Title: Cancer risk following low doses of ionising radiation—a 15-country study

Investigators:

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The study was coordinated by the International Agency for Research on Cancer (IARC).

Study purpose:

To estimate the risk of cancer death, including leukaemia, after low-level exposure to high-energy photon (mainly gamma-ray) radiation in a worldwide population of nuclear industry workers.

Radiation protection standards are mainly based on cancer risk estimates from studies of the Japanese atomic bomb survivors, who were exposed to relatively high-dose exposures at one point in time. This study was carried out to see if risk estimates derived from populations with low-dose, protracted exposures (such as are received by nuclear workers) scientifically support the current standards.

Study Population:

The IARC study followed 407,391 workers (men and women) who wore a radiation dosimeter or badge, and who worked for at least one year in the nuclear industry in one of 15 countries. Included were persons who worked in nuclear power plants, in nuclear research or waste management, or in the production of nuclear fuel, isotopes or weapons. Workers who might have had substantial neutron or internal (for example, plutonium) exposure were excluded because these exposures may have been poorly measured in the past. The study included workers from Australia, Belgium, Canada, Finland, France, Hungary, Japan, South Korea, Lithuania, Slovak Republic, Spain, Sweden, Switzerland, the UK, and the US.

How the study was done:

Cause of death was determined for all workers who had died. For each worker, radiation doses were taken from site records or dose registries within each country, and the total dose over the worker's lifetime was calculated (in Sieverts: Sv). Differences in radiation dose measurement procedures across countries, facilities and time periods were also taken into account. Statistical models were used to see if workers with higher radiation doses had a higher risk of cancer. These models accounted for other factors related to cancer, such as age, gender, time period, duration of employment, and socio-economic status. Because cancer is a disease with a very long latency or induction period, doses were lagged for two years for leukaemia and ten years for other cancers. This means that the doses received in the last two or ten years respectively were not included in the risk estimation as they are thought to have been received too recently to have had an influence on the risk of cancer.

The causes of death studied were: all cancers combined (except leukaemia), and all leukaemia combined (except chronic lymphocytic), because these are the main causes of death on which radiation protection standards are based. Results were compared to findings from the Japanese atomic bomb studies, since they are the primary basis for current radiation protection standards.

In this study, no information was available about whether the workers smoked tobacco or not, but smoking may be an important factor because it is strongly related to risk of certain cancers. Therefore, additional analyses were done of smoking and non-smoking related cancers, and of other, non-cancer smoking related diseases, in order to see if smoking could influence the risk estimates. The risk of all cancer excluding leukaemia was also studied after exclusion of lung cancer and pleural cancer, as these latter two cancers are strongly associated with smoking or asbestos exposure.

Study Findings:

Most of the workers were men (90%), and the average total workplace dose was about 19 millisievert (mSv, which equals 1.9 rem) per worker. Only about 6% of the international cohort had died, with a total of 6519 deaths from cancers other than leukaemia and 196 deaths leukaemia other than chronic lymphocytic.

The excess relative risk (ERR) for all cancers excluding leukaemia was elevated at 0.97 per Sv, with a 95% confidence interval (CI) ranging from 0.14 to 1.97. This means that the ERR for a worker with a dose of 19 mSv (the average dose observed in the study) is 0.02 (95% CI: 0.003, 0.04), corresponding to a 2% increase in that worker's risk of dying from all cancers excluding leukaemia. For a worker with a dose of 100 mSv, the ERR is 0.1 and the corresponding risk increase 10%. For leukaemia other than chronic lymphocytic, the ERR was 1.93 per Sv with a very wide 95% confidence interval which included 0 (<0 to 8.47).

In comparison, results for atomic bomb survivors indicate an ERR of 0.32 per Sv for cancers excluding leukaemia, and an ERR ranging from 1.54 to 3.15 per Sv for leukaemia excluding chronic lymphocytic depending on the statistical model used.

Analyses of smoking and non-smoking related causes of death indicate that, although smoking may play a role in the increased risk of all cancers excluding leukaemia, it is unlikely to explain all of this increased risk.

Discussion:

This study has several important strengths. The use of a common set of methods across facilities and countries helps ensure the accuracy of the risk estimates. This study was restricted only to workers with relatively well-measured radiation exposures, which reduces possible error from poor measurement of other exposures, such as exposures from neutrons and internal radiation. The risk estimates from this study are statistically similar to those of the atomic bomb survivor data at the same radiation dose, but the uncertainty in the estimates suggests that cancer risk could be lower than or up to six times greater per unit of dose than indicated by the A-bomb study. The leukaemia risk estimates are statistically consistent with no increased risk among exposed nuclear workers as well as with a risk nearly three times greater per unit of dose than found in the A-bomb study. Overall, the estimates of risk found in this study suggest that 1 to 2 per cent of deaths from cancer (including leukaemia) among the workers studied may have been caused by radiation exposure.

Conclusions:

This study provides radiation risk estimates from the largest study of nuclear industry workers ever carried out. The study suggests that there is a small increase in cancer risk even at the low doses and dose-rates typically received by nuclear workers in this study. The risk estimates from this study are consistent with those on which current radiation protection standards are based.

An additional report with detailed results for specific cancer types, specific countries, and other factors is scheduled to be available later this year.

Definitions:

Higher-energy photon radiation: Photon radiation includes various external radiations such as gamma-rays, x-rays, and scattered radiations. High-energy photon radiation, as the term is used in this study, refers to photon radiations with energies between 100 and 3000 kilo-electron volts (keV).

Sievert: A sievert (Sv) is a unit of equivalent dose resulting from any radiation type (such as neutron, beta, gamma, x-ray) that takes into account the relative biological effectiveness of the radiation. For a given dose, the equivalent dose in sieverts is equal to the absorbed dose in grays multiplied by the corresponding radiation weighting factor (1 Sv = 1000 mSv = 100 rem).

Excess relative risk (ERR): A measure of the change in relative risk of disease or death (usually, per unit of dose received) for a group of workers who are exposed to a known level, compared to those who are not exposed. The ERR is defined as the relative risk minus one. A positive ERR indicates risk that is greater among the exposed, while a negative ERR shows risk that is lower among the exposed. For example, an ERR per Sv of 1.00 indicates a relative risk that is doubled among those exposed to one sievert, that is increased by 10% among those who receive 100 mSv, and by 1% among those who receive 10 mSv, compared to those who are not exposed.

Cohort: A group of persons identified by common characteristics who are studied over a period of time.

CI (Confidence Interval): Confidence intervals reflect uncertainty in the stated risk estimates, for example, ERRs. Larger intervals indicate greater uncertainty.