

EDITORIAL

An oral radiology perspective of the recent joint ANS—HPS low dose radiation conference



PURPOSE OF THE CONFERENCE

Because we oral and maxillofacial radiologists generally live in a low-dose radiation (LDR) world, I attended the conference to learn more about current research on LDR. Some of the highlights from the meeting are provided below.

The purpose of the conference was to review the status of LDR research and to determine whether the linear non-threshold (LNT) theory of radiation protection remains the best choice for radiation protection and safety today. The conference format was modeled after the 1997 Wingspread Conference, held in Racine, Wisconsin which was the last major scientific meeting to specifically address conflicting views of the health risks of LDR.¹ The main objective of the conference was to determine whether it is possible to know the mechanistic events occurring at the cellular level in the human body during LDR exposure. Furthermore, if the answer is not known, then how do we learn the truth regarding the changes, on a cellular level, during LDR exposure events? As defined by the National Council on Radiation Protection and Measurements (NCRP) Commentary 27 e, LDR is <100 mGy delivered acutely, and a low absorbed-dose rate is <5 mGy h⁻¹.²

One of the primary conference organizers was Antone “Tony” L. Brooks, PhD. Tony is professor emeritus at Washington State University and the author of *Low Dose Radiation: The History of The U.S. Department of Energy Research Program*, published in 2018.³ This book begins with a short autobiography, in which Tony gives the reason for his love of radiation biology—he grew up downwind from the Nevada test sites during active testing for the Manhattan Project. Tony was also the Director of the Department of Energy’s LDR research program from 1998 until 2008. *Low Dose Radiation* provides an excellent review of the state of the science on LDR.

THREE LINES OF EVIDENCE

The presenters who discussed their research findings over the first 2 days of the conference focused mainly on 3 scientific lines of evidence: LNT, hormesis, and threshold, in that order. Dr. David Brenner discussed research

pertaining to the LNT theory. His laboratory’s epidemiologic research supports the LNT theory; however, when measuring the effects of doses in the range of 1 to 5 mSv on the human body, a major confounding problem is the background 40% rate of cancer in the human population. This background cancer rate introduces noise; therefore, he recommended that research begin at radiation doses of 50 to 100 mSv. In summary, Brenner stated, “There seems to be a consensus that LNT does not explain the biology of what happens at the cellular level.”

Dr. Roy Shore was the chair of the committee that drafted NCRP Commentary 27 e, which is the latest update to NCRP Report #136, “Evaluation of the Linear Non-Threshold Dose Response Model for Ionizing Radiation,” published in 2001.^{2,4} He reported that the committee reviewed 29 studies and concluded that for LDR, there is a reasonable consistency with LNT for total solid cancer and evidence of risk for leukemia. However, the data are not precise enough to exclude models that have a dose–response threshold. Perhaps, doses with a dose- and dose rate effectiveness factor >1 would more closely follow the LNT model. Finally, this NCRP Committee endorsed that the LNT model is prudent and practical for radiation protection purposes.

Dr. Kathryn Higley of Oregon State University presented an excellent overview of radiation protection, providing the context for the effects of background radiation, human doses over the past 100+ years, and the response of governmental regulatory agencies in supplying guidance on radiation protection. [Figure 1](#) shows the relationship between the 100 mSv radiation dose level and its effects. Doses below 100 mSv tend to cause effects that are estimations, whereas doses above 100 mSv cause effects that are observed. [Figure 2](#) has letters representing studies that provide evidence to illustrate the estimated versus observed relationship of radiation dose. [Table I](#) correlates the letters with the studies.

Many researchers supported the hormesis theory of radiation and the radiation protection models that utilize a threshold dose of radiation, below which there are no recognized ill health effects. Dr. Mohan Doss presented a review of the Biologic Effects of Ionizing Radiation VII recommendations, along with research updates that highlighted some of the assumptions made by the Biologic Effects of Ionizing Radiation VII committee. These included evaluating the effect that the systematic bias of cigarette smoking by nuclear industry workers had on the International Nuclear Workers

The American Nuclear Society (ANS) and the Health Physics Society (HPS) co-sponsored the Low Dose Radiation 2018 Conference: Applicability of Radiation-Response Models to Low Dose Protection Standards, which was held from September 30 to October 3, 2018, near the Hanford Nuclear site in Pasco, Washington, USA.

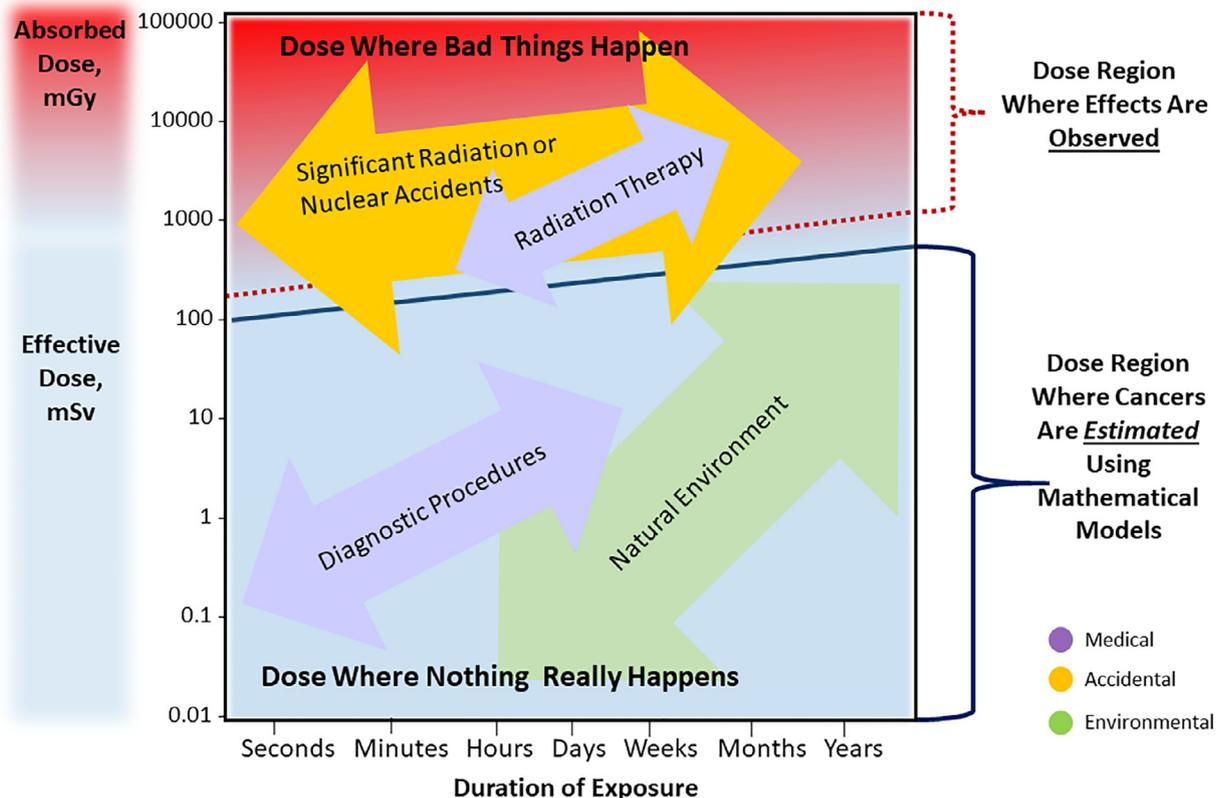


Fig. 1. This graph illustrates the relationship of estimated versus observed radiation effects. The 100 mSv dose level appears to be a significant radiation dose in the relationship of estimated versus observed effects. (Courtesy of Kathryn Higley, PhD, Oregon State University.)

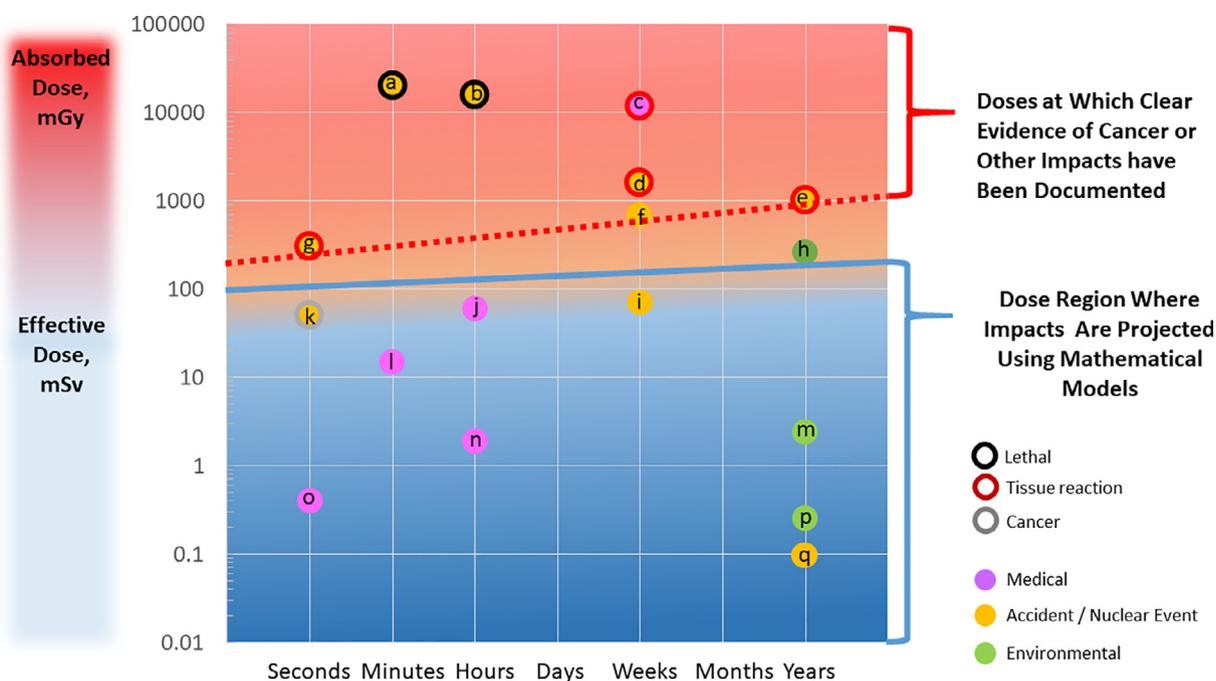


Fig. 2. These letters refer to scientific studies supporting radiation effects described in Figure 1 and as listed in Table I. (Courtesy of Kathryn Higley, PhD, Oregon State University.)

Table 1. Evidence for estimated versus observed effects of radiation with the 100 mSv dose as the differentiating radiation level*

	Category	Effective or absorbed dose (exposure duration)	Circumstances	Documented health impact
a	Accidental	20 Gy (hours)	Tokai-mura criticality (Hayata et al., 2001)	Lethal
b	Accidental	16 Gy (hours)	Chernobyl worker dose (UNSCEAR, 2000)	Lethal
c	Medical	12 Gy (weeks)	Total body irradiation (Oncology, 1999)	Immune suppression
d	Accidental	1600 mSv (weeks)	Maximum infant dose to Chernobyl evacuees (Proehl et al., 2002; Balanov et al., 2007)	Functional thyroid changes and thyroid cancer
e	Accidental	1 Gy (years)	Mayak & Techa River chronic exposure (Standing et al., 2009)	Hematopoietic impairment
f	Accidental	670 mSv (weeks)	Fukushima highest worker dose (WHO, 2013)	None observed
g	Accidental	300 mGy (seconds)	Hiroshima fetal dose (Otake, 1996)	Mental deficit
h	Environmental	260 mSv (years)	Ramsar, Iran (Aliyu and Ramli, 2015)	Unclear
i	Accidental	70 mSv (weeks)	Fukushima evacuees (WHO, 2013)	None observed
j	Medical	60 mSv (hours)	Pelvic vein embolization (Mettler et al., 2008)	None observed
k	Accidental	0.005–0.1 mSv (seconds)	Hiroshima/Nagasaki solid cancer risk estimate, life span study	Risk estimated for cohort
l	Medical	15 mSv (minutes–hours)	CT scan for pulmonary embolism (Mettler et al., 2008)	None observed
m	Environmental	2.4 mSv (years)	Global average natural background (UNSCEAR)	None observed
n	Medical	1.9 mSv (hours)	Thyroid scan 99 mTc (Mettler et al., 2008)	None observed
o	Medical	0.4 (seconds)	Mammogram (Mettler et al., 2008)	None detected; risk estimated
p	Environmental	0.25 mSv (years)	Po-210 dose from consumption of shellfish (Alam, 2011; Pentreath and Allington, 1988)	None detected; risk estimated
q	Accidental	<0.1 mSv (years)	Dietary intake from Fukushima (Harada et al., 2013)	None observed

*These studies correspond to the letters in Figure 2.

UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation; WHO, World Health Organization; CT, computed tomography. Courtesy of Kathryn Higley, PhD, Oregon State University.

study, which was one of the supporting studies for the continued use of the LNT guideline.^{5,6} In addition, Dr. Doss noted that in the low-dose (0.2–0.7 Gy) area of the dose curve for the atomic bomb survivors Life Span Study, the curve appears flat and does not fit the LNT graph.^{7,8}

EFFECTS OF HYDROGEN PEROXIDE

Dr. Helmut Sies presented his research on hydrogen peroxide (H₂O₂), showing that at physiologic levels, H₂O₂ provides enhanced cellular operations—a state of *eustress*. If H₂O₂ is allowed to increase to intracellular concentration levels in excess of approximately 0.1 μM, the cell is considered to be in a state of *distress*.⁹ At radiation levels of 100 mGy and lower, the intracellular level of H₂O₂ remains less than 0.1 μM, which means that the cell is in a state of physiologic *eustress*. Conversely, at radiation levels greater than 100 mGy, the cell is in a state of physiologic *distress*.¹⁰ These findings indicate the need for further study, particularly in the area of how H₂O₂ concentration levels available for oxidation reactions at radiation levels below 100 mGy may affect cellular damage.

MEDICAL DIAGNOSTIC RADIATION AND COMPUTED TOMOGRAPHY

Dr. Cynthia McCullough, a medical physicist from the Mayo Clinic in Rochester, Minnesota, presented the

benefits of medical imaging, specifically focusing on computed tomography (CT). She stated that with proper use, medical imaging (including CT) is safe when justified, optimized, and the “as low as reasonably achievable” principle is followed. One of her take-home messages was that medical imaging needs to find someone or some organization that can act as a third-party advocate for the responsible use of ionizing radiation for diagnostic purposes. This would ensure that the radiology community does not appear to be self-serving.

VALUE OF HUMAN LIFE

Dr. Jim Conca gave a presentation on the value of human life correlated with radiation levels during nuclear site mitigation. He began his presentation by discussing populations that live in areas with high levels of background radiation but do not experience increased cancer rates. This fact contradicts the LNT theory, which states that any increase in the level of radiation will lead to an associated increase in cancer rates.

Conca proceeded to discuss the complex decision-making process to mitigate 21 nuclear sites to emitted radiation levels of a public dose of 1 mSv of radiation per year or less, taking into consideration the 4 lives lost during mitigation efforts. What level is appropriate? Should the public level remain at 1 mSv per year, be increased to 5 mSv per year, or even be increased to the 1934 International Commission on Radiologic

Protection (ICRP) level of 6 mGy per month? What effect would these various radiation safety levels have in terms of human lives lost during mitigation of nuclear sites?

FINAL TOPICS

Speakers on the last day of the conference discussed future plans for radiation safety and the complexities of communicating the risks of radiation and radiation safety to the public. The nuclear accident in Fukushima, Japan, in March 2011 was used as an example. Representatives from the ICRP and the Fukushima community gave first-person presentations on lessons learned. One of the greatest lessons is that there is a gap between what radiation scientists present as risk and how the community perceives radiation risk. This gap in understanding is worsened by feelings of lack of control, understanding, and trust. Earning trust from the public is a 2-way street for the radiation science community, which needs to develop a sense of respect for the culture and emotional needs of the community in which it operates. The conference also reviewed radiation effects in space and the effects of radiation on passengers during airline travel.

HOW DO ORAL AND MAXILLOFACIAL RADIOLOGISTS PROCEED?

Chris Clement, Scientific Officer of the ICRP, stated that one of ICRP's main roles is to protect people—the public as well as radiation workers. Regarding that role, Chris presented the following:

- LNT is not promoted as a precise biologic model to describe dose response and should *not* be used as an assumption in scientific studies on low-dose/low-dose rate response. LNT should be used “as a prudent basis for radiologic protection at low doses and low-dose rates” and is a simplification for protection purposes.
- In the short term, do not expect any changes in current radiation protection and safety guidelines and regulations. For the future, we will likely experience changes—although exactly when those changes will occur and what they will be are still to be determined.
- For the time being, we will continue to use the LNT model as the basis for international, federal, and state regulations. Will the ICRP and the NCRP adopt a “safe” threshold dose of radiation, perhaps in the 10 to 20 mSv range? Possibly. In the 100 mSv range? Maybe, but a threshold dose at this level will likely meet with resistance.
- If a threshold dose is adopted, when will it occur? New guidelines will likely take, at a minimum, 5 to 10 years to adopt. Benchtop scientific research needs to be planned, budgeted, accomplished, evaluated, and incorporated into scientific agencies, such as the ICRP,

the NCRP, the Department of Energy, the International Atomic Energy Agency, and others before being adopted by national and state regulatory agencies.

FINAL MESSAGE

Radiobiologists are investigating the entire area of LDR in search of new research-based models to update radiation safety and protection guidelines. Until new guidelines are issued, continue using proven radiation hygiene principles such as collimation, optimization, and justification. Keep using your lead aprons, if appropriate, in your locale. Follow guidelines and regulations provided by your state boards of radiation protection. LDR is an everyday reality in our professional world. Stay attuned to the research in this area, and keep abreast of the ongoing changes that affect our profession and our patients.

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REFERENCES

1. McClellan RO, Apple MA. Creating a strategy for science-based national policy: Addressing conflicting views on the health risk of low-level ionizing radiation. Final report, Wingspread Conference. United States. doi:10.2172/755413. <https://www.osti.gov/servlets/purl/755413>. Accessed July 23, 2019.
2. National Council on Radiation Protection and Measurements. *NCRP Commentary 27 e: Implications of Recent Epidemiologic Studies for the Linear Non-Threshold Model and Radiation Protection*. Bethesda, MD: NCRP; 2018:210.
3. Brooks AL. *Low Dose Radiation: The History of the U.S. Department of Energy Low Dose Radiation Research Program*. Pullman, WA: Washington State University Press; 2018.
4. National Council on Radiation Protection and Measurements. *NCRP Report #136: Evaluation of the Linear Non-Threshold Dose Response Model for Ionizing Radiation*. Bethesda, MD: NCRP; 2001:297.
5. Richardson DB, Cardis E, Daniels RD, et al. Risk of cancer from occupational exposure to ionising radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS). *BMJ*. 2015;351:h5359.
6. Doss M. Are we approaching the end of the LNT model era? *J Nucl Med*. 2018;59:1786-1793.
7. Hsu WL, Preston DL, Soda M, et al. The incidence of leukemia, lymphoma and multiple myeloma among atomic bomb survivors: 1950-2001. *Radiat Res*. 2013;179:361-382.
8. Grant EJ, Brenner A, Sugiyama H, et al. Solid cancer incidence among the life span study of atomic bomb survivors: 1958-2009. *Radiat Res*. 2017;187:513-537.
9. Sies H. Hydrogen peroxide as a central redox signaling molecule in physiological oxidative stress: oxidative eustress. *Redox Biol*. 2017;11:613-619.
10. Sies H, Feinendegen LE. Radiation hormesis: the link to nanomolar hydrogen peroxide. *Antioxid Redox Signal*. 2017;27:596-598.