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Is there a Need for Protection against Exposure to Low Levels of Ionizing Radiation?

D J Higson, PhD
Fellow of the Australasian Radiation Protection Society
Fellow of the Institution of Engineers, Australia

In some 30-years' study of published work on the biological effects of ionizing radiation, I have found no **evidence to prove** that acute doses less than about 50 mSv, or chronic dose rates up to at least 200 mSv/y, cause increases in the incidence of cancer. The only reason that I know for anyone to consider that there are risks from exposure to lower levels of radiation is that, **for the practice of radiation protection**, the International Commission on Radiological Protection (ICRP) recommends the assumption that the risk is proportional to the dose without a threshold [1] – the so-called "linear no-threshold (LNT) hypothesis" (Fig.1).

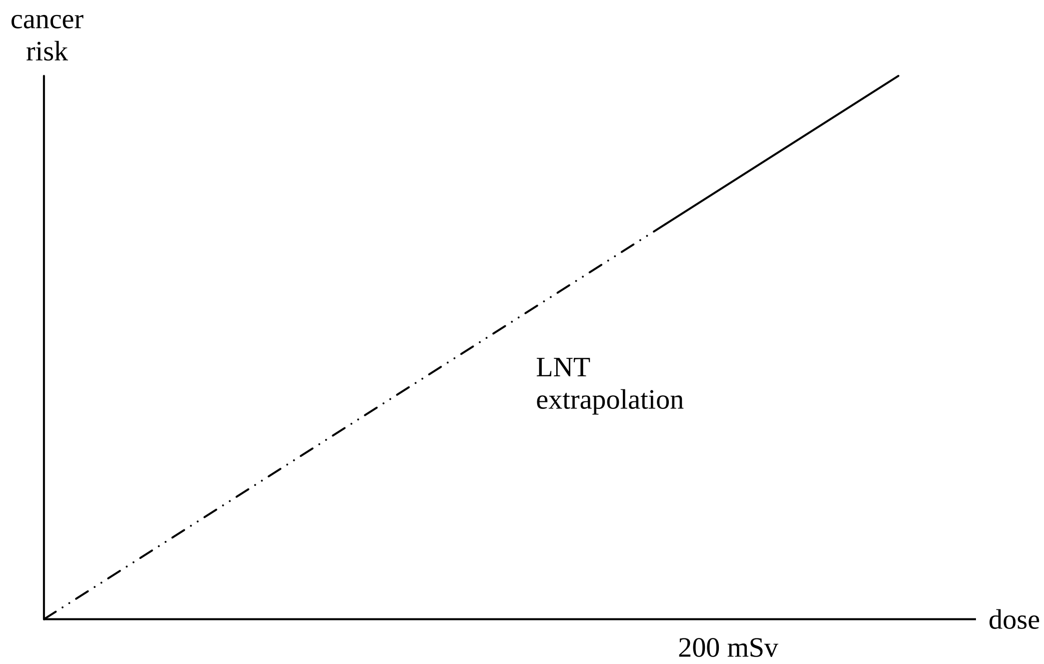

Fig.1: The LNT Model

In fact, there is considerable evidence that risk is not proportional to dose at low levels, that exposure to low level radiation can be beneficial and that some exposure is necessary for normal life and health [2-11]. This is not surprising. The human race (indeed, all life on earth) has evolved in the presence of radiation, the level of which has been higher in the past than it is today. It is a fundamental tenet of evolutionary biology that species adapt to their environment and are at their best when exposed to conditions within the normal ranges in that environment [12]. This is true of exposure to most substances that are usually regarded as toxic, such as "heavy metals" and arsenic, as follows:

- too little (below A on Fig.2) is harmful, e.g. trace element deficiencies;

- small increases above normal (between A and B) are often beneficial;
- large increases (above B) are harmful, *viz* the dose makes the poison.

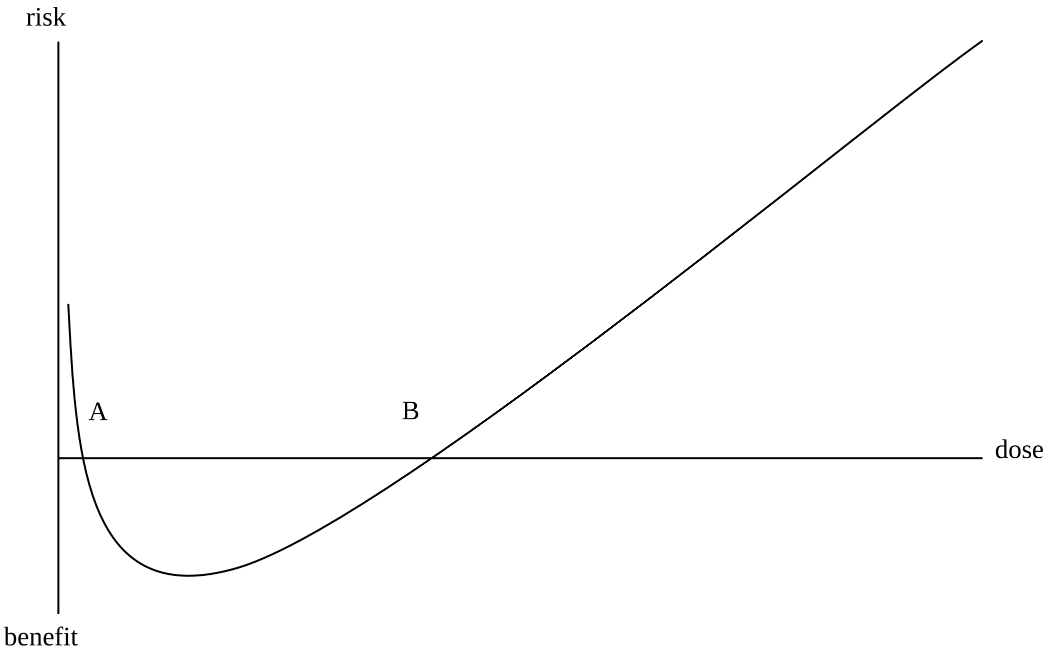

Fig.2: An Illustration of Hormesis

These effects occur also with oxygen, sunlight and many other familiar agents. The first two effects constitute a phenomenon called “hormesis”. Evidently, this applies to naturally-occurring background radiation, which ranges around the world from less than 1 mSv/y to more than 100 mSv/y (lifetime exposures up to several thousand mSv). The exposure of human populations to radiation within this range is not harmful. Cancer incidences are, if anything, lower in areas of high background radiation than in areas of low background radiation [e.g. references 13-15]

Radiation hormesis has been observed experimentally in cells from virtually all types of organisms, in whole plants and animal species other than humans, and in human cells. This is beyond reasonable doubt. Experiments with irradiation of animals suggest that the mechanism of the effect is the induction or activation of cellular protective capacity, additional to that which exists normally to protect against damage from all causes. This “adaptive response” to radiation involves prevention, repair and removal of damage. It reduces the effects of damage from other causes, as well as from radiation. At around 100 mSv in animals, there appears to be a transition – not a step change – from net benefit to net harm. For doses greater than about 100 to 300 mSv, detrimental effects dominate but, as the rate of accrual of the dose decreases, the protective effect of radiation increases and the detrimental effects decrease [11].

It would not be unreasonable to expect that this might also apply to humans but controlled experiments cannot be conducted on people to prove it. Epidemiological information has been provided by radiation exposures due to atomic bombs, accidents, medical procedures and occupations, as well as from natural background sources. However, epidemiology is subject to major confounding factors, particularly cigarette smoking which is far more carcinogenic than the radiation. Major epidemiological studies have been aimed at evaluating risks – not at determining whether benefit occurs. Nevertheless, serendipitous evidence of hormesis has arisen from epidemiology, but it is often ignored [e.g. references 2, 3 and15].

Our profession is concerned with protecting people from the harmful effects of radiation, not with its benefits, but the occurrence of hormesis is important to us because it helps to establish that low levels of radiation are harmless. Radiation hormesis is a matter that the medical profession might wish to exploit. In Japan, considerable success has been reported in the treatment of cancers, including non-Hodgkin's lymphoma, using whole-body or half-body irradiations – typically 100 mSv each time, three times a week for five weeks [16,17]. This therapy appears not to be available in Australia. One barrier to its consideration, investigation and possible acceptance is, I am sure, the entrenched view that any level of radiation is harmful, no matter how small – consistent with the LNT assumption. The application of this assumption has been valuable in the practice of radiation protection but it is not supported by scientific evidence at low doses and low dose rates. Let's take a quick look at the evidence in a bit more detail.

The Lifespan Study (LSS) of Japanese atomic bomb survivors has shown small but statistically significant increases in the incidences of cancers for acute doses that exceed about 100 mSv. At around 50 mSv and less, there is not clear evidence of any health effect [1]. This may be because the evidence is not statistically significant or because there **are** no net health effects. In practice, is there really a difference?

Exposures that are protracted or intermittent are less harmful than acute exposures. North American fluoroscopy studies actually suggest some reduction in breast cancer incidence from accumulations of intermittent exposures at around 100-200 mSv, but there is no real increase until the total doses are greater than about 400 mSv [my interpretation of references 18-20].

There have been claims of risks caused by exposures to medical radiation *in utero* down to about 10-20 mSv but this (like many other matters relating to the effects of low doses) is controversial.

Studies of nuclear industry workers [2,21-23] have found correlations between health and occupational exposure to radiation ranging from positive (beneficial) to negative. Some of the apparently beneficial effects have been explained by critics of the studies as being due to the "healthy worker effect".

Beneficial health effects of radiation were indicated by the US nuclear shipyard workers study [2], carried out between 1980 and 1988, in which death rates of –

- 28,542 nuclear workers, having cumulative occupational doses greater than 5 mSv (collective occupational dose ~1,450 man-Sv), were compared with
- 10,462 nuclear workers, having cumulative occupational doses less than 5 mSv (collective occupational dose ~26 man-Sv), and with
- 33,352 non-nuclear workers, having the same age distribution but no occupational exposure.

The total database for this study covered almost 700,000 shipyard workers, including about 108,000 nuclear workers. The three study groups were selected to represent workers doing identical work and given the same health care. Although the title of the report [2] implies that this was a study of the general health effects of exposure to radiation, it was primarily directed toward adverse health effects – risks – and it did not find any. In fact, the data show that mortality rates from all causes and from all cancers were lower for the workers with the higher exposures, although this was not identified as a finding of the study.

A much more recent study [23] of combined data on nuclear industry workers in 15 countries found increased cancer incidence due to an average cumulative occupational dose of 19.4 mSv. There has been a lot of criticism of this study, not least from ARPS members. Briefly:

- its findings depend for their statistical significance on the inclusion of data from one country (Canada), which show unusually high (and unexplained) cancer mortality;
- it does not include data from the US nuclear shipyard workers study [2], which featured strongly in findings of adaptive response by UNSCEAR in 1994 [3];
- it appears not to take adequate account of smoking.

Furthermore, as discussed earlier in my presentation, acute exposures up to about 50 mSv from atomic bomb explosions and lifetime exposures up to several thousand mSv from natural background radiation do not cause discernible increases in cancer incidences.

Apart from the effects of high doses to workers and to thyroids, there has been no discernible physical harm due to radiation from the Chernobyl reactor accident. The significantly increased incidence of leukaemia that was expected did not occur [24].

During the period 1983 to 2002, the exposure of up to 10,000 residents of apartments in Taiwan, which were contaminated by cobalt-60 from an “orphaned source”, caused estimated cumulative individual doses up to 6 Sv with an average greater than 40 mSv. This incident is reported [15] to have caused reductions in the overall incidences of cancers and hereditary defects, instead of the increases that would have been expected according to the LNT model. There is disagreement as to whether the reductions were large (as first reported) or only minor (as more recently reported), and the long term effects of the exposures remain to be observed.

In the face of all this information, it puzzles me that the radiation protection profession continues subscribing to the view that any level of radiation is harmful, no matter how small. This seems to be a rather too literal interpretation of the linear no-threshold (LNT) model (Fig.1). It is often said that LNT-based estimates of risk are conservative. This would be true if the real risk is somewhere between the estimate and zero but not, however, when the risk is below zero (see Fig.2), i.e. when there is more likely to be benefit than harm from exposure to radiation.

I realise that the LNT assumption facilitates the practice of radiation protection. Outside this field, however, it has had some unfortunate consequences, including:

- disincentives for patients to undertake medical treatment which would be beneficial for them;

- unnecessary mental anguish to exposed persons such as the former residents of the Chernobyl area;
- inappropriate countermeasures adopted after the Chernobyl accident, some of which did far more harm than good;
- the provision of an unwarranted basis for propaganda against the uses and management of radiation, radioactive materials (including waste disposal) and nuclear power;
- unnecessarily stringent standards for clean-up of radioactive contamination, with huge associated expense and waste of scarce national resources.

Contractors are being paid billions of tax-payers' dollars (or pounds) to clean up wartime nuclear sites to less than background levels of radiation. It might be unreasonable to expect them to tell their governments that this is a waste of money – particularly when the public has been led to believe that it is necessary. However, I do consider that it is unethical for professional people to advocate such work unless they truly believe that it will contribute value for money in terms of public safety.

I do not believe it does in this case. Risks from doses up to at least 50 mSv in a year are either negligible or non-existent. Why then do we even consider protecting people from doses that are less than one mSv?

Three years ago, a senior member of this Society told me that, if the first dramatic reports of radiation hormesis in the Taiwanese apartments [15] were true, ARPS would soon be holding its annual conferences in a telephone booth. I don't agree. There is already a world-wide shortage of skilled staff in radiation protection and nuclear safety work. It is getting worse because of the resurgence of the nuclear industry overseas. Australia is fairly well staffed with health physicists at the moment but the report of the Government's recent Uranium Mining Processing and Nuclear Energy Review (the "Switkowski report") identified skill shortage as a critical factor limiting the growth of the uranium and nuclear power industries in this country. And, seriously, we must anticipate that Australia is going to need nuclear power if it wants to control emissions of carbon dioxide.

So there looks like being plenty of work in radiation protection. Perhaps more than we can handle. The real challenge may be to decide the proper priorities in the allocation of skills, effort and resources. Whatever happens, I suggest that we should be concentrating our efforts on problems of real significance.

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