 Dec 31	2420		211	12.9					4800	3.88		
2000 Jan 28	2540	1.7	228	12.4					5400	3.81		
2000 Mar 06	2760	1.9										

Apr 5, 2000, L to R: Cuttler JM, AECL; Bauser EJ, US Navy (ret); Pollycove M, US NRC; Hattori S, CRIEPI

Japanese research – health effects of LDI

Central Research Institute Electric Power Industry

- organized hormesis research steering committee
- involved 14 universities, 2 research institutes
- found extraordinary biopositive effects:

  -cell rejuvenation

  -psychological stress moderation by enzyme stimulation

  -suppression/therapy of adult diseases: diabetes, hypertension .. .

  -cancer suppression by immune system enhancement

  -cancer suppression by activation of DNA repair, cell killing

- difficulty communicating discoveries to world

Cooperation between Japan and Canada?

- Central Research Institute of Electric Power Institute of Japan urged University of Ottawa to review, duplicate and extend the Japanese studies in Canada
- International Centre for Low Dose Radiation Research at University of Ottawa tried to organize:
  - -attachment of Japanese scientists in Canada
  - -participation of Chalk River Laboratories
  - -hospitals in Ottawa
  - -hospitals in Toronto
- Japanese were keen, but there is no interest in Canada

Nuclear Shipyard Worker Study (NSWS)

- Best epidemiological study of radiation workers
- \$10 M study funded by US Department of Energy
- Excellent peer review during 1980-88 study
- Technical Advisory Panel of 8 scientists, expert in: radiation biology, radiation physics, medicine, genetics, industrial hygiene, epidemiology, biostatistics
- Beneficial results of NSWS were intentionally <u>ignored</u>
- 28,000 workers received Co-60 gamma ray exposure
- 32,500 other workers received no or negligible exposure
- Study compared workers in both groups: same jobs, ages
- Average exposure of nuclear workers ~5x background
- Nuclear worker death rate from <u>all</u> causes 24% <u>lower</u>
- This is 16 standard deviations ($p < 10^{-16}$) lower
- This statistical power, <u>no doubt</u> low dose is beneficial
- Surprising result was <u>not</u> mentioned in report narrative
- Cancer mortality 4 standard deviations lower ($p < 10^{-3}$)
- There are no other studies that contradict this study
- Reference is: Matanoski G, ***Health effects of low-level radiation in shipyard workers, final report***. 471 pages, Baltimore MD, DOE DE-AC02-79 EV 10095 (1991) – and it was <u>never</u> published in a scientific journal

Twelve-Year Review of X-Ray Therapy of Gas Gangrene[1]

JAMES F. KELLY, M.D., F.A.C.R., and D. ARNOLD DOWELL, M.D.

Omaha, Nebraska

THE FIRST REPORT on the x-ray treatment of gas gangrene was made in December 1931, before the Radiological Society of North America at the Seventeenth Annual Meeting in St. Louis (1). The mortality rate for gas gangrene up to that time had been 50 per cent or higher and that figure was attained only by the sacrifice of many arms and legs. The mortality rate in the group of 8 cases then reported was 25 per cent, and no additional tissue was removed in any case after x-ray therapy was begun.

The technic used in the 6 cases involving the extremities was described and was considered adequate, but the 2 patients with involvement of the trunk died, and for the a disease as gas gangrene with its former high mortality and morbidity. The x-ray, however, has definitely removed gas gangrene from that group of diseases in which experimental therapy is any longer justifiable.

Chemotherapy has failed in our vicinity and also in other places, as was to be expected, since in a well developed case of gas gangrene there is definite interference in the circulation to the infected area and consequently in the most serious cases the chemical fails to reach the diseased tissues. The x-ray, however, has no difficulty in effectively reaching all cells and fluids in any infected area. Other ways of treating gas gangrene may be developed but there lected from the literature. It is a satisfaction to realize that we have not been misleading in our claims and that the method has in most instances been successful in other hands. It is noteworthy, also, that those cases which have been included in our statistics on clinical evidence only show a much higher mortality rate (twice as great) than cases in which *Cl. welchii* was demonstrated in the laboratory. In that in the group analyzed the error in diagnosis should not exceed 2 per cent, and we hope that it is even less. The cases reported in the literature we have accepted as given.

Anyone with clinical experience in the management of gas gangrene appreciates that the diagnosis depends on several factors, no one of which may be considered as final in the early or doubtful stages of the

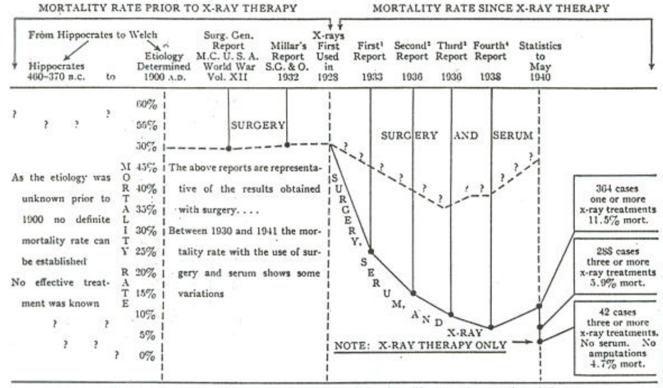


Fig. 1. End of gas gangrene as a serious infection (if x-ray therapy is used).

From Hippocrates' time (460–370 B.C.) to 1900 A.D. the etiology of gas bacillus infection was unknown and as a result the mortality rate during that period cannot be accurately determined. Between 1900 and 1928 the mortality rate was 50%. Since 1928, the mortality has been reduced to 5% by the use of x-ray therapy without serum or radical surgical measures. X-ray therapy will prevent or cure the disease. The broken perpendicular lines separate the three periods.

[1] Kelly, J. F.: Radiology 20: 296–304, April 1933.
[2] Kelly, J. F.: Radiology 26: 41–44, January 1936.
[3] Kelly, J. F., and Dowell, D A.: J. A. M. A. 107: 1114–1118, Oct. 3, 1936.
[4] Kelly, J. F., Dowell, D. A., *et al.*: Radiology 31: 608–619, November 1938.

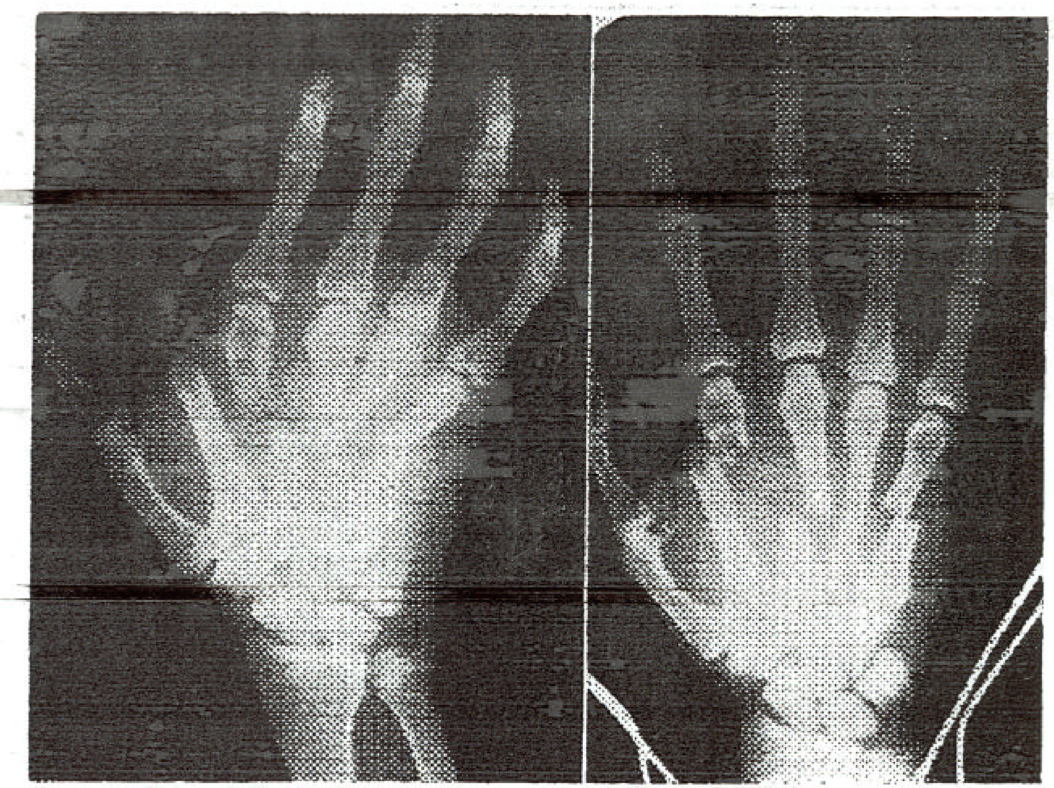
other words, the inclusion of cases with questionable diagnoses has raised rather than lowered our mortality rate.

We have included no case in our statistics which did not have evidence of toxemia, nor have we excluded any in which death occurred because there was a plausible pretext by which it might be rejected. Errors through rejection of true gas bacillus infections which showed no evidence of toxemia because of early x-ray treatment may have occurred, but we believe disease, which is the most important time for the diagnosis to be made.

The consistency of the mortality figures in the foregoing analysis is maintained in figures relative to other important data, and the present study will serve to verify the general trend of our previous reports.

REPORTS IN THE LITERATURE

All reports on the roentgen treatment of gas gangrene that have appeared thus far in the literature have been favorable



Figs. 7–8. Case 1: Severe hand injury, with multiple compound fractures and some gas in tissues (left). Fig. 8 (right) shows same hand a few days after prophylactic x-ray irradiation: no gas in the tissues, no infection, hand on way to complete recovery.

TABLE V: CASES WHICH RECEIVED PROPHYLACTIC IRRADIATION AND HAVE BEEN REPORTED IN THE LITERATURE

Cases Which

those which do not appear until three or four days have elapsed. It is evident from Figure 6 that the second, third, and

Is there a need for LDI therapy?

- > 25% of Canadians die of cancer - all types
- This dreaded disease is not well understood
- Intensive research underway to determine the causes and to find better cures/therapies
- The currently “accepted” therapies:

  -surgery (local)

  -high-dose irradiation (local)

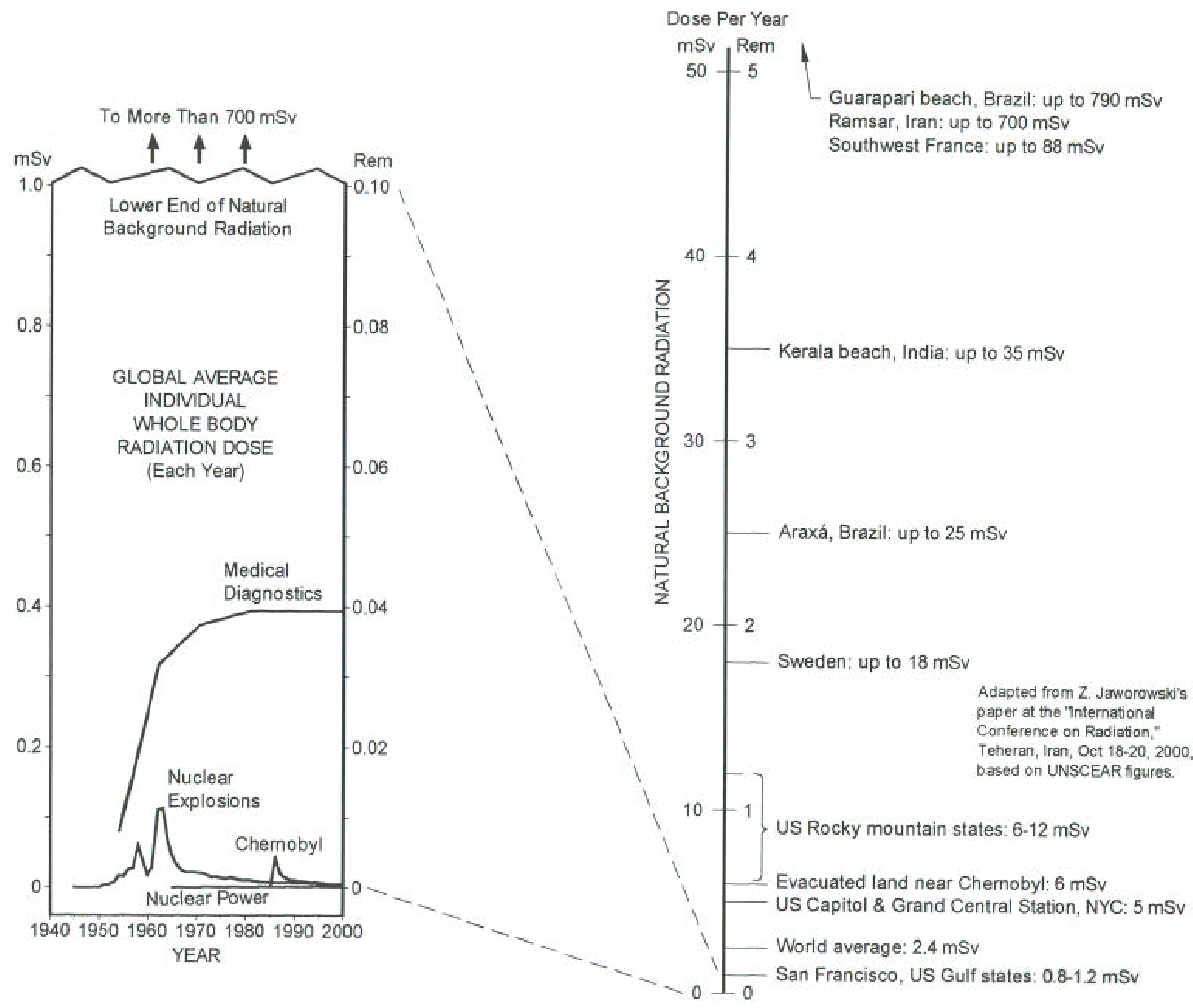
  -chemotherapy (distributed, harsh side-effects)

Cancer patients and other terminal patients

- should have a life-or-death interest in this controversy over beneficial effects.
- Low-dose radiation therapy to stimulate defense mechanisms would:
  - cure certain types of cancer (e.g. NHL)
  - extend lifespan without symptomatic side-effects
  - treat diabetes and other adult diseases.
- Such patients would insist on this therapy, if physicians would only agree to provide it.

Concerns?

- LDI therapy is not widely accepted because
  - physicians lack knowledge about LDI therapy
  - anti-nuclear political activity
  - myth that any amount of radiation causes cancer
- But cancer patients already have cancer!
- They have little to lose from LDI therapy.
- High dose radiation (200 cGy) is permitted!


To More Than 700 mSv
mSv
Rem
1.0
0.10
Lower End of Natural Background Radiation
0.8
0.08
GLOBAL AVERAGE INDIVIDUAL WHOLE BODY RADIATION DOSE (Each Year)
0.6
0.06
Medical Diagnostics
0.4
0.04
0.2
0.02
Nuclear Explosions
Chernobyl
0
0
Nuclear Power
1940 1950 1960 1970 1980 1990 2000
YEAR
Dose Per Year
mSv
Rem
50 5
40 4
30 3
20 2
10 1
0 0
NATURAL BACKGROUND RADIATION
Guarapari beach, Brazil: up to 790 mSv
Ramsar, Iran: up to 700 mSv
Southwest France: up to 88 mSv
Kerala beach, India: up to 35 mSv
Araxá, Brazil: up to 25 mSv
Sweden: up to 18 mSv
Adapted from Z. Jaworowski's paper at the "International Conference on Radiation," Teheran, Iran, Oct 18-20, 2000, based on UNSCEAR figures.
US Rocky mountain states: 6-12 mSv
Evacuated land near Chernobyl: 6 mSv
US Capitol & Grand Central Station, NYC: 5 mSv
World average: 2.4 mSv
San Francisco, US Gulf states: 0.8-1.2 mSv

Recognize public fear of nuclear radiation

- One in four die of cancer
- People want cures for cancer
- People want to know the causes
- People know almost nothing about nuclear radiation
- People believe radiation in any amount causes cancer
- Result of our continued use of LNT model

Gunnar Walinder:

- The LNT hypothesis is a primitive, unscientific idea that cannot be justified by current scientific understanding.
- As practiced by the modern radiation protection community, the LNT hypothesis is one of the greatest scientific scandals of our time.