Evidence of Increasing Sensitivity to Radiation at Older Ages Among Workers at Oak Ridge National Laboratory

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Introduction

Exposure to low level radiation is common for workers in many industries, for patients receiving medical and dental care, and for everyone exposed to the environmental releases from nuclear facilities, weapons detonations, and waste sites [1, 6]. Consequently, questions about the long-term effects of low level radiation exposure are of broad public concern. One way to address questions about the long-term health effects of low level exposure to ionizing radiation has been to study workers in the nuclear industry, many of whom were hired during the early development of nuclear reactors and the United States' atomic weapons program. The literature on radiation health effects, however, is marked with inconsistent findings and critical debate [7]. National and international committees evaluating the health effects of radiation have concluded that the estimates of the effects of occupational exposure to low level radiation tend to be small and extremely unstable. In contrast, the work of Alice Stewart and George Kneale, has repeatedly demonstrated differences in the effects of radiation depending on time-related factors, suggesting that low doses of radiation received at older ages and under long latency assumptions, may be associated with substantial increases in cancer mortality [8, 9].

The goal of this study was to examine the association between external ionizing radiation and cancer mortality among workers employed at Oak Ridge National Laboratory (ORNL), while examining time-related factors which may affect estimates of the dose-response relationship. Compared to other workers in the nuclear industry, workers employed at ORNL have a long history of vital status follow-up and particularly detailed information about external radiation exposure, especially for exposures received in the early years of operation of the nuclear industry [10]. Consequently, this cohort provides some of the best data available on occupational radiation exposure.

Materials and methods

ORNL was created as a facility for research and development of the atomic bomb, and the atomic pile there was used to create small amounts of plutonium. Since World War II, the ORNL facility has been used for energy-related research. This study included all white males hired at ORNL between January, 1943 and the end of 1972, who had worked at least 30 days, had known dates of birth and hire, and for whom there was no record of employment at any other Department of Energy facility (n=8307). Vital status through 1990 was ascertained through Social Security Administration, National Death Index, and employer records. Underlying causes of death, and cancer contributory causes, were coded to the eighth revision of the International Classification of Diseases adapted for the United States (ICDA8). All cancer mortality was defined to include any death for which an ICDA8 code of 140-209 appeared as an underlying or contributory cause.

Exposure to external penetrating radiation, primarily gamma rays, was measured using individual dosimeters that were, for most years, incorporated into security badges necessary for entering the facility [10].

Doses were estimated for work-years for which data were missing (3% of the work-years) using a method that considered radiation doses in time periods adjacent to the missing dose, or annual departmental means.

Poisson regression methods were used to estimate the percent change in cancer mortality rate per unit of radiation dose, adjusting for sociodemographic and employment factors. Analyses controlled for age at risk, year of birth,, paycode (a measure of socioeconomic status), employment status, and, monitoring for internal radionuclide contamination. In order to consider differences in the effects of radiation doses received at different ages, person-time and deaths were classified according to the level of cumulative dose received at all ages, or according to the level of cumulative dose received during specified ranges of age (for example, cross-classifying person-time and deaths according to the level of dose accrued before and after age 45). To evaluate potential biases, we examined dose response associations for separate hire cohorts, for deaths occuring at different ranges of age, and after different periods of followup.

Results

By the end of followup, 561 cancer deaths were identified. A positive association (1.8 % per 10 mSv, se=0.9) was observed between radiation doses received at all ages and cancer mortality, considering a ten year lag assumption. Doses received at older age exhibited stronger associations with cancer mortality than doses received at younger age. Doses received after age 45 were associated with a 5.9 % (se=1.7) increase in cancer mortality per 10 mSv, adjusted for doses received before age 45. Compared to results for radiation doses received at all ages, doses received after age 45 showed more consistent associations with cancer mortality across different periods of follow-up, periods of hire, and ages at risk.

Conclusions

The main finding of these analyses is that radiation demonstrates a strong association with external radiation doses received at older age. Results suggest that sensitivity to the carcinogenic effects of low level ionizing radiation progressively increases with age during adult life. Stewart and Kneale have reached similar conclusions in analyses of workers at US Department of Energy facilities [4, 5, 9]. These results pertain to all cancer mortality under a ten year lag assumption. We focused on all cancer mortality in order to present findings for a broad category of interest, reflecting the potentially large number of sites affected by whole-body exposure to radiation.

In order to consider whether dose response associations differed among workers hired in the early years of operation, we evaluated radiation-cancer dose response relationships separately for workers hired before and after 1947. Following a suggestion of previous researchers, we also considered whether confounding, for example due to cigarette smoking, may have led to excess cancer mortality at ORNL among workers at older age who received higher radiation doses [2, 3]. In order to evaluate dose response associations for deaths occurring at different ages, associations were evaluated separately for deaths occurring at ages less than 70 years and greater than 70 years. Finally, we evaluated the stability of dose response estimates with the inclusion of additional years of follow-up. Associations between occupational radiation doses received at older ages and subsequent cancer mortality were of larger magnitude, better fit, and more consistent between periods of hire, age at risk, and follow-up, than were associations with doses received at all ages. Results suggest that among workers at ORNL doses received at older ages have

a much stronger association with total cancer mortality than expected from BEIR V estimates [6].

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