Suggestions for topics suitable for these Point/Counterpoint debates should be addressed to Habib Zaidi, Geneva University Hospital, Geneva, Switzerland: habib.zaidi@hcuge.ch; Jing Cai, The Hong Kong Polytechnic University, Hong Kong: jing.cai@polyu.edu.hk; and/or Gerald White, Colorado Associates in Medical Physics: gerald.white@mindspring.com. Persons participating in Point/Counterpoint discussions are selected for their knowledge and communicative skill. Their positions for or against a proposition may or may not reflect their personal opinions or the positions of their employers.

The eventual rejection of the linear no-threshold theory will lead to a drastic reduction in the demand for diagnostic medical physics services

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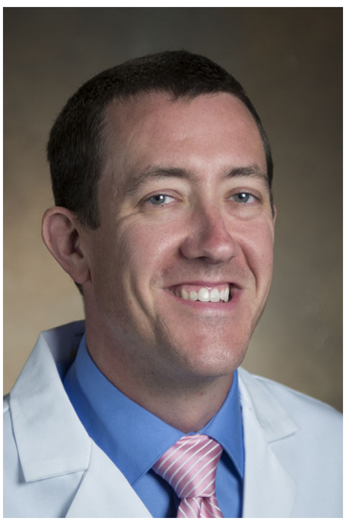
OVERVIEW

Controversies about the linear no-threshold (LNT) hypothesis have been around since the early development of basic concepts in radiation protection and publication of guidelines by professional societies. Historically, this model was conceived over 70 yr ago and is still widely adopted by most of the scientific community and national and international advisory bodies (e.g., International Commission on Radiological Protection, National Council on Radiation Protection and Measurements) for assessing risk from exposure to low-dose ionizing radiation. The LNT model is currently employed to provide cancer risk estimates subsequent to low level exposures to ionizing radiation despite being criticized as causing unwarranted public fear of all low-dose radiation exposures and costly implementation of unwarranted safety measures. Indeed, linearly extrapolated risk estimates remain hypothetical and have never been rigorously quantified by evidence-based studies. As such, is the LNT model legitimate and its use by regulatory and advisory bodies justified? What would be the impact on our profession if this hypothesis were to be rejected by the scientific community? Would this result in drastic reduction in the demand for diagnostic medical physics services? These questions are addressed in this month's Point/Counterpoint debate.



Arguing for the proposition is Aaron Kyle Jones, PhD. Dr. Jones is an Associate Professor and the Chief of the Radiologic Physics Section in the Department of Imaging Physics at MD Anderson Cancer Center. Dr. Jones received his Ph.D. in Medical Physics at the University of Florida under David Hintenlang, Ph.D. His current clinical focus is on interventional and intraoperative imaging. He has authored over 50 peer-reviewed publications and in 2013 he received the Farrington Daniels Award for best paper on Radiation Dosimetry in *Medical Physics*. Dr. Jones is currently leading the pilot phase of the ACR-SIR Fluoroscopy Dose Index Registry and is the physics editor for the *Journal of Vascular and Interventional Radiology*. He has delivered numerous presentations as an invited speaker at national and international conferences. Dr. Jones is certified by the American Board of Radiology in Diagnostic Radiological Physics, the American Board of Imaging Informatics, and is a fellow of the American Association of Physicists in Medicine.

Arguing against the Proposition is Michael K. O'Connor, PhD. Dr. O'Connor received his Ph.D. degree from Trinity

College Dublin, Ireland in 1978. He worked as a Senior Medical Physicist in St. James's Hospital in Dublin before accepting a position in the Department of Diagnostic Radiology at the Mayo Clinic in 1986, where he is now professor of Medical Physics. Dr. O'Connor served as Chair of the Division of medical physics from 1995 to 2008. He has served in many capacities in the Society of Nuclear Medicine (SNM). He is past-president of the Central Chapter of the SNM and served on the computer and instrumentation council of the SNM. In 2010, he was elected a Fellow of the American Association of Physicists in Medicine. His research focus over the last 15 yr has been in the field of semiconductor-based gamma cameras, with particular emphasis on their use in breast imaging. Dr. O'Connor has published over 200 papers in peer-reviewed journals and holds ten patents in the field of Molecular Breast Imaging.

FOR THE PROPOSITION: AARON KYLE JONES, PH.D

Opening Statement

The LNT theory has recently come under increased scrutiny.[1–3] This is due in part to the most recent updates on cancer incidence[4] and mortality[5] from the life span study, which reported increased curvature of the dose–response function at doses from 0 to 2 Gy. This curvature has grown stronger and became significant over time, even as the model has improved.[6] The best-fitting linear quadratic model across the range 0–2 Gy for non-sex-specific cancer for males produced a point estimate for excess relative risk (ERR) of -0.0004 at a dose of 100 mGy in the most recent update.[4]

This should be of keen interest to diagnostic medical physicists, as the LNT theory and the risks of radiation exposure in diagnostic imaging it predicts are driving factors of many aspects of regulation and accreditation. In turn, these requirements drive much of the demand for medical physics services. Most contracts for medical physics services cover only what may be called "Level 1" services.[7] It is no coincidence that these Level 1 services are exactly those required by regulation and accreditation.

Medical physicists have enjoyed the job security created by regulation and accreditation, and we have planted our flag firmly in the ground of the LNT. We continue to cling to this dogma in many areas of the field, including gonadal shielding and CT protocols. Despite the potential negative impact of gonadal shielding on image quality and the corresponding risk of misdiagnosis, it is only now that the idea of revising gonadal shielding recommendations is being given serious consideration.[8,9] The primary reason for the continued adherence to this practice is blind loyalty to the dogma of low-dose radiation effects, and the distorted perception and prioritization of risks that this loyalty causes. The race to push radiation doses lower and lower in x-ray imaging is constant.[10] Both our inboxes and the popular radiology press continually promote the latest "studies" that estimate and extrapolate cancer risks from medical imaging, and the pursuit of the sub-mSv CT continues despite the demonstrated risks to the patient of using radiation doses that are too low.[11] The rejection of the LNT will end then the need to constantly tweak protocols to reduce radiation doses in pursuit of this white whale.

A substantial part of the value of medical physics services perceived by department administrators is in "keeping the doors open", that is., meeting regulatory and accreditation requirements. Beyond meeting these requirements, many of these (primarily Level 1) services add little or no value to the clinical operation, in that they do not increase patient satisfaction, improve outcomes, or reduce costs (instead, they increase costs).Were the LNT theory formally rejected tomorrow, regulatory updates would lag behind for a number of years, but the inevitable changes set in motion by the rejection of the LNT theory will ultimately result in a drastic decrease in the demand for diagnostic medical physics services.

AGAINST THE PROPOSITION: MICHAEL K. O'CONNOR, PH.D

Opening statement

This is an interesting proposition as it implies that medical physicists care only about their field and not about whether or not a scientific concept (the LNT) is valid or not. It further implies that if the LNT theory is rejected, the public and the bureaucratic process that governs radiation and radiation safety, will automatically fall in line with the scientific consensus, and finally implies that medical physics revolves solely around the domain of low-dose radiation and radiation physics. I believe that all three premises are false for the following reasons.

I would posit that most of us enter the field of medical physics for both reasons of scientific curiosity and altruism. The Commission on Accreditation of Medical Physics Educational Programs lists altruism as the first component under the curriculum for ethics and professionalism.[12] A recent article by Klavans and Boyack[13] showed that in the United States, scientists tend to be driven by "a strong sense of individualism and a tendency to question authority", and as a consequence the motivation for medical research tends to be altruistic rather than economic. Hence, I believe that the rejection of the LNT theory would be viewed by the medical physics community as simply the outcome of the scientific process, and the demise of the LNT theory would then allow us to focus our efforts on new areas, rather than expending time and resources to prop up an untenable hypothesis for our own self-interest.

Unfortunately, even if the scientific community was in 100% agreement that the LNT theory is not applicable at low doses, that does not translate into acceptance by the public. Radiophobia is a well-recognized phenomenon.[14–16] In an opinion piece in the New York Times in 2013,[17] David Ropeik wrote that "The robust evidence that ionizing radiation is a relatively low health risk dramatically contradicts common fears.....Without a much broader and persistent effort by various branches and levels of government to help the public understand the actual biological effects of radiation, we will continue to face the threat of deep historic fears that simply don't match the facts." Irrespective of our claims to be altruistic with regard to any advice we try to give the public regarding radiation and the LNT theory, we will be viewed as having a vested interest in this field, and will face similar problems to those encountered by scientists in areas like climate change and evolution. Hence, I would argue that rejection of the LNT hypothesis will have little impact on the public's perception of radiation and the demand for any associated diagnostic medical physics services.

The final implication is that diagnostic medical physics services revolve around the mitigation of the harmful effects of low radiation doses. On the contrary, I would argue that over the last 10–20 yr, the focus of our work has shifted away from quality assurance toward providing the best diagnostic image quality, either through more precise calibration, improved image analysis or reconstruction, better corrections for patient-related artifacts, and at a more fundamental level, development of new and better technologies, for example, energy-sensitive photon counting detectors for CT[18] or total body PET/CT systems.[19] Less concern about low-dose radiation would allow us to focus on more meaningful improvements in imaging systems with a greater benefit to patients.

For all the above reasons, I would argue that the rejection of the LNT hypothesis will have minimal impact on the demand for diagnostic medical physics services.

REBUTTAL: AARON KYLE JONES, PH.D

Dr. O'Connor makes a compelling case against the proposition. However, there are several key flaws in his reasoning.

First, demand for medical physics services is not driven by what we seek in our profession — it is the administrators and hospitals that employ medical physicists, and it is primarily regulation and accreditation that drives this demand.

Second, regulation does not prioritize public opinion. If it did, we would already have meaningful regulation in the United States addressing climate change. Instead, the current political climate is one in which the reduction or elimination of regulation is prioritized. Rejection of the LNT theory would be all the motivation needed to roll back or eliminate much of regulation related to diagnostic imaging. Furthermore, diagnostic medical physicists are not visible or known to patients today, so what reason is there to expect that we would suddenly be sought after when the LNT theory is rejected?

Finally, whether we want to admit it or not, our work is primarily centered around mitigation of potential radiation effects. The current standard of practice in professional diagnostic medical physics is largely the same as it was in the 1990s. My opponent discusses the work done by researchers and a small percentage of diagnostic medical physicists. The primary work of most diagnostic medical physicists is helping their clients meet regulation and accreditation requirements, which primarily deal with mitigation of potential low-dose radiation effects.

There is little doubt that, given the current state of practice of diagnostic medical physics, the eventual rejection of the LNT theory would trigger a drastic reduction in the demand for our services in a relatively short time.

REBUTTAL: MICHAEL K. O'CONNOR, PH.D

Dr Jones has elegantly argued that for many diagnostic medical physicists, contracts for the provision of Level 1 services make up a substantial proportion of their work. However, I would dispute his claim that medical physicists are firmly in the LNT theory camp. Surveys of scientists regarding the most accurate radiation dose–response model for cancer have consistently shown that only about 15–20% support the LNT hypothesis and 65–70% support the threshold model.[20,21]

However, let us assume for the sake of argument that he is correct in that statement, and now fast-forward 10 or 20 years when it has now been shown that the LNT theory is invalid, the regulators have altered the rules governing ionizing radiation and exempt from regulations low-dose exposure situations that do not warrant control.

In the absence of the LNT model, we are left with the threshold model and the radiation hormesis model. The threshold model is not truly a model of how radiation affects the body, but rather recognition of the fact that any effects of ionizing radiation below a certain level (~100 mSv) do not cause harm, which leaves us with radiation hormesis which postulates that the body reacts to radiation in much the same way it does to any other agent or insult. In toxicology, it has been extensively shown over the last 10–20 yr that biphasic (e.g., U-shaped, J-shaped, and bell-shaped) dose responses are induced by a variety of chemical agents and environmental factors[22,23] and regulatory bodies such as the US Environmental Protection Agency are now considering such models in their estimation of risk.

In our new enlightened world 30 yr from now, LNT theory has long been discarded, the public are now educated as to the benefits of low doses of ionizing radiation and there is no longer a race to push radiation doses lower and lower in x-ray imaging. On the contrary, with acceptance of radiation hormesis, a new industry has arisen that offers the public an annual booster dose of radiation every year, particularly if they live in low levels of natural background radiation. How will this booster dose be administered? For those with the means, it might mean an annual trip to the Rocky Mountains. For others it could mean a trip to the nearest clinic for a treatment session with ionizing radiation. Who will oversee the equipment designed to deliver this radiation, to insure that the correct dose is delivered? The medical physicist!

CONFLICTS OF INTEREST

Dr. Jones and Dr. O'Connor have no relevant conflicts of interest.

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