

A REVIEW OF 40 YEARS STUDIES OF HIROSHIMA AND NAGASAKI ATOMIC BOMB SURVIVORS

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The late health effects of ionizing radiation have been studied by the Atomic Bomb Casualty Commission (ABCC) and its successor, the Radiation Effects Research Foundation (RERF) based on a fixed population of atomic bomb survivors in Hiroshima and Nagasaki which had been established in 1950.

The results thus far obtained up to the present can be classified into the following three categories:

- (1) The effects for which a strong association with atomic bomb radiation has been found include malignant neoplasms, cataracts, chromosomal aberrations, small head size and mental retardation among the in utero exposed.
- (2) A weak association has been found in the several sites of cancers, some non-cancer mortalities and immunological abnormalities.
- (3) No association has been observed in some types of leukemia, osteosarcoma, accelerated aging, sterility and hereditary effects.

The effects of the atomic bombs dropped on Hiroshima and Nagasaki in August 1945 consist of a combination of blast, heat, and radiation. The energy released was mostly in the form of blast and heat, accounting for 50% and 35%, respectively. Radiation accounted for only 15% of the total energy, something like a "by-product". For the Hiroshima bomb, the blast waves extended to a distance of 4 km and heat to 3.5 km. On the other hand, gamma rays reached out only to about 2 km and neutrons to a much shorter distance.

The energy distribution of the blast, heat, and radiation of the Nagasaki bomb was similar to that of the Hiroshima bomb. However, the respective components traveled 0.5 or 1 km farther than in Hiroshima because the Nagasaki bomb was more powerful than the Hiroshima bomb. The radiation released by the Nagasaki bomb was characterized by a smaller proportion of neutrons.

The populations of Hiroshima and Nagasaki at the time of the atomic bombings were said to be about 330,000 and 250,000, respectively. The total number of instantaneous deaths and acute radiation deaths until the end of December 1945 has been estimated to be about 1/3 of the total population in both cities.

An important injury caused by the atomic bombing is heat burns. Data from animal experiments suggest that health effects of radiation could be aggravated by a

combination with heat burns. Epilation occurred at around two weeks after exposure to 3 gray of radiation. The occurrence of epilation among those exposed at the time of the Chernobyl nuclear power plant accident indicates that there had been exposure to a similar level of radiation. They were mainly plant workers and firemen.

The late health effects of ionizing radiation have been studied by the United States Atomic Bomb Casualty Commission (ABCC) in cooperation with the Japanese National Institute of Health, and its successor, the Radiation Effects Research Foundation (RERF) which is equally funded by the two governments of Japan and the United States.

The program of the ABCC-RERF studies consists of three groups. First is the follow-up of a fixed population of atomic bomb survivors which had been established in 1950. This includes the Life Span Study for the survey of life span and causes of death, the Pathology Program for the elucidation of causes of disease by autopsy and other means, the Adult Health Study to identify the health status and detect disease in the participants by periodic health examinations, and the In Utero Study of those who had been exposed during the pregnancy of their mothers.

Second is the study of the offspring of atomic bomb survivors. This includes the Mortality Study, Biochemical Genetics Study, and Cytogenetics Study of the Children.

Third includes other studies, such as studies of cardiovascular diseases, cancers, experimental pathology and immunology studies. Efforts were also made from the earliest period to develop accurate estimates of individual radiation doses, and recently the DS86 (Dosimetry System 1986) became available for use. Reanalyses of all relevant epidemiological data have been carried out based on this new dosimetry system, and it has been suggested that health risks for radiation might be several times higher than before.

Various methods have been adopted for following the exposed population for late health effects. The Japanese family registration system enables almost complete follow-up of deaths and their causes. The tissue registry system is unique, and the tumor registries in Hiroshima and Nagasaki have the longest history in Japan.

The results thus far obtained to the present can be classified into the three categories (Table 1):

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(2) A weak association has been found in the several sites of cancers, some non-cancer mortalities and immunological abnormalities.

(3) No association has been observed in some types of leukemia, osteosarcoma, accelerated aging, sterility and hereditary effects.

The periods when the radiation-induced deaths developed after the atomic bombing can be shown schematically (Fig. 1). Acute deaths due to atomic bomb radiation had occurred within 4 months after the bombing. Leukemia began to increase from the

Table 1

**Current evidence from ABCC/RERF studies
for late health-related effects of radiation**

Association with atomic bomb radiation	STRONG Statistically significant results in one or more studies. Questions about potential biases are largely resolved. Risk clearly related to amount of exposure.	WEAK Borderline statistical significance or inconsistent results. More studies may be needed.	NONE No statistically significant effect observed. This may reflect a true lack of effect, or be a consequence of inadequate sample size.
A-Bomb Survivors (except In-Utero Survivors)			
Malignant Tumors	Leukemia (except chronic lymphoid leukemia and adult T-cell leukemia); Breast (women); Thyroid; Colon; Stomach; Lung; Ovary	Esophagus; Salivary glands; Liver; Skin; Urinary bladder; Nervous system; Multiple myeloma; Malignant lymphoma	Chronic lymphoid leukemia; Adult T-cell leukemia; Pancreas; Gallbladder; Rectum; Uterus; Bone
Non-cancer Diseases and Conditions	Radiation cataract; Hyperparathyroidism; Delays in growth and development (exposed at young ages)	Cardiovascular mortality and total non-cardiovascular mortality at high doses (>1.5 Gy); Thyroid diseases; Chronic hepatitis and liver cirrhosis; Myoma uteri	Infertility; Glaucoma; Autoimmune diseases; Physiologic aging; Senile cataracts
Immune Competence	Decrease in T-cell mediated responses; Changes in humoral immune response	Susceptibility to viral infections; Increased autoantibodies	Changes in natural immune responses
Chromosomal Aberrations	Lymphocytes		
Somatic Mutations	Erythrocytes	Lymphocytes	
In-Utero Survivors			
Malignant Tumors		Total solid tumors	Leukemia
Non-cancer Diseases and Conditions	Microcephaly; Mental retardation; Delays in growth and development; Poorer school performance; Lower IQ		Non-cancer mortality
Chromosomal Aberrations		Lymphocytes	

(Notes) For the children of A-bomb survivors (F₁), no effects with statistical significance (including borderline statistical significance) have yet been found in relation to exposure to atomic bomb radiation. With regard to the following effects, it has been confirmed that there are no statistically significant relationships with atomic bomb radiation: Solid tumors, leukemia, stillbirth, major congenital anomalies, early mortality, chromosomal abnormalities and protein variants.

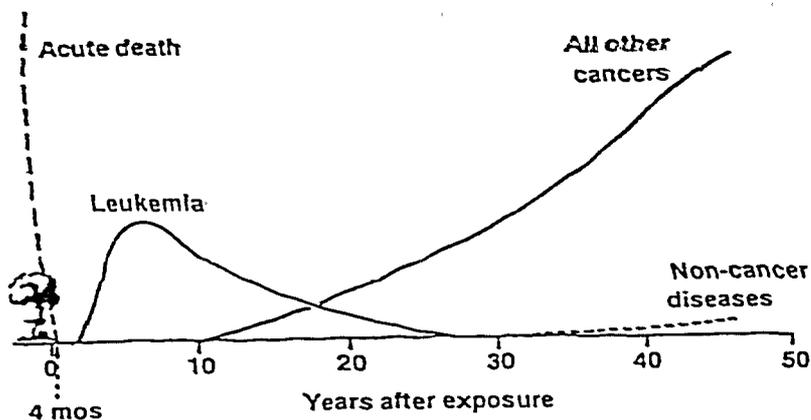


Figure 1 Health effects after A-bombing

can be shown schematically (Fig. 1). Acute deaths due to atomic bomb radiation had occurred within 4 months after the bombing. Leukemia began to increase from the second or third year after exposure and reached the peak at the sixth year. All other cancers started to increase from the tenth year after exposure and is still continuing its increasing tendency.

According to the attributable risk percents to radiation for all causes of death among the survivors during the past 35 years, excess deaths are observed mainly in cancer and few in other causes of death. The breakdown of attributable risk percents for cancer deaths by site indicates that, although the actual number of deaths is small, 55% of leukemia deaths are attributable to atomic bomb radiation, followed by 33% of multiple myeloma, 23% and 22% of urinary and breast cancer, respectively. In colon and lung cancer 15% and 11%, respectively, are attributable to atomic bomb radiation.

One of the most important findings obtained from the In Utero Study is that the frequency of mental retardation was highest among those exposed during the 8th to 15th week of gestation, followed by those in the 16th to 25th week of gestation. No cases have been reported among those exposed during other periods of gestation.

According to the survival status of the exposed in Hiroshima and Nagasaki during the past 40 years which is compared with that of the non-exposed, about 60% of the survivors are still alive. The percentage of survivors among the exposed is not so different from that of the non-exposed.

Since the ABCC-RERF fixed population doses not include those persons who died between the time of the atomic bombings in 1945 and 1950, it has been presumed that this may have resulted in the inclusion of individuals who were more resistant to radiation. However, this fact has not been proved yet.

Finally, I would like to express sincere appreciation to the survivors and their families for their cooperation in the studies by ABCC-RERF.