Introduction to the Radiation Effects Research Foundation

Radiation Effects Research Foundation in Hijiyama Park, Hiroshima

放影研
RERF

Contents

Introduction

The Radiation Effects Research Foundation (RERF) was preceded by the Atomic Bomb Casualty Commission (ABCC), which was established in 1947 and reorganized into the present-day joint U.S.-Japan research organization in 1975, and thus the study of A-bomb survivors has continued for more than 60 years. Continuing the study this far would not have been possible without the steadfast financial support of the governments of Japan and the United States, cooperation of the survivors, and support from the local communities, to whom we extend our deepest gratitude.

There are no other epidemiologic studies of health and longevity on a population of more than 120,000 individuals that have continued for more than 60 years. Nevertheless, the entirety of the effects of A-bomb radiation on human health has not been fully elucidated. Approximately 40% of all A-bomb survivors remain alive. Among A-bomb survivors who were 20 years old or younger at the time of the bombings, however, more than 70% are still living, and thus future research is crucial. With RERF's mission etched firmly in mind, we resolve to make further efforts to contribute to the health and welfare of the A-bomb survivors, and to meet the needs of the global community in terms of radiation-related medical treatment and safety measures.

We have prepared this booklet in hopes that it will aid the reader in understanding our foundation' s activities. We welcome your comments and suggestions.

May 2015

Radiation Effects Research Foundation

1. About the Radiation Effects Research Foundation

Purpose of endowment

The Radiation Effects Research Foundation (hereafter abbreviated as "RERF") was inaugurated in 1975 as a nonprofit organization according to an agreement between the governments of Japan and the United States. The mission of RERF is clearly defined: "to conduct research and studies for peaceful purposes on medical effects of radiation and associated diseases in humans, with a view to contributing to maintenance of the health and welfare of the atomic bomb survivors and to enhancement of the health of all humankind." RERF is also unique in that Japan and the U.S. jointly manage its budget, personnel, and other matters. Article 40 of Japan's Law Concerning Support for the Atomic Bomb Exposed (Atomic Bomb Survivors Support Law*) prescribes the obligation of the Japanese government to promote such research and studies and provide funding.

Important research tasks at RERF include estimating the doses of radiation exposure among A-bomb survivors and analyzing the effects of exposure on human health. An extensive interview survey was conducted in the 1950s, based on which records were compiled for each A-bomb survivor. These records concerned location and structure of the building the survivor may have been in at the time of the bombing. Based on these records, radiation doses were calculated for most of the A-bomb survivors. Our mission is to use this information to document in detail, for posterity, how the A-bombings and their radiation affected A-bomb survivors. Furthermore, the results of all studies are made public, and in addition to contribution to the welfare of A-bomb survivors, these results have significantly contributed to the establishment internationally of dose limits for radiation protection purposes.

Along with our hope that never again should such devastation from nuclear weapons occur, we must not forget that the noble sacrifice of A-bomb survivors contributes to protecting the safety, in terms of radiation exposure, of many persons throughout the world.

History

The predecessor organization to RERF was the Atomic Bomb Casualty Commission (ABCC). ABCC was established after the end of World War II (in Hiroshima in 1947,[1] and in Nagasaki in 1948) by the U.S. National Academy of Sciences (a private scientific organization), with funding from the U.S. government (Atomic Energy Commission). It was joined in 1948 by the Japanese National Institute of Health, part of the Ministry of Health and Welfare, and studies were conducted on A-bomb survivors within a framework of binational collaboration. In practice, however, ABCC had the initiative, and the U.S. side bore most of the expenses.

ABCC was established to determine how, over the long term, exposure to radiation affected the health of A-bomb survivors. At that time, Japan was occupied by the Allied Forces. Many people were critical of the United States, which had dropped the bombs, for studying the A-bomb survivors, who were the victims of the bombings, and objected to these studies.[2] We who continue the programs begun by ABCC regret any misfortune or unhappiness the early studies caused the survivors. Despite these circumstances, many A-bomb survivors cooperated in the ABCC studies. Because of their cooperation, the long-term studies got off to a good start and continue successfully to this day.

The results of early ABCC studies were reported to the Japanese Ministry of Health and Welfare, and they served as the basis for enactment of the A-bomb Survivors Medical Treatment Law* in 1957.

(*Described in the Glossary section at the end of the booklet)

Notes: 1. Some people assert that ABCC demolished a military cemetery to construct the research laboratory on Hijiyama in the city of Hiroshima in 1950. However, as mentioned in the “Short History of the Military Cemetery on Hijiyama,” the truth is that, “demolition was based on a 1944 agreement (one year before the end of the war) between the military and municipal authorities that all grave markers were to be removed for the construction of a joint grave marker, under which all the war dead involved would be enshrined.” Reportedly, the military and municipal authorities intended to use the site to construct an antiaircraft gun base.

2. Many of the researchers involved in conducting the early studies understood the criticism and felt compassion, and hoped to elucidate radiation’s effects for the sake of the survivors.

2. Yield (energy) of A-bombs dropped on Hiroshima and Nagasaki

The yields of energy generated by the atomic bombs dropped on Hiroshima and Nagasaki are thought to have been equivalent to 16,000 tons and 21,000 tons, respectively, of TNT (trinitrotoluene, explosive used in dynamite). A yield of such magnitude is unimaginable from a single conventional bomb. However, some hydrogen bombs (i.e., bombs in which the energy of the A-bomb is used to ignite nuclear fusion* of hydrogen atoms, as occurs in the sun) with a yield of more than one million tons (1 megaton) of TNT have since been produced by the U.S. and former U.S.S.R. The bomb tested by the U.S. in the Bikini atoll in 1954, when the fishing boat Lucky Dragon Five was exposed to the so-called "ashes of death," was reported to have had a yield as high as 15 megatons.

The energy of the A-bombs was generated by nuclear fission.* About 50% of the energy was released as blast, 35% as heat, and 15% as radiation. The blast and heat rays affected areas within a radius of 4–5 km from the hypocenter, but little radiation seems to have reached beyond 2.5 km in Hiroshima and 3 km in Nagasaki (Figures 1 and 2). Radiation dose increased with proximity to the hypocenter but varied because of shielding* provided by buildings, terrain, and the like. Since the bombs detonated in the air at heights of 503 and 600 meters in Nagasaki and Hiroshima, respectively, radioactive contamination on the ground was minimal (if the bombs had detonated on the ground, contamination could have rendered the areas uninhabitable).

Exposure to A-bomb radiation can be classified into primary exposure (mainly to gamma rays and neutrons) and exposure to residual radiation.* Residual radiation consists of radiation induced by neutrons and radioactive fallout contained in black rain. The levels of induced radiation were highest near the hypocenters, but decreased rapidly with distance from the hypocenters and time after the A-bombings. The levels of radioactive fallout were highest in the Koi and Takasu districts in Hiroshima and in the Nishiyama district in Nagasaki.

Figure 1. Distribution of energy released from the atomic bombs (%) and distance attained

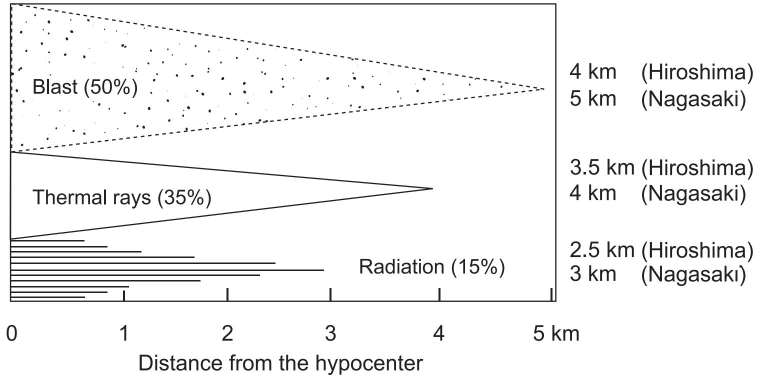
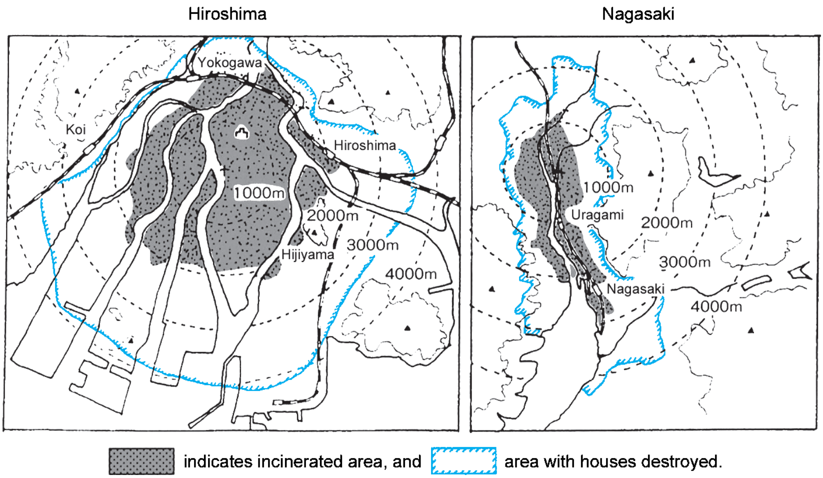


Figure 2. Areas incinerated by the atomic bombs and areas with houses destroyed by the bombs



3. What is radiation?

Radiation can be thought of as "transmission of energy through space" (according to Dr. Sohei Kondo, Professor Emeritus of Osaka University). Specifically, radiation comprises electromagnetic waves* or particle radiation with kinetic energy, which typically refer to X rays, gamma rays, beta particles (Figure 3), alpha particles, and neutrons.

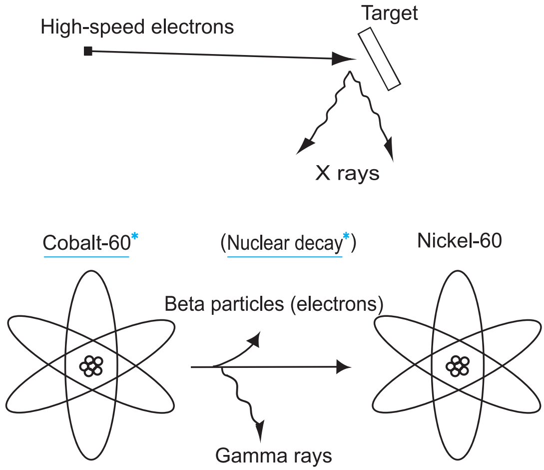
The X ray was discovered in 1895 by Dr. Wilhelm Conrad Roentgen, who observed that a strange light was emitted when high-speed electrons collided against metal. An X ray has the same properties as ordinary light (i.e., electromagnetic waves). However, the X ray has a higher energy (shorter wave length) and is capable of passing through substances. When it passes through the human body, it causes various injuries to cells.

The gamma ray is also an electromagnetic wave with the same properties. The difference is the process of its generation; it is released as extra energy when atomic nuclei decay. A-bomb radiation is composed mostly of gamma rays.

Together, alpha particles, beta particles, and neutrons are called particle radiation. Not electromagnetic waves, they are particles with high energy (i.e., velocity). Among the cosmic rays* that originate in the cosmos are particle rays with so much energy that they pass right through the earth.

The ability to release radiation is called "radioactivity," and materials having such ability are called "radioactive substances."

Figure 3. X rays have the same properties as gamma rays (they both behave as electromagnetic waves), although they are produced differently.



Radiation dose

The amount of radiation absorbed by the body (absorbed dose) is expressed in units of gray* (Gy). Milligray (mGy) is also used. One mGy equals 0.001 Gy.

Different types of radiation and different sites of exposure in the body produce different health effects, even when the radiation dose is the same. Units of radiation based on this idea are expressed in sievert* (Sv). One millisievert (mSv) equals 0.001 Sv.

Because A-bomb radiation consisted of mainly gamma rays but also a small fraction of neutrons, we use “weighted dose,” a sum of gamma-ray dose and 10 times the neutron dose in Gy.

Radiation in daily life

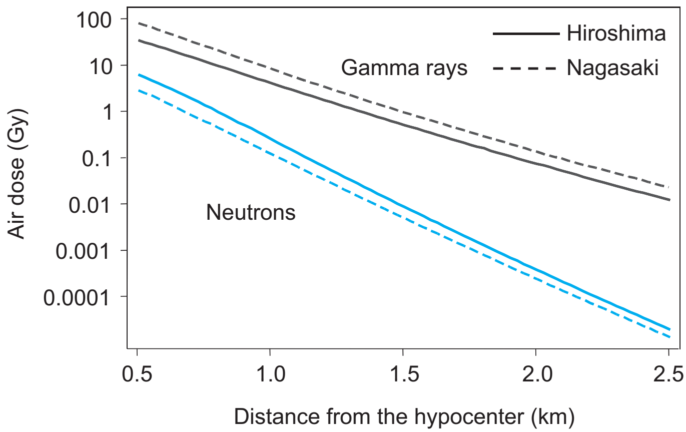
As long as one lives somewhere on earth, exposure to “natural radiation” is a given. The annual dose of exposure to this radiation averages 2.4 mSv (0.2 mSv from one’s body, 0.5 mSv from the ground, 0.4 mSv from space, and 1.3 mSv from mid-air radon. For those working on international air flights, who spend increased hours at high altitudes, annual exposure to cosmic radiation increases to about 2 mSv).

4. Radiation doses in Hiroshima and Nagasaki

Figure 4 shows the association between distance from the hypocenter and air dose in Hiroshima and Nagasaki. Air dose means the radiation dose in the air irrespective of shielding by terrain or structures. In the case of A-bomb exposure inside an average Japanese house, about half of the radiation dose was absorbed by the house. That is, the radiation dose inside such a house was about 1/2 of the air dose (dose received outdoors without shielding).

Radiation dose from the atomic bombings decreased by about one-half every 200 m from the hypocenter. The closer a survivor was to the hypocenter, the greater the effects were from the blast and thermal rays as well as from radiation. It is now understood that burns exacerbated the detrimental effects of radiation on the body.

Figure 4. Distance from the hypocenter and air dose (without shielding) according to DS02 (Dosimetry System 2002*)

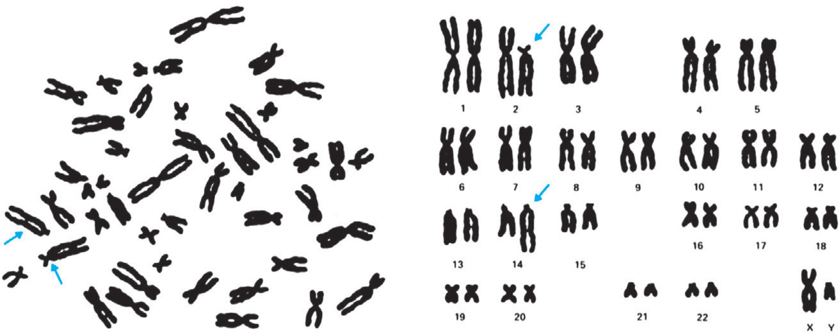


Methods of estimating radiation dose

In addition to the radiation dosimetry system (currently, DS02), one method, in use since the 1960s, studies chromosomes. One cc of blood contains a few million lymphocytes (a kind of white blood cell). When cells start dividing after being cultured for two days, chromosomes can be observed. Microscopic examination of abnormalities that occur in the chromosomes reveals the approximate amount of radiation to which individuals were exposed (Figure 5).

It is also possible to estimate radiation dose by using the electron spin resonance (ESR) method on extracted-tooth enamel.

Figure 5. To the left is a dividing cell with two abnormalities, as indicated by the arrows. To the right is an alignment of the same chromosomes in the order of their size. Abnormal chromosomes were produced by an exchange between segments of the No. 2 chromosome and the No. 14 chromosome (arrows).



5. Effects of radiation on humans

5.1. Acute (early) effects

The effects of radiation on human health vary depending on the amount of radiation received. Whole-body exposure to 10 Gy or more over a short period of time would undoubtedly cause loss of life even with current medical technology. This dose corresponds to exposure to the atomic bomb without shielding at 0.8 km from the hypocenter in Hiroshima (see Figure 4). The radiation dose at which about half of all exposed died within 60 days is considered to be about 3 Gy in Hiroshima. This corresponds to doses received by those exposed to the bomb inside standard Japanese houses about 1 km from the hypocenters. Acute symptoms such as nausea and vomiting were observed among about 10% of those exposed to 1 Gy. Among those exposed to 0.5 Gy, decreased lymphocyte counts in blood were observed.

At 2 km or more from the hypocenter, radiation dose in the air decreased to 0.1 Gy or less, and acute effects were no longer observed. At 3 km or more from the hypocenter, the air dose decreased to 0.002 Gy (2 mGy) or less. This radiation dose instantaneously received is equivalent to the cumulative natural radiation dose to which people are typically exposed over the course of a year (about 0.002 Sv).

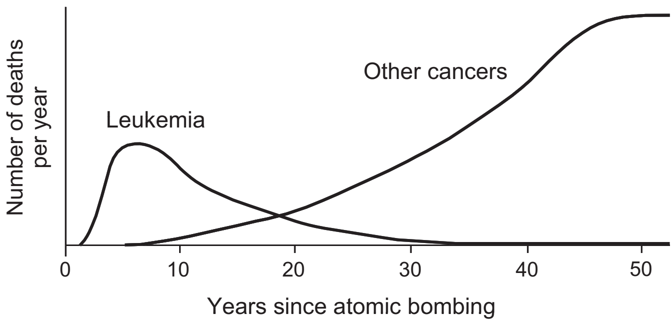
The maximum radiation doses received from induced radiation* by those who entered the exposed cities after the bombings are estimated to have been about 0.8 Gy for Hiroshima and 0.3–0.4 Gy for Nagasaki, assuming that those exposed to induced radiation were present at the hypocenter for an extended period (indefinitely) since immediately after the bombing. The maximum doses from radioactive fallout are estimated to have been 0.01–0.03 Gy in the Koi and Takasu areas of Hiroshima, and 0.2–0.4 Gy in the Nishiyama area of Nagasaki.

5.2. Late effects

5.2.1. Summary

Several years after the war, radiation cataract* was found to have increased among A-bomb survivors (unlike senile cataract, radiation cataract is generally not progressive and few people lose their eyesight). Later, the number of leukemia and other cancer deaths due to radiation exposure increased. The leukemia rate reached its peak 5–10 years after A-bomb radiation exposure, and decreased thereafter, but some marginal effect seems to remain even now. It took about 20 years, on the other hand, for the increase of cancers such as those of the stomach and lung to become apparent. (The reasons for such a difference are not clearly understood. See Figure 6.)

Figure 6. Excess deaths from leukemia and cancer due to radiation exposure compared with non-exposed cases (by number of years after A-bomb radiation exposure) (Not to scale)



5.2.2. Distinguishing radiation-related diseases

No known diseases are unique to radiation-exposed persons. If an A-bomb survivor becomes sick, it cannot be deduced that the disease was directly caused by A-bomb exposure. Thus, it becomes necessary to compare disease rates among persons exposed to significant radiation doses with rates among persons exposed to negligible levels of radiation. This is an example of an epidemiological cohort study. Such investigation has shed light on the relationship between radiation exposure and disease.

5.2.3. Deaths due to cancer

In addition to leukemia, evidence has been obtained that there is an increase in deaths from cancers of the stomach, lung, colon, breast, and so on. However, no increase has yet been observed for uterine, pancreatic, and prostate cancers.

Cancer rates have been found to increase in proportion to radiation dose (see Figure 8 on page 14). The table below shows average relative risk* for leukemia mortality and other cancer incidence or mortality due to exposure to a weighted dose of 1 Gy.

Table. Relative risk of leukemia and cancer due to radiation exposure to a weighted dose of 1 Gy

	Relative risk
Leukemia	About 5
Other cancers	About 1.5

Note: Sex-averaged relative risk for survivors exposed at age 30

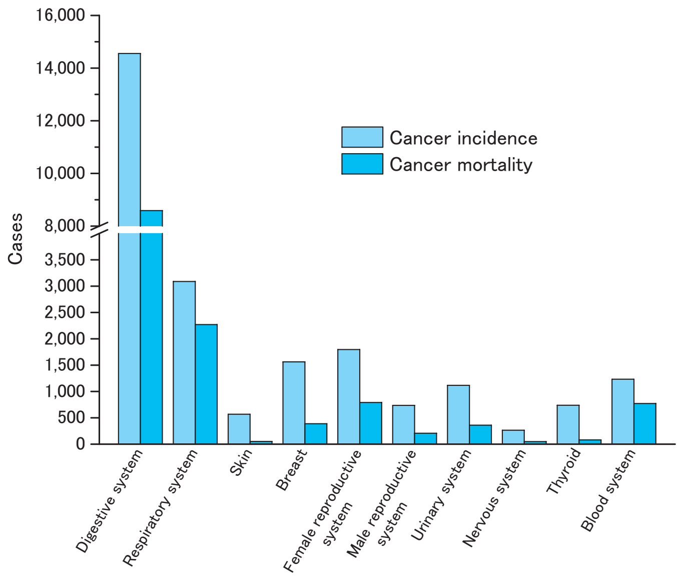
For all persons directly exposed within 2.5 km (mean weighted dose of around 0.2 Gy) among the RERF's Life Span Study subjects (see page 19), the overall relative risk for leukemia is about 2.0, while that for other cancers is about 1.1 (see the figure on page 20).

5.2.4. Cancer development

Although cancer was virtually an incurable disease in the past, it can now, in many cases, be cured if it is detected early. Therefore, it is necessary not only to study cancer deaths, but also to study the general situation surrounding cancer development, in order to understand the effects of A-bomb radiation on human health. Although this is not an easy task, cancer registry systems have been in place in the cities of Hiroshima and Nagasaki since the 1950s, thanks to the efforts of the local medical associations. The systems are continued today as the Hiroshima Prefectural and City Cancer Registries and the Nagasaki Prefectural Cancer Registry.

Figure 7 shows cancer incidence as obtained from these registries. The numbers of cancer deaths are also shown for comparison. No major

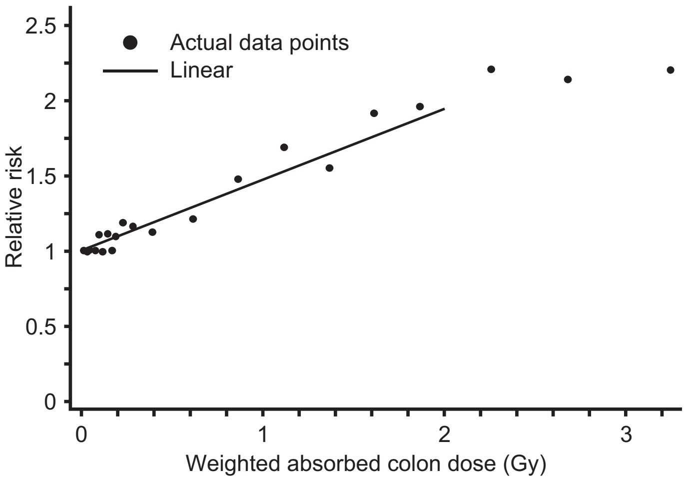
Figure 7. Comparison between the number of cancer cases and cancer deaths. The number of deaths for skin cancer, breast cancer, and thyroid cancer is much smaller than their incidence (1958–2002).



difference exists between incidence and deaths for cancers of the respiratory organs and the hematopoietic system. The same is not true, however, for other cancers. For example, a simple operation at the early stages can cure skin cancer, which is often visible. Early detection of breast cancer is also possible by direct palpation of the affected site. A characteristic of thyroid cancer, which cannot be detected by touch, is its lower level of malignancy compared with other cancers. Among such cancers, it is obvious that the number of deaths is significantly less than the number of cases.

Figure 8 shows the relationship between radiation dose and the development of all cancers excluding leukemia. The relationship is generally linear in nature. The figure shows that cancer incidence increases by a factor of 1.5 with an exposure to radiation of about 1 Gy.

Figure 8. Relationship between radiation dose and the relative risk of incidence of all cancers, excluding leukemia



5.2.5. Variation depending on age at the time of exposure

Increased cancer incidence is related not only to radiation dose, but also to age at the time of radiation exposure. It is known that lifetime cancer risk is highest among those exposed to A-bomb radiation when young. Since those who were exposed to radiation when 10 years old or younger are now in their sixties and seventies and reaching their cancer-prone years, early detection and treatment are important.

5.2.6. Noncancer diseases

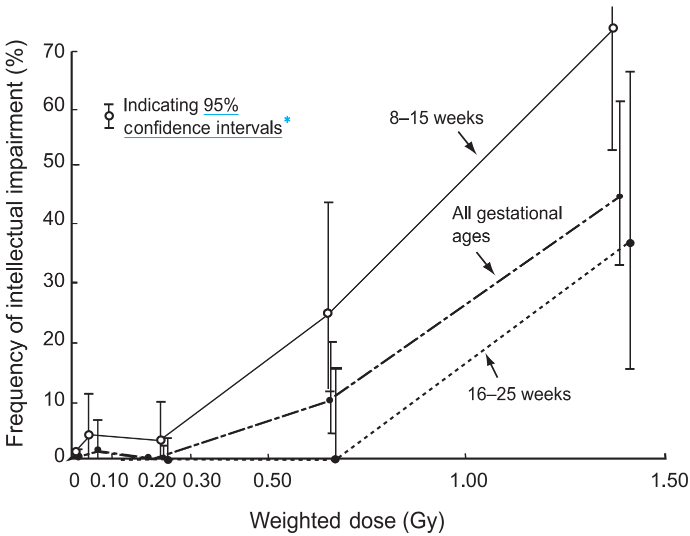
Effects of radiation exposure are not confined to cancer (malignant tumor). Presently, diseases that show a clear association with radiation are benign thyroid tumors, benign parathyroid tumors, uterine myoma, and gastric polyp. In addition, it has been suggested that radiation exposure may have an effect on deaths caused by heart and liver diseases. Studies to verify this hypothesis are ongoing.

5.2.7. Effects of prenatal (*in utero*) exposure

Brain development was affected for some people who were exposed while still in the womb (A-bomb microcephaly,* intellectual impairment, and decreased IQ). This effect was not observed in those who were exposed to A-bomb radiation when they were children or adults. Persons exposed during weeks 8–15 of gestation have shown the highest risk (Figure 9). This is probably because fetal brain cells are particularly susceptible to radiation damage during this period, due to their active cell division and proliferation. The effect of a slight decline in the post-birth growth of prenatally exposed children has also been observed.

Mortality and cancer incidence for this population have also been studied. To date, the cancer incidence of those exposed prenatally tends to increase with radiation dose at a comparable rate with the incidence among those exposed when they were children.

Figure 9. Frequency of intellectual impairment among prenatally exposed survivors in relation to radiation dose



5.2.8. Effects on the children of A-bomb survivors

In the aftermath of the atomic bombings, one of our concerns has been to determine whether abnormalities increased among the children born to A-bomb survivors. At the time research was initiated in 1948, Japan still employed a rationing system, which dated to the middle of the war, for certain food. Out of consideration for their health in particular, there was a special ration for pregnant women. Through use of an application for this special ration, more than 90% of women pregnant at least five months were confirmed, and thereafter a follow-up study was conducted to obtain information on miscarriage and malformation at the time of birth (physicians examined approximately 77,000 newborn individuals from 1948–1954). Also conducted were a study on chromosomes (of approximately 16,000 subjects from 1967–1985) and a study on hemoprotein (of approximately 24,000 subjects from 1975–1985). A mortality study (of approximately

77,000 subjects for deaths due to leukemia, cancer, and other causes from 1946 to the present) and a cancer incidence study (of the same subjects from 1958 to the present) have also been conducted. To date, no increase of such abnormalities among the A-bomb survivors' children due to parental A-bomb radiation exposure has been observed. Recently, genomic studies have also been initiated. Health examinations were conducted to detect diseases including cancer, heart disease, hypertension, and diabetes considered to be undetectable at birth (for approximately 12,000 subjects from 2002 to 2006), as well as precursor states of the diseases. The health examination study is ongoing.

6. Publication of research findings

The research findings of RERF have been published as scientific papers in national and international journals, and also as part of technical books. RERF's technical reports, which had been printed and published in-house since 1959, were discontinued after publication of the 1992 issues and succeeded by the RERF Report series since 1993. The RERF Reports consist of publications carried in scientific journals, with a Japanese summary. When necessary, papers with too much data for publication in a journal are published as special reports.

On the RERF website (http://www.rerf.jp/), various studies are explained in detail—from their background to their results. Data used for the risk estimation of A-bomb-related cancers can also be freely downloaded from the homepage.

When data are made available, study participants have been grouped by several factors, such as dose, sex, and the like, so that individuals cannot be identified. All personal information is closely managed by RERF to assure protection of the human rights of A-bomb survivors.

7. International collaborations and our hopes

RERF actively participates in international collaborations. This makes the experience and knowledge gained through our studies of A-bomb survivors widely available for the benefit of the world. Such activity involves cooperation with international organizations including the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the World Health Organization (WHO), and the International Atomic Energy Agency (IAEA). The International Commission on Radiological Protection (ICRP) has issued recommendations on radiation exposure dose limits based on RERF study results, and the recommendations have been promulgated throughout the world. RERF has thus contributed to the establishment of global radiation protection standards.

Additionally, several projects were initiated as a consequence of the accident at the Chernobyl nuclear power plant on April 26, 1986. One was the Hiroshima International Council for Health Care of the Radiation-exposed (HICARE), organized on the basis of collaboration among Hiroshima Prefecture and City, local medical associations, universities, hospitals, and research institutes. The Nagasaki Association of Hibakushas' Medical Care (NASHIM), operated by Nagasaki City and Prefecture, local medical associations, and other related organizations, was another such project. The purpose of these projects is to train physicians and researchers from countries where people have been exposed to radiation. RERF annually accepts more than 100 short-term trainees and several long-term trainees through these projects.

In 1996, the A-bomb Dome in Hiroshima was designated a world heritage site. This designation was very important to the city on which the A-bomb was dropped. At the same time, we must remain mindful of those people all over the world who have been exposed to radiation and consider Hiroshima and Nagasaki to be the places where they can acquire the most reliable knowledge about radiation exposure. RERF's mission, to contribute to the welfare and medical care of A-bomb survivors, also includes contribution to medical treatment and health studies for people throughout the world exposed to radiation. We hope that our knowledge and experience can make this research institution worthy of the recognition Hiroshima and Nagasaki claim around the world. To this end, RERF considers close collaboration and cooperation with the local communities of Hiroshima and Nagasaki to be of utmost importance.

— Appendix 1 —

Characterization of the RERF study populations

Life Span Study (LSS) population

Consisted of about 120,000 persons at the launch of the study. Epidemiological studies of the causes of death and of the development of cancer are carried out on this population.

Adult Health Study (AHS) population

Consisted of about 20,000 persons at the launch of the study. Through biennial health examinations and mail questionnaires, diseases are detected at their early stages, and other specific kinds of health problems are studied.

In utero population

Consists of about 3,600 persons. Studies of microcephaly and intellectual impairment were carried out in the past. At present, analyses of the causes of death, including those due to cancer, are being carried out.

F_1 population

Consists of about 77,000 persons. Studies of deformities and hereditary disorders were carried out in the past. At present, epidemiological studies of the causes of death, including those due to cancer, are being conducted. In subsets of this population, abnormalities in blood protein (about 24,000 persons) and chromosomes (about 16,000 persons) were studied. Clinical examinations on a subset of about 12,000 persons are also underway. Preparations for the DNA study of about 1,000 families are underway, with a pilot study already begun.

— Appendix 2 —

Information related to A-bombs and radiation

Number of deaths caused by A-bombs

The precise number is unknown. The numbers of deaths by the end of 1945 are estimated to be 140,000 (±10,000) and 70,000 (±10,000) in Hiroshima and Nagasaki, respectively.

Total number of A-bomb survivors

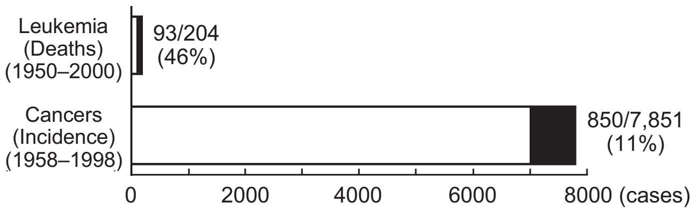
In 1950, when the first National Census after World War II was carried out, as many as 284,000 persons indicated that they had been exposed to the atomic bombings of Hiroshima and Nagasaki. This figure does not include "early entrants" (those who had entered the cities after the bombings). The LSS and AHS populations mentioned in Appendix 1 were established by selecting A-bomb survivors identified from this census.

Percentage of A-bomb survivors RERF has followed of the total number of A-bomb survivors

The number of survivors that have been followed in the RERF epidemiological studies is estimated to be slightly less than half of those exposed within 2.5 km from the hypocenter, and about a quarter of those exposed beyond 2.5 km, although the exact number of exposed is unknown.

Number of leukemia deaths and cancer cases among the Life Span Study subjects

The numbers of leukemia deaths and cancer cases among A-bomb survivors exposed to at least 0.005 Gy in the Life Span Study cohort are shown in the figure below. The black areas (93 out of 204 leukemia deaths and 850 out of 7,851 cancer cases) indicate excess leukemia deaths and cancer cases attributable to radiation exposure.



— Appendix 3 —

Glossary

Atomic Bomb Survivors Support Law (page 2)

Enacted in 1994, this law integrated the previous two laws: the Law Concerning Special Measures for the Atomic Bomb Exposed and the A-bomb Survivors Medical Treatment Law. It stipulates that the Japanese government should assume the responsibility of implementing comprehensive relief measures for the health, medical care, and welfare of the atomic bomb survivors.

A-bomb Survivors Medical Treatment Law (page 3)

Established in 1957, this law decreed that A-bomb survivors were entitled to A-bomb survivors' health handbooks, biannual health examinations for better health management, detailed health examinations in the event that any abnormality was found, and medical compensation if they were certified as eligible by the Minister of Health and Welfare. These measures were incorporated into the Atomic Bomb Survivors Support Law in 1995.

Nuclear fusion (page 4)

The fusing of two nuclei at high temperatures, which is the opposite of nuclear fission. Nuclear fusion also emits enormous amounts of heat.

Nuclear fission (page 4)

Uranium and plutonium have large and unstable atomic nuclei, which spontaneously split (fission) and emit heat. When a neutron emitted as a consequence of nuclear fission is absorbed by another nucleus, this causes another fission reaction, which causes further fission, and so on, producing a chain reaction (principle behind atomic bombs).

Shielding (page 4)

Radiation loses its energy in varying degrees when it penetrates substances. Lead is used as a shield against gamma and X rays. The shielding effect of concrete buildings is far greater than that of wooden houses.

Residual radiation (page 4)

There are two sources of residual radiation. One is fallout, and the other is neutron activation (induced radiation). Fallout occurred as black rain, which contained the radioactive fission products of uranium (Hiroshima) or plutonium (Nagasaki), as well as nuclear substances that had not undergone nuclear fission. The doses were highest in areas where the rain fell—the northwestern part of Hiroshima and the eastern part of Nagasaki. Neutron activation occurred when neutrons released from the bomb hit materials in the soil or buildings, resulting in the generation of radioactive atoms. In this case, the doses were highest at the hypocenters.

Electromagnetic wave (page 6)

Electromagnetic waves have characteristics of both waves that travel at the speed of light and particles. This general term is used for electric, infrared, visible, ultraviolet, X, and gamma rays, among others.

Cosmic rays (page 6)

Various types of radiation originate in the cosmos. The radiation is thought to be produced when stars form or burn out. Although most cosmic radiation is absorbed in the atmosphere, some does reach the ground.

Cobalt-60 (page 7)

Cobalt is a stable element that usually has 27 protons and 32 neutrons in the nucleus, with an atomic mass number of 59. (Cobalt is used for making blue pigment.) However, cobalt with 33 neutrons (cobalt-60), which is produced by the nuclear fission of plutonium, is unstable and emits radiation.

Nuclear decay (page 7)

Nuclear decay is the process by which an atomic nucleus breaks down to form a different element (disintegration). Extra energy is emitted as radiation during the process.

Gray (Gy) (page 7)

One gray (Gy) represents the dose, regardless of radiation type, when 1 joule (J) of energy is absorbed by 1 kilogram of a given substance.

Sievert (Sv) (page 7)

Sievert (Sv) has two different uses. One is “equivalent dose,” which is obtained by multiplying the tissue-absorbed dose (in Gy) by a factor weighted in accordance with type of radiation. The other is “effective dose,” which is obtained by multiplying the tissue-equivalent dose (in Sv) by a factor that takes into account differences in health effect depending on affected tissue. Both units are used for radioprotective purposes. RERF uses equivalent dose weighted in accordance with type of radiation, but since tissue-specific factors are not incorporated into this calculation, Gy is used instead of Sv to avoid confusion with effective dose.

DS02 (Dosimetry System 2002) (page 8)

This is the latest system used to estimate radiation doses from the atomic bombs. Because of the questions concerning evaluation of neutrons in the DS86, which was developed in 1986, several years were spent on reassessment. Using up-to-date knowledge of nuclear physics and computer technology, a more accurate and improved system was finalized in 2002, called DS02. It allows calculation not only of individual doses, but also of the doses to which different organs were exposed (organ doses), on the basis of the data obtained from individual A-bomb survivors.

Induced radiation (page 10)

Please refer to the description of residual radiation (page 21).

Radiation cataract (page 11)

Radiation cataract occurs when the posterior of the lens of an eye clouds at the center, either in a round or a donut shape, as a result of damage to some of the cells making up the eye lens.

Relative risk (page 12)

The term “relative risk” is used here to refer to how much higher the risk of cancer is in those exposed to A-bomb radiation compared with the cancer risk in non-exposed people. (“Risk” indicates the possibility of danger.)

A-bomb microcephaly (page 15)

Microcephaly is caused when the actively proliferating cells of the fetal brain become damaged by radiation and are unable to produce a sufficient number of brain cells.

95% confidence interval (page 16)

This confidence interval is a measure of the reliability of an estimated value and indicates that the value falls in the interval range with a 95 percent likelihood. The wider the confidence interval, the less reliable the given value is.

— Appendix 4 —

Introduction to the RERF departments

Department of Epidemiology: This department studies over 200,000 A-bomb survivors and their children, primarily for incidence of cancer and cause of death. In epidemiological studies it is important to follow a fixed population for a long time. In terms of the scale, mean radiation dose, and duration, the RERF study population is the largest in the world.

Department of Statistics: This department is responsible for analyses of the statistical problems that arise from the study of A-bomb radiation effects and support of other research departments, as well as overall dosimetry work, including radiation dose calculation for A-bomb survivors.

Department of Clinical Studies: This department conducts biennial health examinations of the Hiroshima and Nagasaki A-bomb survivors, an initial population of some 20,000. These exams are conducted for the dual purpose of determining health status—including psychological health—and detecting diseases at an early stage. The results of these health examinations are then shared with the participants, who are referred to specialized hospitals when necessary.

Department of Genetics: This department studies the health status and DNA of children of A-bomb survivors. The department also measures the blood cells of survivors for chromosome aberrations and analyzes teeth for trace substances produced by radiation to estimate radiation doses.

Department of Radiobiology/Molecular Epidemiology: This department studies the effects of radiation on the immune system, seeks to determine if there are any abnormalities in the genes of blood cells, and also conducts gene analysis of cancer cells.

Department of Information Technology: This department manages information investigated and analyzed in each of the departments at RERF and disseminates information throughout the world. It is also in charge of the management of RERF scientific papers, publications and various materials, as well as library operations.

Secretariat: The Secretariat conducts general administrative work to support the research departments, including activities regarding communication of research findings as well as editing of RERF's publications and website.

Memo

Tours of the Radiation Effects Research Foundation

Our facilities are open for individual or group tours throughout the year. Please contact us in advance for a guided tour. Reservations for guided tours also can be made on our homepage.

Tours available: 9:00–16:00, Monday through Friday
(excluding holidays)

First edition: August 5, 1995
Seventh revision: May 1, 2015

Published by the
Radiation Effects Research Foundation

5-2 Hijiyama Park, Minami-ku, Hiroshima, 732-0815
Phone: 082-261-3131 (switchboard)

1-8-6 Nakagawa, Nagasaki, 850-0013
Phone: 095-823-1121 (switchboard)

Homepage: http://www.rerf.jp/

Radiation Effects Research Foundation in Nagasaki