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Editorial

Radiation Exposure and Health Effects – is it Time to Reassess the Real Consequences?

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Abstract

Our acceptance of exposure to radiation is somewhat schizophrenic. We accept that the use of high doses of radiation is still one of the most valuable weapons in our fight against cancer, and believe that bathing in radioactive spas is beneficial. On the other hand, as a species, we are fearful of exposure to man-made radiation as a result of accidents related to power generation, even though we understand that the doses are orders of magnitude lower than those we use everyday in medicine. The 70th anniversary of the detonation of the atomic bombs in Hiroshima and Nagasaki was marked in 2015. The 30th anniversary of the Chernobyl nuclear power plant accident will be marked in April 2016. March 2016 also sees the fifth anniversary of the accident at the Fukushima nuclear power plant. Perhaps now is an opportune time to assess whether we are right to be fearful of the effects of low doses of radiation, or whether actions taken because of our fear of radiation actually cause a greater detriment to health than the direct effect of radiation exposure.

Key words: Environmental; health effects; nuclear accident; radiation

Statement of Search Strategies Used and Sources of Information

This paper reflects expert opinion and current literature accessed by the authors; no formal search strategy has been defined.

Health Effects of Low-dose Radiation in our Environment: What do we Know?

We are all exposed to a certain level of background radiation. Most background radiation comes from radon, which is generated from the rocks that comprise the crust of our planet. A smaller amount (16%) comes from artificial sources, mainly medical exposures, with a very small amount (1%) coming from the nuclear industry as a whole, including atmospheric testing of atomic weapons (Figure 1). The average dose received by all of us from background radiation is around 2.4 mSv/year, which can vary depending on the geology and altitude where people live – ranging between 1 and 10 mSv/year, but can be more than 50 mSv/year. The highest known level of background radiation affecting a substantial population is in Kerala and Madras states in India, where some 140 000 people receive doses that average over 15 mSv/year from gamma radiation, in addition to a similar dose from radon. Comparable levels occur in Brazil and Sudan, with average exposures up to about 40 mSv/year to many people. Taking the individual average dose of 2 mSv/year, someone who lived to the age of 80 years would have accumulated 160 mSv of radiation from natural sources during their lifetime.

The health effects of radiation can be divided into two, and show subtly different relationships between dose and effect. Early, deterministic or tissue effects are seen at high doses (>1 Sv), associated with cell killing in the tissues exposed, and show a direct correlation with dose. We are used to seeing these effects in cancer patients treated with radiation – vomiting and diarrhoea, loss of hair, etc. The

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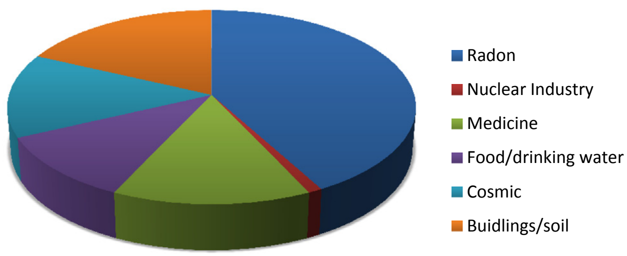

Fig 1. Sources of background radiation. Eighty-five per cent of an individual's annual dose of radiation comes from natural sources (radon, a gas that is emitted from the rocks that form the crust of the planet; food/drinking water; cosmic radiation; exposure from buildings and soil). Fifteen per cent is from man-made sources, largely from exposures for medical reasons (14%). The remaining 1% comes from the nuclear industry. Fallout from atomic weapons testing or use and nuclear accidents accounts for around 0.3% of an individual's annual radiation dose. Figure redrawn from data available at http://www.world-nuclear.org/info/Safety-and-Security/Radiation-and-Health/Nuclear-Radiation-and-Health-Effects.

longer-term effects or stochastic effects are seen at lower doses, where the dose is correlated with the probability of the effect, rather than directly with dose. The stochastic effect of most public concern is that of cancer.

Many of the health effects that we attribute to radiation are not produced exclusively by radiation and not all types of cancer have been shown to be elevated in populations exposed to ionising radiation. Cancer can be caused by a variety of chemical carcinogens, exposure to sunlight, obesity and a great many other factors. There are no validated biomarkers that enable us reliably to identify a cancer as being caused by radiation. Radiation increases the number of cancers within a given exposed population, rather than changing the biology of the cancers induced. This makes it impossible to separate the number of cancers that have been caused by radiation from those that are due to other causes. Because the same health effects can be caused by factors other than radiation, we define the contribution that a given dose of radiation makes to a health outcome (e.g. cancer) as the excess relative risk. This is defined as the rate of disease in the exposed population divided by the rate of disease in an unexposed population minus 1. The risk is usually defined as being a given percentage per Sievert, which enables the risk to be defined regardless of the type of radiation to which the population is exposed.

Most of the information on the health risks of radiation in healthy populations comes from the life span studies, which were established after the detonation of the atomic bombs in Japan in 1945. Assembled in 1950 these cohorts have now been followed for 65 years. Of the 120 000 original subjects, 54 000 were within 2.5 km of the epicentre of the detonations and 45 000 were located 2.5–10 km away. Forty per cent are still alive. The control population (26 000 individuals) were not present at the detonations, but lived in Hiroshima or Nagasaki between 1951 and 1953. Individual dose estimates are available for 92% of the population, with some survivors receiving over 2 Gy and the mean dose 200 mSv. The results of these studies have been recently reviewed by Kamiya *et al.* [1].

In brief, survivors of the atomic bombs in Hiroshima and Nagasaki have a dose–response relationship that is linear for solid cancer, but the precise shape of the curve is still unclear at low doses. Survivors who were children when exposed have a higher risk of cancer than those exposed at older ages; the risk of cardiovascular diseases and some other non-cancer diseases is increased at higher doses. In children exposed to high doses of atomic bomb radiation in the womb, development of the central nervous system and stature were affected, and the risk of cancer increased with maternal dose. Risks of hereditary malformations, cancer, or other diseases in children of atomic bomb survivors did not increase detectably with paternal or maternal dose, based on follow-up to date; atomic bomb survivors exposed to high doses of radiation tend to show deterioration of the immune system similar to that observed with ageing, and many survivors exposed to high doses of radiation have minor inflammatory reactions. Cancer risk increases after exposure to moderate and high doses of radiation (more than 0.1–0.2 Gy); however, whether cancer risk is increased by acute low doses (0.1 Gy or lower) or low dose rates is unclear.

There are a number of other large cohort studies involving both acute and protracted radiation exposures that confirm the data from the lower dose range of the life span study. These include the National Registry of Radiation Workers (NRRW), a study of UK nuclear workers [2]; the Techa River residents who were exposed to discharges of radioactive waste into the river near which they lived [3]; the cohorts of workers who cleaned up after the Chernobyl accident [4]. There are also data from Yangjiang, an area of high natural background radiation in China [5] and from the workers at British Nuclear Fuels Limited (BNFL) [6]. It is to be noted that most of the estimates of excess relative risk lie close to 0, particularly in the dose range between 0 and 0.1 Sv, and in most cases the 95% confidence intervals (where given) span 0. This indicates that there is no statistical evidence that an effect of radiation at these levels is proven scientifically, but rather could be a chance association.

Because of their 'all or nothing' nature and the difficulty in separating out low level, but prolonged, radiation exposure from background, it is difficult to estimate risks or a threshold of effect due to occupational radiation exposure when stochastic effects are considered. In practice, risk is extrapolated from high levels of exposure and a linear, no threshold (LNT) model assumed, i.e. there is no exposure level below which the risk is zero. When the individual radiation dose, from sources other than background radiation, falls below 100 mSv, it is generally accepted that it is difficult to show statistically that any cancers in the population under study are caused by radiation, as it is much more likely that those cancers are caused by all the other factors that we know also cause them. At the present time it is not clear whether there is a difference between a single dose exposure of 100mSv or a protracted low dose exposure that totals 100 mSv over time. However, it is generally

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