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Effects of Low Doses and Low Dose Rates of External Ionizing Radiation: Cancer Mortality among Nuclear Industry Workers in Three Countries

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Studies of the mortality among nuclear industry workforces have been carried out, and nationally combined analyses performed, in the U.S., the UK and Canada. This paper presents the results of internationally combined analyses of mortality data on 95,673 workers (85.4% men) monitored for external exposure to ionizing radiation and employed for 6 months or longer in the nuclear industry of one of the three countries. These analyses were undertaken to obtain a more precise direct assessment of the carcinogenic effects of protracted low-level exposure to external, predominantly γ , radiation. The combination of the data from the various studies increases the power to study associations between radiation and specific cancers. The combined analyses covered a total of 2,124,526 person-years (PY) at risk and 15,825 deaths, 3,976 of which were due to cancer. There was no evidence of an association between radiation dose and mortality from all causes or from all cancers. Mortality from leukemia, excluding chronic lymphocytic leukemia (CLL)—the cause of death most strongly and consistently related to radiation dose in studies of atomic bomb survivors and other populations exposed at high dose rates—was significantly associated with cumulative external radiation dose (one-sided P value = 0.046; 119 deaths). Among the 31 other specific types of cancer studied, a significant association was observed only for multiple myeloma (one-sided P value = 0.037; 44 deaths), and this was attributable primarily to the associations reported previously between this disease and radiation

dose in the Hanford (U.S.) and Sellafield (UK) cohorts. The excess relative risk (ERR) estimates for all cancers excluding leukemia, and leukemia excluding CLL, the two main groupings of causes of death for which risk estimates have been derived from studies of atomic bomb survivors, were -0.07 per Sv [90% confidence interval (CI): -0.4, 0.3] and 2.18 per Sv (90% CI: 0.1, 5.7), respectively. These values correspond to a relative risk of 0.99 for all cancers excluding leukemia and 1.22 for leukemia excluding CLL for a cumulative protracted dose of 100 mSv compared to 0 mSv. These estimates, which did not differ significantly across cohorts or between men and women, are the most comprehensive and precise direct estimates of cancer risk associated with low-dose protracted exposures obtained to date. Although they are lower than the linear estimates obtained from studies of atomic bomb survivors, they are compatible with a range of possibilities, from a reduction of risk at low doses, to risks twice those on which current radiation protection recommendations are based. Overall, the results of this study do not suggest that current radiation risk estimates for cancer at low levels of exposure are appreciably in error. © 1995 by Radiation Research Society

INTRODUCTION

Current estimates of cancer risk associated with external exposure to low-linear energy transfer (LET)^{2,3} ionizing

²Low-LET radiations: γ and X rays in the range 100 to 2500 keV.

³Abbreviations used: AEA, Atomic Energy Authority; AECL, Atomic Energy of Canada Ltd.; AWE, Atomic Weapons Establishment; CLL, chronic lymphocytic leukemia; CML, chronic myeloid leukemia; DDREF, dose and dose-rate effectiveness factor; ERR, excess relative risk; IARC, International Agency for Research on Cancer; ICRP, International Commission on Radiological Protection; LET, linear energy transfer; ORNL, Oak Ridge National Laboratory; RERF, Radiation Effects Research Foundation; RR, relative risk; SES, socio-economic status; UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation.

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