Report of findings: Mortality among a pooled cohort of U.S. nuclear workers exposed to ionizing radiation

We studied cancer-related deaths in 119,195 U.S. nuclear workers who were monitored for exposure to ionizing radiation at work. We then compared their death rates to those in the general U.S. population.

What We Found

- We found a small, but statistically significant positive association between the workers' ionizing radiation dose and:
  - All non-smoking-related cancers combined,
  - Multiple myeloma,
  - The combined group of cancers including leukemia, lymphoma, and multiple myeloma
- In our study, the average total dose received was 20 millisieverts (mSv) (equal to 2 rem). About one in eight workers received a total dose to the bone marrow of 50 mSv (equal to 5 rem) or more.
  - The risk of non-smoking-related cancers increased by about 3.5% and the risk of multiple myeloma increased by about 20% at 50 mSv, compared to workers who had no exposure.
- There was no association between ionizing radiation and death from smoking-related cancers or from cardiovascular disease.
- We found that rates of most causes of death were lower for the workers we studied than for the general U.S. population. However, rates of death from cancer of pleura (the tissue lining the lung) and mesothelioma were higher for the workers we studied than for the general U.S. population.
  - We do not think this is due to radiation exposure.
  - We think this is possibly due to sources of asbestos within the US Department of Energy (DOE) sites, the shipyard, or elsewhere.

What does this mean?

Exposure to ionizing radiation cannot be avoided completely. According to the National Council on Radiation Protection & Measurements, on average persons in the U.S. receive an effective dose of about 6.0 mSv, or 0.006 Sieverts (Sv) each year from natural and man-made radiation sources.

The link between ionizing radiation exposure and some cancers is well known. However, much of this knowledge comes from studies of acutely exposed people, such as Japanese atomic bomb survivors and radiation therapy patients. Questions remain about using information from these studies to describe risks under much different (smaller doses over a longer period of time) exposure conditions, such as those experienced by nuclear workers.

This study supports previous findings and strengthens the evidence of a relationship between certain cancers and ionizing radiation. This relationship is observed not only at high doses following acute exposure, but also from prolonged, low exposures found in the workplace.

This information emphasizes the need for continued efforts to reduce ionizing radiation exposure to levels that are as low as reasonably achievable.

What should you do?

- If you currently work with radioactive materials or non-radioactive hazardous materials, contact your health and safety representative or employer if you have questions on how to best protect yourself from exposure.
- Share this information with your doctor if you are concerned about your health or have questions about these illnesses.

How the Study Was Done

Our approach is sometimes referred to as a retrospective cohort study, meaning that we followed the health experience of a group of persons over a time period beginning at some point in the past. We followed a group (cohort) of nuclear workers who were employed at one of four DOE sites or a nuclear shipyard. We followed this cohort from the start of their radiation work until 2005.

We estimated their excess relative rate, or ERR (that is, the relative risk minus 1) from exposure. The relative rate is the mortality rate in an exposed group compared to the mortality rate (for the same cause) in an unexposed group. For example, an ERR of 0.5 means that the cancer rate among persons with a given level of exposure was 50% higher than the rate among persons without exposure.

We were interested in the risk of certain cancers as it relates to the amount of radiation received during employment. To accomplish this, our study had four general steps:

Step 1. We assembled the study cohort.
Employment records were used to identify 119,195 workers from Hanford, Idaho National Laboratory, Oak Ridge National Laboratory, and the Portsmouth Naval Shipyard who worked at one of these facilities for at least 30 days and were monitored for external radiation exposure by wearing a radiation dosimeter, or "badge". We studied men and women who started working before the late 1970s (Hanford, Oak Ridge National Laboratory, and Portsmouth Naval Shipyard) or late 1980s/early 1990s (Savannah River Site, Idaho National Laboratory).

Step 2. We evaluated each worker's potential job-related exposures.
We used historical records of personal monitoring data that were maintained by dose registries, government records, and employer records to estimate the equivalent dose from gamma, neutrons, and tritium to each worker from all occupations (sometimes referred to as the worker's career whole-body dose).

Step 3. We obtained death information.
We studied cause of death among these workers beginning with their date of first monitoring for radiation exposure through 2005. To do this, we linked workers' information to national death databases and other record sources to learn whether a worker was alive or deceased and, if deceased, his or her underlying cause of death. For this study, we examined deaths from several causes: all cancers combined, cancers of the blood and lymphatic system combined (leukemia, lymphoma, and multiple myeloma), as well as some individual cancers. We split the all-cancer group into those that are smoking-related and those that are not smoking-related, to better understand whether cigarette smoking might confound our study. We did this because we did not have smoking information for the cohort, and smoking is a very important risk factor for many cancers. We also looked at a combined category of mesothelioma and pleura cancer to see whether exposure to asbestos might be a confounder in our study.

Step 4. We examined the relationship between radiation dose and selected outcomes.
Using standard methods of statistical modeling, we assessed the dose-response relation between ionizing radiation exposure and each cancer outcome of interest. We also compared the cohort's mortality rate for these different cancer outcomes to that of the general U.S. population.

Cancer Causes of Death We Evaluated:

- All cancers combined
- All cancers of the blood and lymphatic system combined
  - Leukemia
  - Lymphoma
  - Multiple myeloma
- Smoking-related cancers: oral cavity, esophagus, stomach, colon, rectum, liver, pancreas, larynx, lung, cervix, bladder, kidney and ureter
- Non-smoking related cancers: breast, brain, male genital (including prostate), uterus, skin, bone and connective tissue, eye, peritoneum, pleura, mesothelioma, thyroid and endocrine glands, lymphoma, multiple myeloma.

Study limitations

This study has a number of limitations including incomplete or imperfect information on radiation doses and other risk factors such as asbestos exposure and tobacco use. The impact from these limitations is believed small and unlikely to change study conclusions.

For more information

Schubauer-Berigan MK, Daniels RD, Bertke SJ, Tseng CY, Richardson DB [2015]. *Cancer mortality through 2005 among a pooled cohort of U.S. nuclear workers exposed to external ionizing radiation.* Radiat Res. 183:620–631. DOI: 10.1667/RR13988.1 [Epub ahead of print] PubMed PMID: 26010709.

February 2016