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Things to know when reading this article:

1. **"Aunt Minnie.com" is a major internet radiology site.**
2. **X-radiation doses are measured in rads, or in the International System, in Grays.**
   a. **1 Gray (Gy) = 100 rads**
   b. **1cGy (centigray) - 1 rad**
3. **In PLAIN FILM studies it would be hard to exceed 3 rads for a multi-view study on the largest body part (lumbar spine), and many plain film exams create less than 1 rad dose; for example, a 7v cervical study would involve ¼ to ½ rad, a 2v chest study would involve about 1/20 rad, and extremity studies would be measured in thousandths of rads.**

STUDIES CAST DOUBT ON LOW-LEVEL RADIATION DANGERS

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By: Eric Barnes

Aunt Minne.com staff writer

Are the risks of low-dose radiation exposure being overestimated? It's a tantalizing idea, and one that's gaining attention as some imaging proponents look for ways to counter criticism of techniques such as whole-body CT screening.

Radiologists' views are all over the map. Many physicists say the science simply isn't ready yet -- that solid conclusions on the dangers or benefits of low-level radiation could take a decade or more to produce. In the end, the debate over radiation dose touches on everything from politics to law, economic interests to malpractice worries. Toss in conflicting study data, and it can quickly turn volatile.

One can find at least three broad schools of thought among radiologists. Some believe that radiation of the type and amounts seen in diagnostic imaging poses little or no danger to patients. Another group sees the radiation dangers as very real, a stance that makes most CT screening of asymptomatic individuals suspect if not unethical. A third group, citing unproven risks and an abundance of caution, advocates minimizing the radiation dose and assessing the need for each and every exam until the risk can be reliably assessed.

Meanwhile, medical physicists and other scientists have begun arriving at their own conclusions, with many questioning the very premise of low-level radiation danger. This group includes the Health Physics Society of MacLean, VA, which has stated that "Below 10 rad ... the risks of health effects are either too small to be observed or nonexistent."

The society's views were noted in a recent article from the *American Journal of Roentgenology*, in which Dr. Bernard Cohen from the department of physics at the University of Pittsburgh reviewed dozens of studies on the effects of low-level radiation. The evidence, he concluded, demonstrates that such doses are probably not harmful, and may even be beneficial (*AJR,* November 2002, Vol. 179:5, pp 1137-1143).

The study echoes research published in 2001 by Dr. Amy Berrington and colleagues, who took a long look at 100 years of mortality data acquired from British radiologists who were registered with the British Radiological Society between 1897 and 1997. Even among the earliest radiologists, who were exposed to substantial radiation doses in excess of 100 cSv/y (100 R/y) in the years before the first radiological protection recommendations were published in 1920, Berrington et al found no evidence of an effect from radiation exposure on disease, except for cancer. And while the number of cancer deaths increased among these early radiologists, overall mortality did not (*British Journal of Radiology*, June 2001, Vol. 74:882, pp. 507-519).

Additional perspective on the BJR study came last fall from Dr. John Cameron, professor emeritus, departments of radiology and medical physics, University of Wisconsin, Madison. In a letter pointedly titled "Radiation Increased the Longevity of British Radiologists," Cameron dissected the British data, calculating that even though cancer cases were somewhat elevated among those radiologists who likely received enormous doses, this group's total death from all causes was no higher than that of other physicians. And once the radiation levels dropped slightly after 1920, radiologist longevity began to surpass that of other doctors, suggesting a beneficial effect from the radiation they were exposed to on the job (*BJR,* July 2002 Vol. 75:895, pp. 637-639).

Cancer risk from low-level radiation

Substantial money has been spent on reducing radiation dose to the lowest possible level, Cohen wrote in the *AJR*. The article suggests that some of these efforts may be misplaced, in that the radiation risk underlying them is based on the no-threshold theory of carcinogenesis, which holds that "if 1 Gy (100 rad) of exposure gives a cancer risk R, then the risk from 0.01 Gy (1 rad) of exposure is R/100, the risk from 0.00001 Gy (1 mrad) is R/100,000, and so on. According to the no-threshold theory, the cancer risk is not zero regardless of how small the exposure," Cohen wrote.

(In terms of imaging exams, a back-to-front chest x-ray delivers a surface entrance dose of about 0.02 cGy (rad), at least 100 times lower than the dose of 2-5 cGy (rads) seen in a standard chest CT.)

So according to the no-threshold theory, "a single particle of radiation hitting a single DNA molecule in the nucleus of a single cell of the human body can initiate a cancer," Cohen wrote. "The probability of such a cancer initiation is therefore proportional to the number of such hits, which is proportional to the number of particles of radiation, which is proportional to the dose. Thus the risk is proportional to the dose."

But real-world experience doesn't jibe with the theory, which also "predicts that the cancer risk should be approximately proportional to the mass of the animal," Cohen wrote. "The cancer risk in a given radiation field is very similar for a mouse weighing 30 g and a human weighing 70 kg. Our very definition of dose would be misleading if only the total number of hits ... was relevant regardless of the target mass, because the definition of dose is based on the energy absorbed per unit mass of tissue, which is proportional to the number of radiation hits per unit of target mass."

Working to prevent nearly all cancers are the body's defense mechanisms, Cohen wrote. The body produces enzymes that repair 99.99% of cell damage, and low-level radiation is known to stimulate the process of apoptosis, by which damaged cells "commit suicide" (*Journal of Nuclear Medicine*, July 2001, Vol. 42:7 17N - 27N; *JNM*, September 2001, Vol. 42:9, pp. 26N - 32N, 37N).

These results mean that cancer-initiating events aren't the controlling factor in determining the dose-response relationship for low-level radiation, and that the principal effect of low-dose radiation is in modifying biologic defense mechanisms, Cohen wrote.

The literature contains many examples of this protective effect, Cohen observed. One study showed that the percentage of chromosomal aberrations that occurred in mouse cells exposed to 65 cGy of radiation (38% of bone marrow cells and 12.6% of spermatocytes) was reduced to 19.5% and 8.4%, respectively, when these exposures were preceded by an x-ray exposure of 0.2 cGy (*International Journal of Radiation Biology*, July 1990, Vol. 58:1, pp. 187-194).

Another study showed a similar effect in female drosophila. And a study of rats showed that 50 cGy of x-ray exposure increased the amount of an antioxidant, superoxidase dismutase, by 50%, while decreasing the amount of lipid peroxide by about 20%. Significantly, both of these effects were reversed at much higher doses.

The effects of low-level radiation on the immune system are relevant, however, because such radiation destroys cells that have persistent DNA damage, Cohen stated.

Even the data most commonly cited to support the no-threshold theory, that of Japanese atomic bomb survivors, and occupational data from findings of an International Association for Research on Cancer study, "...give no statistically significant indication of increased incidence of cancer for doses of less than 25 cSv," Cohen wrote, summarizing the study's conclusions (*Radiation Research*, July 1996, Vol. 146:1, pp. 1-27; and July 1998, Vol. 149:5, pp. 525-528).

A study of lung cancer rates among women exposed to fluoroscopic examinations for tuberculosis came to similar conclusions. Lung cancer rates among these Canadian women, as well as a one-point study of 10,000 tuberculosis patients in Massachusetts, showed a protective effect up to 20 cSv and 100 cSv (*Radiation Research*, June 1995, Vol. 142:3, pp. 295-304; and *Cancer Research*, November 1989, Vol. 49:21, pp. 6130-6136.)

"The International Association for Research on Cancer study of 95,673 monitored radiation workers in the United States, the United Kingdom, and Canada found 3,830 deaths for all cancers except leukemia (146 deaths), but no deaths exceeding what was expected," Cohen wrote.

The data show no indication of an excess risk below 40 cSv, and only slightly higher (1.4 SD) for higher doses (*Radiation Research*, May 1995, Vol. 142:2, pp. 117-132).

A study of naval shipyard workers who service nuclear-propelled ships compared workers who were and those who were not occupationally exposed to radiation. It found that workers exposed to the highest levels of radiation (> 0.5 cSv) had a cancer mortality rate that was 85% of the rate experienced by workers who were not exposed. By far the most important finding was the very significant decrease of 24% in deaths from all causes among workers exposed to the highest doses (U.S. Department of Energy, 1991, report No. DOE DEAC-02-79 EV 10095).

A notorious 1957 accident that occurred in the former Soviet Union, in the Eastern Urals of Siberia, exposed 7,852 villagers to large radiation doses. According to Cohen, follow-up of the villagers showed that the rate of cancer mortality among those exposed was much lower than that of unexposed villagers (*A Science of the Total Environment*, March 1994, Vol. 142:1-2, pp. 119-125).

Farther east in Taiwan, another environmental study is reaching some interesting preliminary conclusions, Cohen wrote. In Taipei and the surrounding area, some 1,700 apartment units were built using steel contaminated with cobalt-60, exposing the 10,000 occupants to 4.8 rem in the first year and 33 rem for as long as 16 years. According to government statistics, 173 cancers and 4.5 leukemias should have been expected, and according to the no-threshold theory, an additional 30 leukemias. To date, however, only 5 cancers and one leukemia have been reported (*Trans American Nuclear Society*, 1999, Vol. 1, p. 18).

In three studies, workers who inhaled plutonium were shown to have lower lung cancer mortality rates than those who were not exposed. A similar effect is seen in those exposed to radon in their homes, in a study that looked at 90% of the population in 1,729 counties in the U.S. In a review article, the data were analyzed for more than 500 possible confounding factors, Cohen wrote in an earlier article (*Technology 2000*, Vol. 7, pp. 657-672).

"The evidence presented in this review leads to the conclusion that the linear no-threshold theory fails badly in the low-dose region, because it grossly overestimates the risk from low-level radiation," Cohen wrote. "This means, for example, that the cancer risk from diagnostic radiography is much lower than is given in usual estimates, and may well be zero."

British radiologists and American shipyard workers

Discussing the 100-year study of British radiologists in a letter to the *British Journal of Radiology*, Dr. John Cameron noted that the earliest British radiologists did have a 75% higher cancer mortality rate compared to all male physicians, due clearly to the large radiation doses to which they were exposed.

"However, even the heavily exposed pre-1921 radiologists had a SMR (standard mortality ratio) for non-cancer 14% lower (<0.05) than the SMR for non-cancer of all male medical practitioners," Cameron wrote. "Since 80% of the radiologists died from non-cancer causes, the decreased SMR for non-cancer completely canceled their 75% excess cancer mortality. In other words, even the earliest radiologists did not suffer any decrease in longevity due to their large exposures." Thus, the risk could be considered as zero, Cameron wrote (*BJR*, July 2002 Vol. 75:895, pp. 637-639).

As for the nuclear shipyard workers, Cameron said the results could not have more clearly demonstrated the beneficial effects of low-level radiation (Is Radiation an Essential Trace Energy? *Forum on Physics and Society*, October 2001).

"The important finding from the (Naval Shipyard Worker Study) is support of the hypothesis that a moderate dose rate of radiation is beneficial to the health," Cameron wrote. "The (workers with cumulative doses greater than 0.5 rem) had a death rate from all causes 24% lower than the control group.... If the study aim had been to look for health benefits of ionizing radiation, it would have been a huge success. As a study to find radiation risks, it was an abysmal failure."

Cameron pressed his point in an e-mail to *Auntminnie.com*, bemoaning a "long history of non-scientific influences on radiation protection policies."

"It will take many years to overcome the problems brought about when private nonprofit organizations, i.e., the ICRP (International Commission on Radiological Protection, of Stockholm) and NCRP (National Council on Radiation Protection and Measurements, of Bethesda, MD), which choose their own members, adopted an assumption which is contradicted by excellent human data," Cameron wrote.

In response, NCRP president Thomas Tenforde, Ph.D., said his organization, chartered by the U.S. Congress, is in fact paying close attention to scientific developments on the question of low-level radiation.

"We currently have a distinguished panel of scientists conducting a thorough review of the ecological epidemiology studies on which Dr. Cohen has based his statements about the overestimation of effects of low-level radiation," Tenforde told *AuntMinnie.com*.

Using available health-effects data from atomic bomb survivors and other sources, the NCRP proposed limitations on exposure of workers and members of the public to ionizing radiation in 1993 (Report No. 116), he said. Those recommendations included the conservative assumption of a linear dose-response curve extending from high to low doses. In 2001, the reasonableness of the assumed linearity was confirmed through an extensive analysis of published dose-response data presented in the NCRP's Report No. 136, Tenforde said.

As for Cohen's AJR article, Tenforde said there may be problems with the methodology used in some of the studies, but that the research will certainly provide some valid insights as well. In any case, the complete results of the NCRP's scientific review will be published in a scientific journal in 2003.

Tenforde also dismissed the notion of a bias against using new data to revise exposure guidelines. He said the goal is simply to ensure that any new recommendations are based on solid evidence. This will require a very broad base of information that could take a decade or more to assemble.

"What's happening is that the guidelines promulgated internationally are on the conservative side because we don't have as much information as we would like to have on the low-dose exposures that occur in industry and to the public," Tenforde said. "Our general philosophy is that we utilize the limited data we have ... to predict what might occur all the way down to extremely low doses. As the data improves, we can refine risk coefficients and modeling to come up with better recommendations."

Dr. Jack Valentin, scientific secretary of the ICRP, also responded to Cameron's comments. He noted that the ICRP is an independent organization funded by grants from a variety of organizations interested in radiological protection, including the International Atomic Energy Agency, the European Commission, the U.S. Nuclear Regulatory Commission, and many others.

"Most of the grants (the ICRP receives) constitute research funding received in open competition with other applicants," Valentin wrote in an e-mail to *AuntMinnie.com*.

"The risk estimates used by ICRP are consistent with those of the United Nations Scientific Committee on the Effects of Atomic Radiation," he wrote. "As seen in the UNSCEAR (2000) report, available at www.unscear.org, Cohen's results on low-dose risk are subject to different interpretations. Cohen and some other authors consider that low-dose risks are lower than the ICRP estimates. As seen (for example) in the UNSCEAR report, there are also a number of reports, again open to different interpretations, claiming that low-dose risks are higher than the ICRP estimates."

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