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Genetic effects

Genetic studies

Study	Period	Genetic effect
1 Frequency of untoward outcomes of pregnancy (abortions, stillbirths, deformities, infant mortality, and sex ratio)	1948 ~ 1954	Absent
2 Sex ratio	1948 ~ 1962	Absent
3 Growth and development (height, body weight, mental development)	1965	Absent
4 Chromosomal aberrations	1967 ~ 1984	Absent
5 Malignant tumor frequency	1960 ~ present	Not detected
6 Mortality rate	1960 ~ present	Not detected
7 Gene mutation frequency	1977 ~ 1984	Absent
8 DNA studies (preliminary study)	1985 ~ present	Not known

1. Genetic studies

In order to evaluate the genetic effects of atomic bomb radiation on the children of atomic bomb survivors, a study was conducted on abnormal pregnancy outcomes between 1948 and 1954. A total of 71,280 pregnancies were investigated, consisting of 15,410 registered pregnancy cases involving atomic bomb survivors in Hiroshima and Nagasaki, and 55,870 controls.

However, no statistically significant genetic effects due to atomic bomb radiation were observed in any of the following categories: sex ratio, stillbirths, neonatal deaths, and infant mortality rates for ages up to 9 months, and congenital malformations in stillborn

babies or within the first nine months of life.

Although the sex ratio study was repeated on 47,624 children of survivors in Hiroshima and Nagasaki between 1948 and 1962, the results were the same.

In order to investigate the growth and development of the children of atomic bomb survivors, approximately 200,000 elementary, junior high and senior high school students in Hiroshima and Nagasaki were surveyed in 1965, but no impairment was found relative to the controls.

The results of these studies are summarized in the above table; the DNA study began in 1985 and is still under way. Study findings are discussed in the following sections.

Chromosome aberrations		Exposed	Controls
Number of examinees	Males	3,914	3,682
	Females	4,408	4,294
	Total	8,322	7,976
A. Sex chromosome abnormalities			
Males	XYX	3 (0.77)	5 (1.36)
	XXY	7 (1.79)	9 (2.44)
	Mosaicism	1 (0.26)	—
	Others	1 (0.26)	2 (0.54)
Females	XXX	5 (1.13)	4 (0.93)
	Mosaicism	2 (0.45)	3 (0.70)
	Others	—	1 (0.23)
B. Autosomal structural rearrangements			
	Reciprocal translocations (balanced)	7 (0.84)	13 (1.63)
	D/D, D/G translocations (balanced)	10 (1.20)	6 (0.75)
	Inversions (balanced)	1 (0.12)	6 (0.75)
	Others (including unbalanced)	5 (0.60)	2 (0.25)
C. Autosomal trisomy			
	21 trisomy	1 (0.12)	—
Total aberrations		43 (5.17)	51 (6.39)

() Figures in parentheses indicate frequency per 1,000 examinees. However, the percentages for sex chromosome abnormalities apply only to the affected sex.

(Awa, 1988)

2. Chromosome studies

A study on chromosomal aberrations was performed on the children of atomic bomb survivors between 1967 and 1984.

The study covered 16,298 children (7,596 males and 8,702 females), consisting of 9,828 in Hiroshima (4,716 exposed and 5,112 controls) and 6,470 in Nagasaki (3,606 exposed and 2,864 controls). The average age at the time of examination (24 years) was the same for both the exposed and control populations (the age range being 12 to 38 years).

1. Sex chromosome abnormalities:

No radiation effect was observed in either numerical abnormalities (XYX, XXY, XXX and mosaicism) or in structural rearrangements (e.g. inversion of the Y chromosomes).

2. Autosomal structural rearrangements (reciprocal translocations, Robertsonian translocations, inversions, and extra marker chromosomes etc.):

Since structural abnormalities (rearrangements) are predicted to be induced by radiation at a frequency proportional to dose, they provide a good index for investigating the genetic effects of radiation. However, no significant difference between the exposed and control populations was found with respect to the frequencies of structural abnormalities, including both balanced rearrangements (e.g. translocations) and unbalanced ones.

3. Chromosomal trisomy (21 trisomy, i.e. Down's syndrome):

No increase was observed in the children of atomic bomb survivors.

Cancer incidence	Parental gonadal dose (Sv)		Total
	0	≥ 0.01	
Number of children	41,066	31,150	72,216
All cancers	49	43	92 (100%)
"Heritable" cancers	10	9	19 (21%)
Retinoblastoma	4	1	5
Wilms' tumor	1	4	5
Neuroblastoma	3	1	4
Osteosarcoma	1	1	2
Embryonal carcinoma	1	1	2
Sarcoma, kidney	0	1	1
Leukemia	17	16	33 (36%)
Others*	22	18	40 (43%)

*including 15 brain tumors

Number of cancer cases in liveborn children (age < 20 years, 1946-1982)

3. Cancer incidence and mortality rates

The Radiation Effects Research Foundation has continued to perform follow-up studies on children who were conceived after the detonation of the atomic bombs (thus born after May 1946) and for whom at least one parent was a survivor of either the Hiroshima or Nagasaki atomic bombs.

1. Cancer incidence study

A study was conducted for the period 1946-1982 on the cancer incidence at all sites for subjects aged under 20 years. Among the 72,216 subjects were 92 cancer cases, but no significant increase in cancer risk was associated with parental exposure.

2. Mortality study

The 1946-1985 mortality rate study published in 1990 reported 3,852 deaths among the 67,586 persons for whom it was possible to estimate doses using DS86 dosimetry. Excluding the 584 individuals who died from extrinsic causes and the 359 deaths from unknown causes, there were 2,909 deaths due to disease. Of these, malignant neoplasms accounted for 115 deaths, and other diseases for 2,766.

No significant increases in mortality in relation to parental dose were observed in the mortality rates from either fatal cancer or other diseases.

Mutations producing changes in electrophoretic mobility

	Exposed	Controls
Parental gonadal dose	$\geq 0.01\text{Sv}$	$< 0.01\text{Sv}$
Children examined	11,364	12,297
Equivalent locus tests	544,779	589,506
Mutations	2	4
Mutation rate / locus / generation	0.37×10^{-5}	0.68×10^{-5}

Mutations producing decreased enzyme activity

	Exposed	Controls
Children examined	4,989	5,026
Equivalent locus tests	60,529	61,741
Mutations	1	0
Mutation rate / locus / generation	1.65×10^{-5}	0

4. Biochemical genetics study (gene mutation rates)

Between 1977 and 1984, 11,364 children of Hiroshima and Nagasaki atomic bomb survivors as well as 12,297 controls were examined for protein variants using two techniques, starch gel electrophoresis and enzyme activity measurements, in order to determine whether the variants had been produced as a result of mutations in the parental germ cells.

As shown in the table, no significant difference in mutation rates was observed between the exposed population (2 cases, with a mutation rate of 0.37×10^{-5} per locus per generation) and controls (4 cases, with a mutation rate of 0.68×10^{-5} per locus per generation). Thus no radiation-caused genetic effect was detected. However, the presence of such an effect cannot completely be discounted due to various factors such as low

parental doses and the fact that much of the data was obtained using a technique suited to the detection of point mutations, which are rather rare among radiation-induced mutations.

In order to compensate for these disadvantages, mutation studies at the DNA and RNA level are being attempted. With the introduction of techniques to detect deletional mutations, which are the predominant form of radiation-induced mutation, this research is expected to yield dividends.