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New radiation risks

A CND report by Dr Ian Fairlie

Summary
Recent epidemiology evidence shows that radiation is more dangerous than previously believed. In scientific parlance, radiation risks have increased. It is now clear that radiation is considerably more dangerous than accepted by most governments, both in terms of the size of its cancer risk, and in terms of other diseases apart from cancer, now shown to be caused by radiation (ie radiogenic). These new risks should be addressed by the UK government's Health Security Agency. In particular, stricter individual limits should be introduced for radiation exposures, especially to women and children who are more radiosensitive than adult males.

1. New cardiovascular risks

At present, radiation is commonly associated with cancer, but persuasive new evidence shows that radiation also causes cardiovascular diseases. However, because the currently accepted risks for standard-setting purposes refer only to cancer, this means that the government should increase current radiation risks, i.e. make safety limits more strict. In particular, in CND's view, the current public limit for radiation of 1 mSv per year should be tightened.

What is Cardiovascular Disease (CVD)?

CVD is an umbrella term for a suite of diseases and their ill effects. The two important types are cerebro-vascular disease (effects on the brain) and ischaemic heart disease (caused by narrowed arteries that supply blood to heart muscle). They include arteriosclerosis and atherosclerosis, which in turn cause heart attacks and strokes. These terms are defined below.

Arteriosclerosis is the thickening, hardening and loss of elasticity of artery walls. This restricts the blood flow to organs and tissues and leads to severe health risks.

Atherosclerosis is a specific form of arteriosclerosis in which an artery wall thickens as a result of invasion of white blood cells and proliferation of smooth muscle cells creating a plaque.

Heart attacks occur when the flow of blood to the heart is severely reduced or blocked. The blockage is usually due to the buildup of fat, and cholesterol in the heart's arteries. Heart attacks are often fatal.

Strokes occur when low blood flow (often from atherosclerosis) to the brain results in damage to, and death of, brain cells. Strokes are often fatal due to brain damage and its malfunction. For more information on cardiovascular diseases, see box below.

Background Note on Cardiovascular diseases (CVDs)

Cardiovascular diseases (CVDs) are the leading cause of death globally. Most (>80%) CVD deaths are from heart attacks and strokes.

The British Heart Foundation estimates that in the UK more than half of us will get a heart or circulatory condition during our lifetimes. Heart and circulatory diseases cause around a quarter (27 per cent) of all deaths in the UK; that's more than 170,000 deaths a year, or 480 each day – one every three minutes.

The main risk factors for heart disease and stroke are unhealthy diets, physical inactivity, tobacco use and harmful amounts of alcohol. These cause raised blood pressure, raised blood glucose, raised blood lipids, being overweight and obesity. Cessation of tobacco use, reduction of dietary salt, eating more fruit and vegetables, regular physical activity and avoiding alcohol have all been shown to reduce cardiovascular disease risks. Government policies that encourage people to choose healthy habits are essential.

However, it is not just bad habits that cause CVD: new evidence shows that radiation causes CVD as well.

Some history of CVD risks

Until the 1960s, heart tissue had been thought to be relatively radio-resistant. Even as late as the 1980s, the issue of whether radiation exposure led to CVD was controversial, but increased mortality from heart disease and stroke was actually observed among the Japanese atomic bomb survivors (Shimizu et al, 2010, Takahashi et al, 2017) and among children exposed in early childhood (Tatsukawa et al, 2008).

Since then, a number of authoritative studies (Little MP et al, 2008; Bruno et al, 2013; Kreuzer et al, 2015; Gillies et al, 2017) have shown that cardiovascular risks are indeed raised, even after exposures to low levels of radiation. In fact, for many years, US oncologists had considered that it was cardiovascular risks (rather than cancer) that limited the survival times of their cancer patients after they had received radiation therapy treatment for tumours (Heidenreich and Kapoor, 2009).[1]. But this fact was not widely known.

In 2010, Shimuzu et al (2010) concluded that stroke and heart disease combined now account for about one-third of the radiation-associated excess deaths in the atomic bomb survivors. But the authors pointed out that this was also the proportion of cancer deaths in the Japanese bomb cohort. In other words, radiogenic stroke and cardiovascular disease are in the same league as radiogenic cancer risks. The authors stated that these new risks should be taken into consideration by radiation authorities in setting limits to radiation exposures.

Kreuzer et al (2015) also stated that evidence was emerging that low radiation doses increase the long-term risk of cardiovascular disease. They concluded that:

"This would have major implications for radiation protection with respect to medical use of radiation for diagnostic purposes and occupational or environmental radiation exposure."

Most important is the very recent large meta-analysis[2] of 93 health studies on cardiovascular diseases published in the influential *British Medical Journal* (Little et al, 2023). This concluded:

"Our findings suggest that radiation detriment might have been significantly underestimated, implying that radiation protection and optimisation at low doses should be rethought. This finding has considerable implications for the system of radiological protection …. This added risk would nearly double the low dose detriment."

These conclusions were supported in an accompanying BMJ editorial (BMJ, 2023).

The new meta-analysis is important for a number of reasons. First, because it's a large and powerful study, statistically speaking: in other words, the findings are reliable. Second, the observed risks were at low levels of exposure. For example, the mean cumulative doses in the major INWORKS studies were (red bone marrow) 17.6 mGy, and (colon) 19.2 mGy protracted over many years follow-up. These doses are very low - below normal background radiation levels - yet increased risks were still observed.

Third, the study actually observed non-linearity of the dose-response relationship, suggesting the risks were higher per unit dose at low doses than over the whole dose range. The significance is that the commonly accepted linear dose-risk relationship may not in fact be safe enough.

Fourth, the BMJ article discusses risks to medically exposed patients but in the list of studies (set out in Supplement S3 Tables S3.2-S3.5 in the study's web appendix 1) about half of the 93 studies were of nuclear workers and populations near nuclear facilities. Therefore, the study's findings cover occupational and environmental exposures not just medical ones.

How does radiation cause CVD?

We don't know for sure, but inflammatory factors are thought to be involved. Various theories exist on how radiation causes CVD, but no consensus exists at present. However, CVD diseases have longish latency periods, do not appear to have a threshold, and are progressive. In other words, they have similar characteristics to radiation's cancer effects. It may well be the case that a, as yet undiscovered, common mechanism exists for both radiogenic cancer and radiogenic CVD. In more detail, Hildebrandt (2010) explained:

"The mechanisms of radiation-induced vascular disease induction are far from being understood. However, it seems to be very likely that inflammatory responses are involved. If … inflammatory response is … the most likely cause of radiation-induced cardiovascular disease after low exposures, this … implies a role for non-targeted[3] radiation effects."

If the latter point about non-targeted effects is correct, this could be significant for low-dose CVD effects, as they could be greater than we currently think (Kadhim et al, 2013).

Quantitative risks of CVD

It is necessary to try and establish just how high the CVD risks are, i.e. to quantify them.

Shimuzu et al (2010) indicated linear, possibly linear quadratic, radiation – CVD relationships among the Japanese bomb survivors down to about 100 mGy, although the precise relationship at lower doses remained unclear. For heart disease, the estimated excess relative risk per gray was 0.14 (95% CI: 0.06 to 0.23, P<0.001). This means there was a 14% increase in CVD risk compared to people who were unexposed to radiation and the finding was highly statistically significant.

In 2017, the INWORKS study of nuclear industry workers (Gillies et al, 2017) found a statistically significant association between radiation dose and all non-cancer causes of death largely driven by all circulatory diseases (ERR/Sv = 0.22; 90% CI: 0.08, 0.37) which is a wider category of diseases.

The new BMJ study in 2023 observed an 11% increase per Gy (95% CI: 0.08, 0.14) for all cardiovascular disease, with ischaemic heart disease and cerebrovascular disease the most strongly associated with radiation (Little et al, 2023). Taken together, these studies have similar findings and point to a 11% to 14% increased relative risk per Gy for CVD.

How does this risk compare with currently observed cancer risks?

The most recent result for solid cancer risks is found in the latest report of the INWORKS study (Richardson et al, 2023). This found an ERR per Gy = 0.52 (90% CI:27% -97%) which is about four times higher than the CVD risk. Of course, when radiation limits are being set, we should look to the total fatal risks of radiation, that is, we need to add the two fatal risks (from cancer and CVD) together.

Absolute risks

However, another way of expressing risk exist – absolute risk. Indeed, up to the year 2000 or so it was usually the only way of expressing it. Unfortunately, many people are confused by the existence of two types of risk, but they are explained in the box below.

The new BMJ study has made estimates not only of the relative risk but also of the absolute risk of CVD from radiation. These vary slightly from country to country because they measure the risk compared to a background population risk which of course is different from country to country. (For example, stomach cancers are far more prevalent in Japan compared to all other countries, due to the high Japanese consumption rates of some sea foods which are carcinogenic.)

Relative risks and absolute risks

All risks concern increases in danger, and increases can be expressed in two ways. That is, absolutely (or additive) or relatively (or multiplicative).

Let's take an example of a pint of milk whose price has just been increased from, say, 75 pence to £1.25. You could say that the price was increased by 50 pence per pint: this is the absolute increase. But you could also say that the price had been increased by 50p/75p x 100% = 66% per pint.

Both methods are correct. The latter is the increase relative to the old price.

The same goes for risk. This can be expressed as an absolute risk per Gy which affects everyone. Or as a relative risk per Gy, relative to people who were not exposed. Both are correct methods, just like the pint of milk example.

The BMJ study estimates that the absolute risk of CVD disease in England and Wales is 3.66% per Gy of radiation with a 95% confidence interval of 1.69% to 2.98%. Ie this is a reliable finding not a chance one. The risks are dominated by cerebrovascular disease and ischaemic heart disease. The authors (Little et al, 2023) state 3.66% is a "modest but significant" risk. It can be compared with the current (but outdated) absolute risk of fatal cancer used by the ICRP of 5% per Sv.

The authors concluded that:
"Our findings suggest that radiation detriment might have been significantly underestimated, implying that radiation protection and optimisation at low doses should be rethought."
Also:
"These findings have implications for… policy makers involved in managing radiation risks to radiation workers and the public."

The problem is that the new CVD risks have been known and discussed for many years, but nothing has happened. For example, 14 years ago the UK Government's premier advisory body on radiation risks, the Advisory Group on Ionising Radiation (AGIR) stated:
"Radiological protection does not currently include circulatory diseases in the calculation of health detriment from low dose exposures. It is therefore timely to review the evidence for radiation association and causation of circulatory diseases and consider the likely need and implications for radiological protection to take these diseases into account in protection of health from low dose exposures and medical exposures." (McMillan et al, 2010)

But nothing was changed. So the question remains – will the UK Government take notice of the new findings above and tighten currently recommended radiation limits? E.g. the legal annual limit for individual exposures to the public which is currently set at 1 millisievert/year (1 mSv/a)?

An ICRP task group (TG119) is looking at this issue and many of the authors of the 2023 BMJ article are members. Let's cross our fingers.

2. Current risks for cancer have also increased

The current absolute risk from radiation (expressed as cancer deaths per sievert of exposure) of 5% per Sv was mainly established in 1990 by ICRP Publication 60 and re-iterated in ICRP Publication 103 in 2007.[4] These risks are based on the Life Span Study (LSS) of ~85,000 Japanese survivors of the atomic bombs dropped on Hiroshima and Nagasaki in 1945.

This figure is now not just outdated but is obsolete, as recent epidemiological evidence indicates that the LSS-based risks are too low and need to be revised. The new evidence is from the International Nuclear Workers' Study (INWORKS) (Hamra et al, 2016; Richardson et al, 2023) a metastudy of about 310,000 nuclear power workers in the US, UK, and France.

Nuclear workers in these studies were exposed to radiation which was measured in their film badges and TLD dosimeters, of which records had been kept for many years. In epidemiology, cohort/-study size is all-important as the larger the study the more confidence we have that its findings are real and not chance occurrences. The INWORKS studies cover four times as many exposed people than the LSS study, which lends authority and statistical weight to their findings. Indeed, these new risks should now be used for setting radiation safety limits etc. rather than the LSS study.

By how much should current risks be increased?

We can estimate from the latest study (Richardson et al, 2023) that the present ICRP risk of 5% per Sv for radiogenic fatal cancer should be increased to at least 13% per Sv, i.e. a 2.6-fold increase.

Gender sensitivity to radiation

A further issue needs to be considered by radiation authorities – that women and children are more sensitive to radiation than men.

In 2006, US BEIR VII report (NRC, 2006) indicated that women were at higher risk of radiogenic solid cancer than men of equivalent age (see Table ES-1 of BEIR VII). This showed adult women were at least 50% more sensitive to radiation than men, and that female children were approximately 10 times more sensitive to radiation than adult males (Olson 2011, 2019).

Unfortunately, the apparent increased female susceptibility to radiation was not remarked upon by the BEIR Report or by the press at the time. Future recommendations should take into account that women and children are more sensitive to radiation than men.

The need for safer limits

Unfortunately, the above new and added risks are not being taken into account by UK regulatory agencies. Nor is the increased radiosensitivity of children and women taken into account.

In CND's view, these matters need to be addressed immediately by, inter alia, the UK government's Health Security Agency. The above quotations by scientists in several scientific reports need to be taken seriously and responded to.

CND recommends that the revised absolute risks of fatal cancer (13% per Sv) plus CVD (3.66% per Sv) should be added together and a new single fatal risk of at least 17% per Sv should be published.

As this considerably increases our perception of radiogenic risks, consideration should also be given to tightening the annual public limit for radiation exposures from all sources at least threefold from 1 mSv/a to 0.3 mSv/a for adult males. For adult women the limit should be tightened further to 0.1 mSv/a and for all children tightened to 0.03 mSv/a to recognise their increased sensitivities to radiation.

Footnotes

1 In more detail, it is well known that high radiation doses to treat tumours (called radiotherapy) will usually result in adverse effects later. But it provides the cancer patient with some added years of life, as without the treatment, the patient could die from the untreated tumour(s).

2 A meta-analysis adds together data from several studies in order to increase the statistical significance of the findings in individual studies

3 "Non-targeted" means the radiation damage is not to the DNA molecule itself.

4 In the US, these risks were also broadly set out in the 2006 report of the US National Academy of Sciences' BEIR VII report (US National Research Council, 2006).

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162 Holloway Rd • London N7 8DQ • 020 7700 2393 • www.cnduk.org