Public Summary

INTRODUCTION

The health effects of low levels of ionizing radiation are important to understand. Ionizing radiation—the sort found in X-rays or gamma rays—has sufficient energy to displace electrons from molecules. Free electrons, in turn, can damage human cells. One challenge to understanding the health effects of radiation is that there is no general property that makes the effects of man-made radiation different from those of naturally occurring radiation. Still another difficulty is that distinguishing cancers that occur because of radiation exposure from cancers that occur due to other causes. These facts are just some of the many that make it difficult to characterize the effects of ionizing radiation at low levels.

Despite these challenges, a great deal about this topic is well understood. Specifically, substantial evidence exists that exposure to high levels of ionizing radiation can cause illness or death. Further, scientists have long known that in addition to cancer, ionizing radiation at high doses causes mental retardation in the children of mothers exposed to radiation during pregnancy. Recently, data from atomic bomb survivors suggest that high doses are also connected to heart disease and stroke.

Because ionizing radiation is a threat to health, it has been studied extensively. This report is the seventh in a series of publications from the National Academies concerning radiation health effects, referred to as the Biological Effects of Ionizing Radiation (BEIR) reports. This report, BEIR VII, focuses on the health effects of low levels of low linear energy transfer (LET) ionizing radiation. Low-LET radiation deposits less energy in the cell along the radiation path and is considered less destructive per radiation track than high-LET radiation. Examples of low-LET radiation, the subject of this report, include X-rays and γ-rays (gamma rays). Health effects of concern include cancer, hereditary diseases, and other effects, such as heart disease.

This summary describes:

- how ionizing radiation was discovered,
- how ionizing radiation is detected,
- units used to describe radiation dose,
- what is meant by low doses of ionizing radiation,
- exposure from natural “background” radiation,
- the contribution of man-made radiation to public exposure,
- scenarios illustrating how people might be exposed to ionizing radiation above background levels,
- evidence for adverse health effects such as cancer and hereditary disease,
- the BEIR VII risk models,
- what bodies of research the committee reviewed,
- why the committee has not accepted the view that low levels of radiation might be substantially more or less harmful than expected from the model used in this BEIR report, and
HOW IONIZING RADIATION WAS DISCOVERED

Low levels of ionizing radiation cannot be seen or felt, so the fact that people are constantly exposed to radiation is not usually apparent. Scientists began to detect the presence of ionizing radiation in the 1890s. In 1895, Wilhelm Conrad Roentgen was investigating an electrical discharge generated in a paper-wrapped glass tube from which most of the air had been evacuated. The free electrons generated in the “vacuum tube,” which were then called cathode rays, were made of X-rays and are man-made and generated by machines, whereas gamma rays occur from naturally occurring elements in the earth and outer space. People are continuously exposed to gamma rays from naturally occurring elements in the earth and outer space.


UNITS USED TO DESCRIBE RADIATION DOSE

Ionizing radiation can be in the form of electromagnetic radiation, such as X-rays or gamma rays—a form of radiation that has sufficient energy to displace electrons from molecules. Free electrons, in turn, can damage human cells. One challenge to understanding the health effects of radiation is that there is no general property that makes the effects of man-made radiation different from those of naturally occurring radiation. Still another difficulty is that distinguishing cancers that occur because of radiation exposure from cancers that occur due to other causes. These facts are just some of the many that make it difficult to characterize the effects of low levels of ionizing radiation at low doses. Despite these challenges, a great deal about this topic is well understood. Specifically, substantial evidence exists that exposure to high levels of ionizing radiation can cause illness or death. Further, scientists have long known that radiation exposure can cause cancer. Studies show that ionizing radiation at high doses causes mental retardation in the children of mothers exposed to radiation during pregnancy. Recently, data from atomic bomb survivors suggest that high doses are also connected to other health effects such as heart disease and stroke. Because ionizing radiation is a threat to health, it has been studied extensively. This report is the seventh in a series of publications from the National Academies concerning radiation health effects, referred to as the Biological Effects of Ionizing Radiation (BEIR) reports. The BEIR VII report includes the most recent and comprehensive data on the health effects of low levels of ionizing radiation and on the risk of genetic effects. It is intended to provide our own search engines and external engines with highly rich, chapter-representative searchable text on the opening pages of each chapter. Because it is UNCORRECTED material, please consider the following text as a useful but insufficient proxy for the authoritative book pages.

Below are the first 10 and last 10 pages of uncorrected machine-read text (when available) of this chapter, followed by the top 30 algorithmically extracted key phrases from the chapter as a whole.

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population exposure, while mammalian source contributed 18% (see Figure PS-2, pie chart in the lower left portion of the figure). In Figure PS-2, the man-made radiation component (upper right portion of the figure) shows the relative contribution of each major category of man-made radiation to the total population exposure. T-7 Medical X-rays are the largest contributor to the total population exposure, followed by diagnostic and medical CT scans, nuclear medicine, X-rays from other medical procedures (e.g., mammography, nuclear medicine, CT scans), and finally, domestic X-ray imaging (e.g., dental X-rays, mammograms, CT scans, and other medical procedures). T-8 The results of the BEIR VII Phase 2 study are in agreement with previous estimates from other national and international organizations, such as the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). These organizations have shown that the majority of the radiation exposure to the population is from CT scans, mammography, and nuclear medicine procedures.

**Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2**

**Figure PS-2:** Pie chart showing the contribution of man-made radiation sources (18%) to the total radiation exposure of the United States. (Based on data from the National Council on Radiation Protection and Measurements Reports 92-93 and 100. Washington, DC: NCRP.)

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### Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2

**Figure PS-3:** The committee's estimates for the linear-no-threshold (LNT) model are based on the results of epidemiological studies of atomic bomb survivors. The committee also considered radiation risk information from studies of children of A-bomb survivors. The indicators that were used included adverse pregnancy outcomes (i.e., stillbirths, early neonatal deaths, congenital abnormalities); deaths among live-born infants over a follow-up period of about 26 years; growth and development of the survivors and their children; and incidence of cancer in the children of survivors. The committee concluded that there is strong evidence of increased cancer risk among the children of A-bomb survivors. However, the committee also noted that there is a lack of evidence of increased risk for other health effects, such as congenital abnormalities and growth and development delays. The committee recommended that further research be conducted to better understand the biological and genetic mechanisms underlying the increased cancer risk among the children of A-bomb survivors.

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**Health Risks from Low Levels of Ionizing Radiation: BEIR VII Phase 2**

**Part G: Radiation Induced Genetic Effects**

The committee concludes that current scientific evidence is consistent with the hypothesis that there is no threshold for carcinogenic effects of radiation. The evidence is not consistent with the notion of a threshold for genetic damage. The committee concludes that the excess relative risk (ERR) per gray from the studies of acute or fractionated high dose-rate exposures are statistically compatible and in the range 0.1–0.4 per Gy. For breast cancer, both the ERR and the excess absolute risk (EAR) appear to be quite variable across studies. A pooled analysis of A-bomb survivors and selected medically exposed cohorts indicated that the EAR for breast cancer was similar (about 10 per 10^4 person-years ([PY]) per gray at age 50) following acute and chronic exposure.

**EVIDENCE FROM EPIDEMIOLOGY**

**Studies of Atomic Bomb Survivors**

The Life Span Study (LSS) cohort of survivors of the atomic bombings in Hiroshima and Nagasaki continues to serve as a major source of information for the evaluation of radiation effects in humans. This cohort includes individuals who received radiation doses ranging from less than 0.01 Gy to over 1000 Gy. The committee concludes that the excess relative risk of breast cancer is similar following acute and chronic exposures. The excess relative risk of breast cancer is also similar following exposure of the fetus in utero or Radiation: BEIR VII Phase 2

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that there is a linear, no-threshold dose-response relationship between exposure to ionizing radiation and the development of cancer in humans. RECOMMENDED RESEARCH NEEDS A more detailed listing of the BEIR VII recommended research needs can be found at the end of Chapter 13. Research Need 1: Determination of the level of various molecular markers of DNA damage as a function of low-dose ionizing radiation. Currently identified molecular markers of DNA damage and other biomarkers that can be identified in the future should be used to quantify low levels of DNA damage and to identify the chemical nature and repair characteristics of the damage to the DNA molecule. TABLE ES-1: The Committee's Preferred Estimates of the Lifetime Attributable Risk of Impairment and Mortality for All Solid Cancers and for Leukemia. All Solid Cancers Leukemia Male Male Female Female Excess cases (including nonfatal cases) from exposure to 0.1 Gy 800 (400, 1400) 2100 (1800, 2500) 800 (400, 1500) 2100 (1800, 2500) Number of deaths in the absence of exposure 22,100 17,300 710 530 NOTE: Number of cases or deaths per 100,000 exposed persons. 95% subjective confidence intervals.

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Representative terms from entire chapter:

radiation exposure