

Study on the Effect of Atomic Bomb Radiation on Thyroid Function

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ABSTRACT

The thyroid function of 6112 cases directly exposed to the atomic bomb within 1.5 km (exposed group) and of 3047 cases directly exposed beyond 3.0 km from the hypocenter (control group) was analyzed and the following results were obtained.

1) The frequency distribution curves of TSH values of both groups closely resembled each other in males, but the curve of the exposed group deviated to the right due to high TSH values. In females, the distribution width of TSH values of the exposed group was wide with a low peak and when compared to the control group, the curve was remarkably deviated to the right due to TSH values.

2) The frequency of hypothyroidism was 1.22% in males of the exposed group and 0.35% in males of the control group, while in females it was 7.08% and 1.18%, respectively, showing a significantly higher rate in the exposed group in both sexes. By exposure dose, the frequency was 1.03% in males of the 1~99 rad group and with increase of exposure dose the frequency elevated, being 3.67% at exposure dose of 200 rad or more. In females, the frequency was 6.23% and 7.76%, respectively, showing a significantly higher frequency when compared to the control group.

3) The prevalence rate of positive MCHA among the cases of hypothyroidism was 16.4% in males of the exposed group and 88.9% in males of the control group, while in females the prevalence was 25.3% and 63.3%, respectively, showing a remarkably low rate in the exposed group.

Most of the reports on thyroid diseases among atomic bomb survivors have been with regard to thyroid cancer^{1,10,11,13}. A high rate of thyroid cancer has been observed among proximally exposed survivors and in the group exposed to 50 rad or more¹⁰. There are not so many reports regarding thyroid function among the survivors. It is considered to be a very important problem to determine, at present, about 40 years after exposure the effect of radiation on the thyroid and to observe these effects with aging. For the purpose of studying the effect of atomic bomb radiation on thyroid function, a study was made on thyroid stimulating hormone values and anti-thyroid antibodies using atomic bomb survivors

directly exposed within 1.5 km. A control group of atomic bomb survivors directly exposed beyond 3.0 km from the hypocenter was used for a comparative examination of the thyroid stimulating hormone level, the prevalence of hypothyroidism, and its etiology in the two groups.

MATERIALS AND METHODS

The subjects of the present study are 9159 cases composed of 6112 cases (1983 males and 4129 females) who were directly exposed within 1.5 km from the hypocenter (hereinafter referred to as exposed group) and who underwent the prescribed general examination for

atomic bomb survivors at our Clinic between April and the end of November 1984, and 3047 cases (994 males and 2053 females) who were directly exposed beyond 3.0 km from the hypocenter (hereinafter referred to as control group) who were similarly examined. The composition of this sample classified by sex and age is shown in Table 1.

Of these exposed survivors, the exposure dose (T65DR) has been estimated by the Radiation Effects Research Foundation (RERF) for 951 males and 2155 females for a total of 3106 cases. Cases having undergone thyroidectomy or isotope therapy and cases of early entry were excluded from this study.

In the examination of the survivors, determinations of thyroid stimulating hormones⁷⁾ by the solid phase TSH-RIA method using blood dropped on filter paper (hereinafter abbreviated TSH) and of antithyroid microsome antibody by the microsomal hemagglutination test (hereinafter abbreviated MCHA) were made together with detailed history taking and palpation of the thyroid. Cases whose TSH value by the solid phase method exceeded 10 μ U/ml or whose MCHA was positive underwent further examination to determine the TSH value by the double antibody method. Also T₃-RIA value, T₄-RIA value, and anti-thyroglobulin antibody were determined.

Table 1. SUBJECTS

Exposure Status (Distance from Hypocenter)		Age (yrs)					Total
		38~49	50~59	60~69	70~79	80~	
≤ 1.5 km	Male	323	615	400	461	184	1983
	Female	608	1334	1148	812	227	4129
	Total	931	1949	1548	1273	410	6112
≥ 3.0 km (Control)	Male	286	341	174	150	43	994
	Female	475	646	510	348	74	2053
	Total	761	987	684	498	117	3047
Total	Male	609	956	574	611	227	2977
	Female	1083	1980	1658	1160	301	6182
	Total	1692	2936	2232	1771	528	9159

Cases with thyroidectomy or undergoing isotope therapy were excluded.

RESULTS

1. Comparison between TSH value determined by the solid phase method using dried filter paper blood and that determined by the double antibody method.

TSH values determined by the solid phase method using dried filter paper blood were plotted on the X-axis, while TSH values determined by the double antibody method using serum were plotted on the Y-axis. Fig. 1 shows the correlation of the two values for 860 cases. The correlation coefficient was 0.929 ($p < 0.01$), showing an extremely high correlation between the two. The regression equation was $Y = 2.3X - 11.9$ and the mean TSH value for 860 cases was 9.5 μ U/ml by the solid phase method and 10.0 μ U/ml by the double antibody method.

2. Frequency distribution of TSH values by the solid phase method

(1) Comparison between the exposed group and control group

Fig. 2 shows the frequency distribution of TSH values by sex and age. For the males shown in the upper set, the frequency distribution curves of both groups at ages less than 70 were very similar, though the curves of the exposed group were somewhat deviated to the right due to high TSH values. At ages 70 or more the mode of both groups was almost identical, but the curves of the exposed group showed a lower peak than those of the control group and the frequency width of the curve was wider. An increase of cases with high TSH values was observed. On the other hand, in the females, the mode of the 38~49 years age

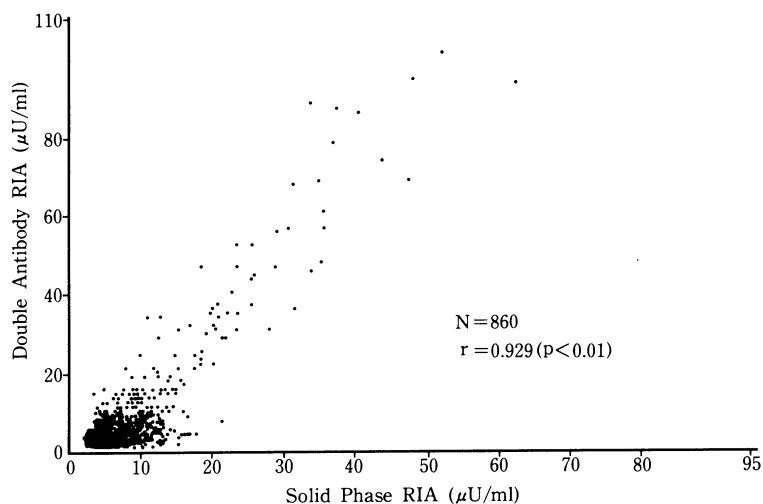


Fig. 1. Correlation of TSH levels between solid phase and double antibody RIA

group showed that the TSH value of both groups was $4.3 \mu\text{U/ml}$ with no difference between the two, but the peak of the exposed group was lower and the distribution curve was deviated toward the right due to the high TSH values. In the groups more than 50 years of age, the distribution curve of the control group showed no difference from that of the 38~49 years age group, but in the exposed group the mode was $5.9\sim 6.3 \mu\text{U/ml}$ which was higher than the $4.5\sim 4.6 \mu\text{U/ml}$ of the control group. Furthermore, the peak of the curve was lower and the distribution width of the frequency distribution curve was wider than that of the control group. The curve as a whole deviated remarkably to the right due to high TSH values.

When the cases were combined, for males the mean \pm S.D. of the TSH value was $5.1 \pm 2.8 \mu\text{U/ml}$ in the exposed group and $4.2 \pm 1.0 \mu\text{U/ml}$ in the control group. For females it was $6.8 \pm 3.5 \mu\text{U/ml}$ in the exposed group and $4.7 \pm 2.2 \mu\text{U/ml}$ in the control group. The TSH value was significantly higher in the exposed group when compared to the control group in both sexes ($p < 0.001$). Comparison by sex of the frequency distribution curves of the TSH values after adjusting the age of both groups is shown in Fig. 3. In males, the frequency distribution curves of both groups showed a very close resemblance. The mode of the exposed group was $4.5 \mu\text{U/ml}$ and that of the control group was $4.2 \mu\text{U/ml}$. The curve of the exposed group was slightly deviated to the right due to the high

TSH values. In females, the frequency distribution curve of the control group approximated that of the males, but the mode of the exposed group was $5.9 \mu\text{U/ml}$ which is higher than the $4.5 \mu\text{U/ml}$ of the control group. In general, there was a remarkable difference in the TSH distribution curves between the two groups. The exposed group showed, in comparison with the control group, a curve with a lower peak and a wider distribution width, indicating that there was an evident increase in cases with high TSH values.

2) Comparison by exposure dose

Among those in the exposed group, individual exposure dose (T65DR) has been estimated by Radiation Effects Research Foundation (RERF) for 3106 cases (951 males and 2155 females). The exposure dose was 1~99 rad in 626 males and 1575 females and 100 rad or more in 204 males and 367 females. The mean \pm S.D. of TSH values in males belonging to 1~99 rad group was $5.1 \pm 2.5 \mu\text{U/ml}$ and in males belonging to the group exposed to 100 rad or more was $5.5 \pm 4.1 \mu\text{U/ml}$. In females it was $6.8 \pm 3.5 \mu\text{U/ml}$ and $6.9 \pm 3.9 \mu\text{U/ml}$, respectively, showing no remarkable difference between the two groups. A comparison by sex of frequency distribution curves of TSH values after adjusting the age of both groups is shown in Fig. 4. The frequency distribution curve of the males of the 1~99 rad group was similar to that of the control group, but the mode was $4.5 \mu\text{U/ml}$ and

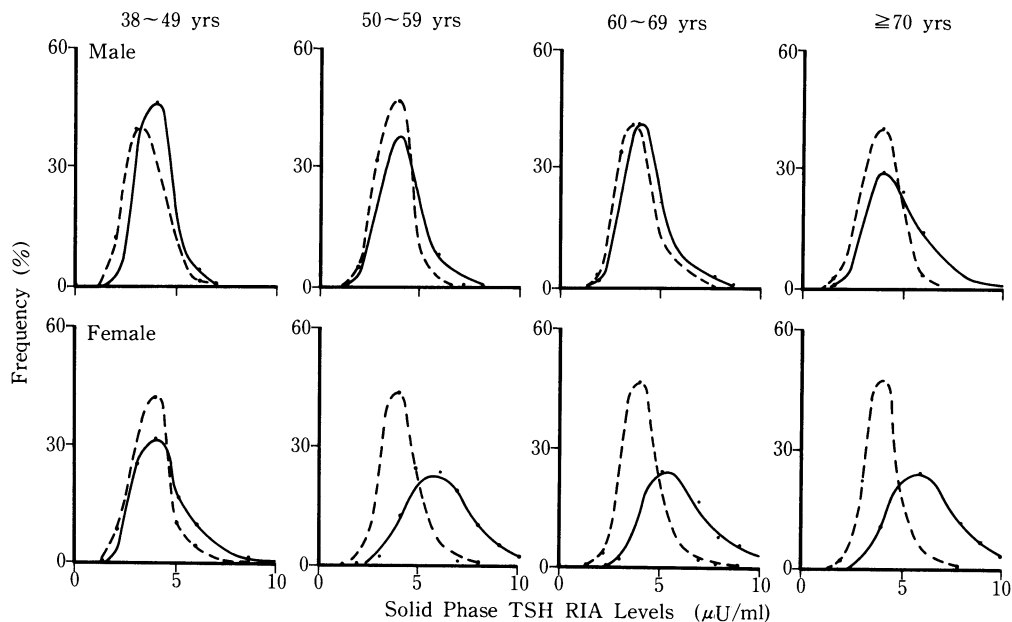


Fig. 2. Frequency distribution of TSH levels by age and exposure status
Exposed group ●—●; Control group ○—○

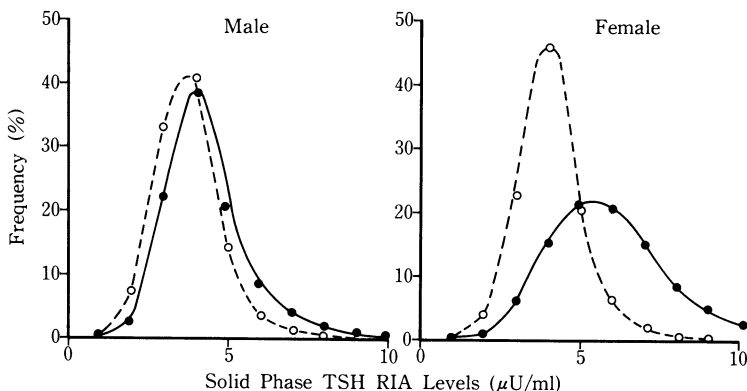


Fig. 3. Frequency distribution of TSH levels by sex and exposure status (age adjusted)
Exposed group (●—●) was composed of 1983 males and 4129 females and control group (○--○) of 994 males and 2053 females.

4.2 $\mu\text{U/ml}$, respectively, with the curve of the 1~99 rad group generally deviating to the right due to high TSH values. In females, the curves of the two groups were remarkably different. The mode of the curve of the 1~99 rad group was 5.7 $\mu\text{U/ml}$ in contrast to 4.5 $\mu\text{U/ml}$ of the control group, the peak was low, and the curve deviated to the right due to remarkably high TSH values. This indicates that many cases having a high TSH value were included. An identical tendency was also observed in the group exposed to 100 rad or more. In males, the mode of this group was 4.5 $\mu\text{U/ml}$ and that of the con-

trol group was 4.2 $\mu\text{U/ml}$, while in females, it was 5.8 $\mu\text{U/ml}$ and 4.5 $\mu\text{U/ml}$, respectively.

3. Prevalence rate of hypothyroidism

1) Comparison between the exposed group and control group

Cases whose TSH value was 10 $\mu\text{U/ml}$ or more by the solid phase method or the double antibody method and cases being administered thyroid hormones for hypothyroidism were diagnosed as having hypothyroidism. No difference in prevalence of hypothyroidism in males under 70 years old could be observed between the ex-

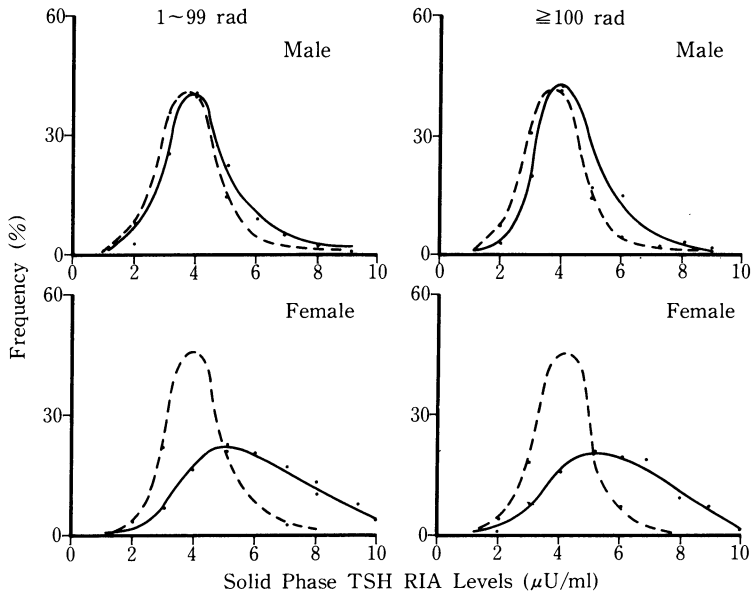


Fig. 4. Frequency distribution of TSH levels by sex and radiation dose (age adjusted)
Dose group ●—● ; Control group ●—●

posed group and control group, but in males of 70 or over the prevalence was 3.26% in the exposed group, which is significantly higher than the 0.52% observed in the control group ($p < 0.01$). In comparing the total of cases after adjusting the age, the prevalence rate was 1.22% in the exposed group and 0.35% in the control group, the rate being significantly higher ($p < 0.01$). In females, the prevalence rate was significantly higher than that of the control group in all age groups. As a whole, the prevalence rate in the exposed group was 7.08%, which is significantly higher than 1.18% observed in the control group ($p < 0.005$).

The prevalence rate of cases whose TSH value was $20 \mu\text{U/ml}$ or more and/or of cases being administered thyroid hormones for hypothyroidism was, after adjusting the age of both groups, 0.59% for males in the exposed group, which is significantly higher than the 0.11% in the control group ($p < 0.05$). Also in the females, the prevalence rate in the exposed group was 1.23%, which is significantly higher than the 0.67% for the control group ($p < 0.05$). The prevalence rate of cases of subclinical hypothyroidism not being administered thyroid hormones for hypothyroidism with TSH value $\geq 10 \mu\text{U/ml}$ and $\text{T}_4\text{RIA} > 4 \mu\text{g/dl}$ was 66.7% in males and 86.8% in females of the exposed group and

100.0% in males and 54.5% in females of the control group. As the number of males was small, no difference between the two groups could be observed, but in the females, the frequency was significantly higher in females of the exposed group ($p < 0.01$).

2) Comparison by exposure dose

Comparison of the prevalence rate of cases with hypothyroidism by exposure dose is shown in Fig. 6. The prevalence rate of cases with TSH value $\geq 10 \mu\text{U/ml}$ or being administered thyroid hormones for hypothyroidism in males was 1.03% in the 1-99 rad group, 2.06% in the 100-199 rad group, and 3.67% in the 200 rad or more group, showing an elevation with an increase of exposure dose. They were all significantly higher than the 0.33% observed in the control group ($p < 0.05$, $p < 0.005$, and $p < 0.005$, respectively). Similarly in females, the prevalence rate in the 1-99 rad group was 6.23%, that in the 100-199 rad group 6.16%, and that in the 200 rad or more group 7.76%, showing a higher prevalence rate tendency in the high dose group. In comparison with 1.32% of the control group, the prevalence rate in all the exposure groups was significantly high ($p < 0.005$). The prevalence rate of cases with TSH value $\geq 20 \mu\text{U/ml}$ or being administered thyroid hor-

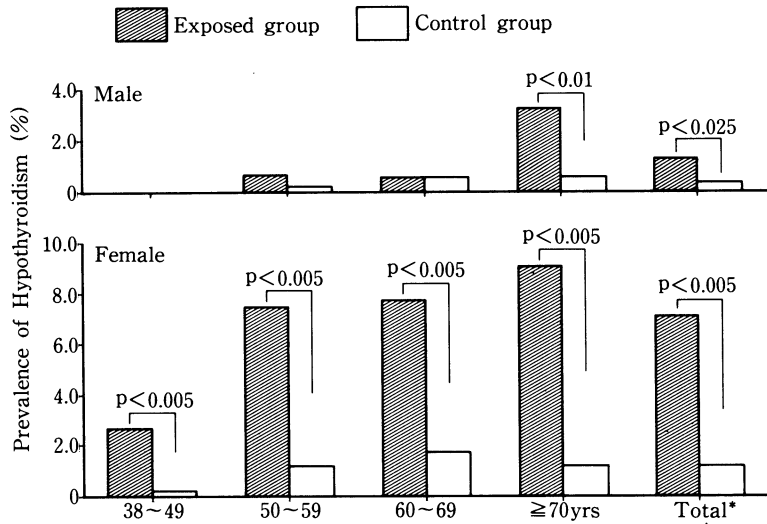


Fig. 5. Prevalence rate of cases with hypothyroidism by age
Hypothyroidism : TSH levels $\geq 10 \mu\text{U/ml}$ or hypothyroidism under treatment

mones for hypothyroidism was in males belonging to the 200 rad or more group 3.71% which is significantly high when compared with the 0.11% of the control group ($p < 0.005$). Also in the females, the prevalence rate in the 200 rad or more group was 2.02%, showing a higher prevalence rate tendency than the 0.67% of the control group. The prevalence rate of subclini-

cal hypothyroidism was 71.4% in males and 82.4% in females belonging to the 1~99 rad group, 100% and 87.5% in those belonging to the 100~199 rad group, and 0% and 71.4% in those belonging to the 200 rad or more group. As the number of male cases was small, a dispersion in the values was observed.

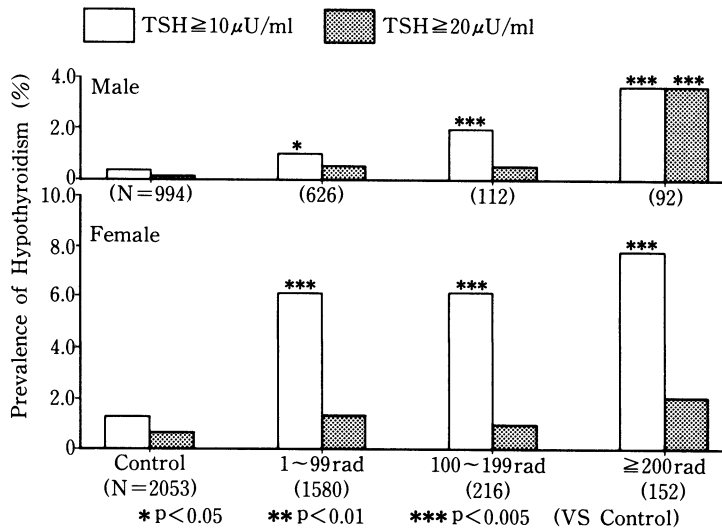


Fig. 6. Prevalence rate of cases with hypothyroidism by radiation dose (age adjusted)
Hypothyroidism : TSH levels $\geq 10 \mu\text{U/ml}$ (or $\geq 20 \mu\text{U/ml}$) or hypothyroidism under treatment

4. Positive rate of antithyroid microsome antibody

1) Comparison between the exposed group and control group

Those cases whose antithyroid microsome antibody titers (MCHA) were higher than 1×10^2 and positive were considered to be positive cases. Fig. 7 shows the prevalence rate of cases with positive MCHA by sex and age. In males, the prevalence rate of cases with positive MCHA was 4.7% in the 38~49 years age group of the exposed group and 3.1% in the control group, 5.4% and 4.8%, respectively, in the 50~59 years age group, 6.4% and 5.3%, respectively, in the 60~69 years age group, and 6.3% and 2.3%, respectively, in the 70+ years age group. In general, in comparison with the control group, the prevalence rate tended to be higher in the exposed group. In the exposed group, the prevalence rate of cases with positive MCHA increased with age, but a plateau was observed at ages over 60. In the control group, a peak was observed in cases in their sixties with a remarkable decline noted after 70. In comparison with the control group, the prevalence rate was significantly elevated at age over 70 in the

exposed group ($p < 0.01$).

The prevalence rate of positive MCHA was about twofold higher in females than males, but when examined by age, the positive rate in the 38~49 years age group was 9.8% in the exposed group and 7.5% in the control group, 12.6% and 10.1% in the 50~59 years age group, 14.0% and 10.1% in the 60~69 years age group, and 10.3% and 10.0% in the 70+ years age group. In the exposed group, the peak was seen in the 60~69 years age group, but the rate declined after the age of 70. In the control group, a plateau was observed after the age of 50. A comparison of the prevalence rate of positive MCHA made after age adjustment of both groups showed that the rate was 5.7% in males of the exposed group and 3.9% in males of the control group. The rate was significantly higher in the exposed group ($p < 0.05$). In females, it was 12.0% and 9.6%, respectively, with a higher rate in the exposed group ($p < 0.01$).

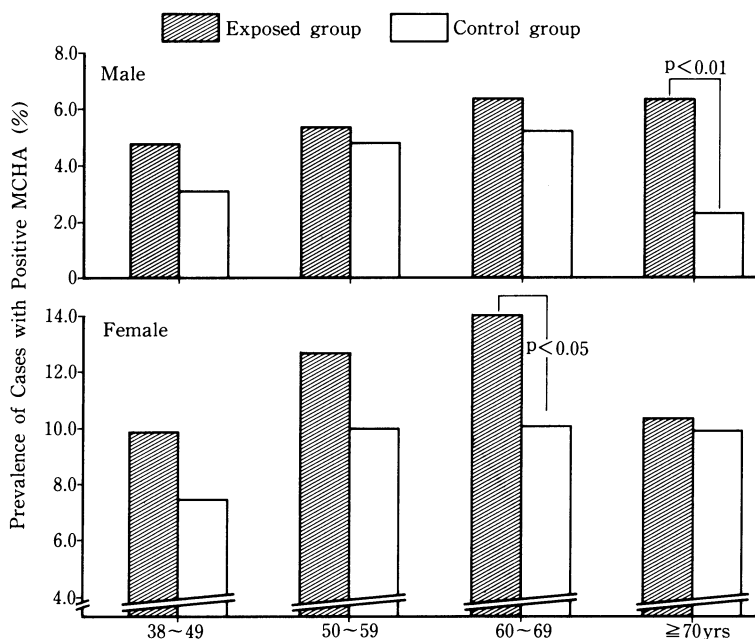


Fig. 7. Prevalence rate of cases with positive antithyroid microsome antibody

2) Comparison by exposure dose

The cases were classified into three exposure groups; a 1~99 rad group, a 100~199 rad group, and a 200+ rad group. Age adjustment of each group was made with the control group for comparison of the prevalence of positive

MCHA. The prevalence rate of positive MCHA in males was 5.2% in the 1~99 rad group, 4.0% in the 100~199 rad group, and 7.0% in the 200+ rad group, showing no significant difference with the 3.9% observed in the control group. In females, the rate was 13.3% in the

1~99 rad group, 14.2% in the 100~199 rad group, and 11.0% in the 200+ rad group. In comparison with the 9.6% observed in the control group, the rates in the 1~99 rad group and 100~199 rad group were significantly higher ($p < 0.005$ and $p < 0.05$).

5. Comparison between the prevalence rate of positive MCHA and that of hypothyroidism

Those whose antithyroid microsome antibody titers (MCHA) were more than 1×10^2 and positive were regarded to be positive MCHA cases. Fig. 8 shows a comparison by sex and age of the prevalence rate of hypothyroidism and that of positive MCHA. The prevalence rate of hypothyroidism in both sexes of the control group was generally lower than that of the exposed groups with a slight increase with age and at 60 years or over a plateau or a decline was observed. In the exposed group the rate increased with age, the 70+ years age group in particular showing the highest rate. The prevalence of positive MCHA in males of the exposed group showed a plateau at 60 or over, but in

the control group the rate declined after 70 years and over. In females of the exposed group, the rate peaked between 60 and 69 years and declined at over 70 years, but in the control group, a plateau was observed at ages over 50 years. As described above, the prevalence rates of hypothyroidism were different in both groups but showed an almost similar trend by age in both sexes. The prevalence rate of positive MCHA revealed a remarkable difference between the sexes. In particular among the elderly cases of 70 or over, the prevalence of positive MCHA in males of the exposed group showed a rate similar to that of those in their sixties. However, in the control group the positive MCHA was significantly lower for cases of 70 years or more. In the females, the prevalence rate of positive MCHA showed a plateau in those of the control group over the age of 50, but in the exposed group it remarkably decreased for those in their sixties. No consistent trend could be observed between the prevalence rate of hypothyroidism and that of positive MCHA.

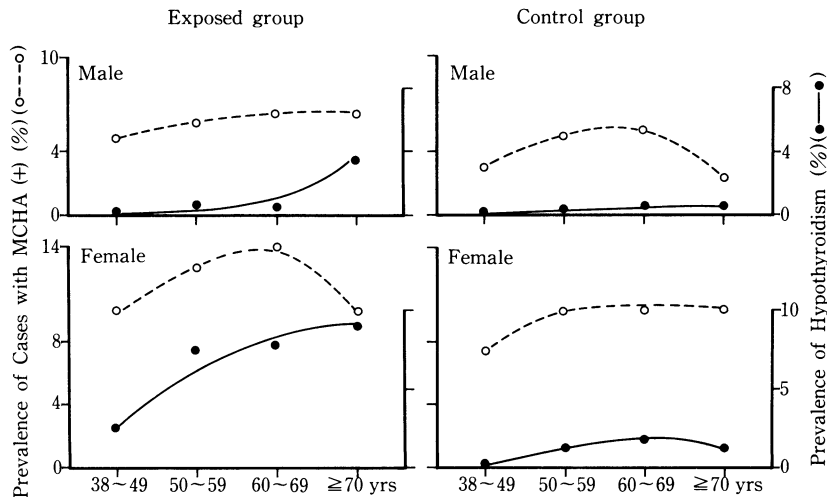


Fig. 8. Comparison of rate of cases with positive antithyroid microsome antibody and with hypothyroidism
Hypothyroidism : TSH levels $\geq 10 \mu\text{U/ml}$ or hypothyroidism under treatment

6. Prevalence rate of positive MCHA among hypothyroidism cases

1) Comparison between the exposed group and control group

As it is considered that many of the cases of hypothyroidism develop from chronic thyroiditis, a comparison was made of the prevalence rate

of positive MCHA among hypothyroidism cases between the exposed group and control group. In males of the 50~59 years age group, the prevalence rate of positive MCHA was 25% among 4 cases of the exposed group and 100% in one case of the control group; in males of the 60~69 years age group it was 0% among 2

cases and 0% in one case; and in males of the 70+ years age group it was 16.7% among 18 cases and 100.0% in one case. In females of the 38~49 years age group the rate was 40.0% among 15 cases of the exposed group and 0% in one case of the control group; it was 25.8% among 97 cases and 62.5% among 8 cases in the 50~59 years age group; it was 25.3% among 87 cases and 77.8% among 9 cases in the 60~69 years age group; and it was 22.0% among 82 cases and 60.0% among 5 cases in the 70+ years age group. In both sexes, the prevalence rate of positive MCHA was low in the exposed group. In the comparison after age adjustment, the prevalence rate of positive MCHA in males of the exposed group was 16.4% which is significantly lower than the 88.9% observed in the control group ($p < 0.025$). Also in the females, the rate was 25.3% in the exposed group, which is significantly lower than the 63.3% observed in the control group ($p < 0.005$) (Fig. 9).

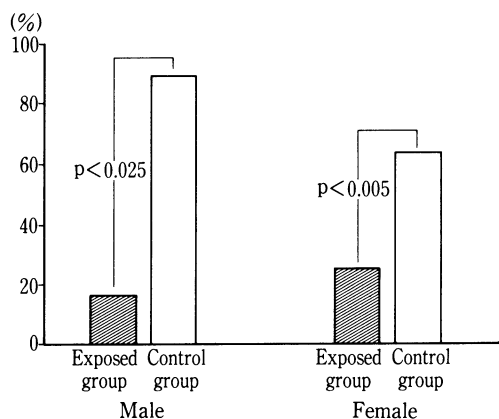


Fig. 9. Prevalence rate of cases with positive antithyroid microsome antibody by sex in hypothyroidism (age adjusted)
Hypothyroidism : TSH levels $\geq 10 \mu\text{U/ml}$ or hypothyroidism under treatment

2) Comparison by exposure dose

The exposure dose was classified into a 1~99 rad group and a 100+ rad group and a comparison was made of the prevalence rate of positive MCHA in cases of hypothyroidism between the exposure groups and control group after age adjustment. In males, the prevalence of positive MCHA was 21.9% among 8 cases in the 1~99

rad group, 31.3% among 5 cases in the 100+ rad group, and 81.3% among 3 cases in the control group, indicating that the rate was lower in the exposed groups. In females, the prevalence rate was 27.8% among 98 cases in the 1~99 rad group, 19.5% among 24 cases in the 100+ rad group, and 64.0% among 23 cases in the control group, demonstrating that the rate was significantly lower in the exposed groups ($p < 0.01$ and $p < 0.005$) (Fig. 10).

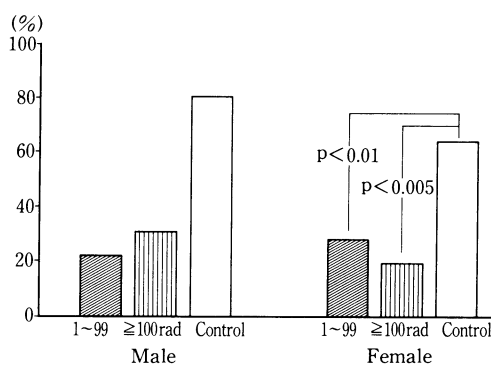


Fig. 10. Prevalence rate of cases with positive antithyroid microsome antibody by radiation dose and sex in hypothyroidism (age adjusted)
Hypothyroidism : TSH levels $\geq 10 \mu\text{U/ml}$ or hypothyroidism under treatment

DISCUSSION

With the aim of assessing the effect of atomic bomb radiation on thyroid function, examination of thyroid function was made in 6112 survivors directly exposed within 1.5 km and, as their controls, in 3047 survivors directly exposed more than 3.0 km from the hypocenter. Studies of this type require a large sample and examination of wide scope together with methods of high accuracy. Therefore, in this study, determination of TSH values was made by the solid phase RIA method, using dried filter paper blood²⁾ which was employed nationwide in 1975 as a screening test for congenital neonatal hypothyroidism. Irie et al³⁾ determined TSH values of approximately 10,000 residents using filter paper blood and reported a prevalence of 0.28% of hypothyroidism including subclinical hypothyroidism. This method is regarded to be a reliable screening test for thyroid diseases. As a fundamental study, the correlation between

the TSH values obtained by the heretofore employed double antibody method using serum and those by the present method was examined and was demonstrated to be extremely high.

The frequency distribution curves of TSH values obtained by the solid phase method in males did not show a marked difference between the exposed groups and control group, but the curve of the exposed groups slightly deviated to the right due to high TSH values, suggesting that the TSH level was generally elevated when compared to that of the control group. On the contrary, in females, in comparison with that of the control group the frequency distribution width of TSH values of the exposed groups was wide and the peak was low with the curve generally deviated toward the right. The mean TSH value of both sexes was significantly higher in the exposed groups, demonstrating that the TSH level was elevated when compared to that of the control group. When examined by exposure dose, in both sexes the TSH values were elevated in both the 1~99 rad group and 100+ rad group when compared with the control group.

The prevalence rate of hypothyroidism including subclinical hypothyroidism and cases under treatment for hypothyroidism was 1.22% in males of the exposed group and 0.35% in males of the control group, while in females it was 7.08% and 1.18%, respectively, indicating that in both sexes the prevalence was significantly higher in the exposed group than in the control group. The prevalence rate of hypothyroidism in males by exposure dose was 1.03% in the 1~99 rad group, 2.06% in the 100~199 rad group, and 3.67% in the 200+ rad group, showing an elevation with an increase in dose. The rate in the 100+ rad groups was significantly higher than the 0.33% observed in the control group. In females, the rate was 6.23% in the 1~99 rad group, 6.16% in the 100~199 rad group, and 7.76% in the 200+ rad group. The rates in all the exposed groups were significantly higher than the 1.32% of the control group. The prevalence rate in the control group was somewhat higher than the prevalence rate of 0.28% observed in residents by Irie et al⁹⁾, but this may be due to differences in the sex-age composition of the subjects and in the assay kit used in the determination.

There are few reports on the relation between thyroid function and atomic bomb radiation exposure, but Yokota et al¹⁴⁾ in analyzing the prevalence of thyroid diseases among 7735 examinees of the Nagasaki A-Bomb Hospital in 1960 have suggested a relation between hypothyroidism and atomic bomb radiation. A similar report was also published by Oshiumi et al⁹⁾ in 1972. These reports concern outpatients and there has been no report on an epidemiological study of a large number of cases. As the progress of hypothyroidism is slow, hardly any subjective symptoms are experienced and it is considered extremely rare that hospital visits are made for this condition. It is therefore considered impossible to elucidate the relation between atomic bomb exposure and abnormal thyroid function without making a uniform quantitative analysis of hormones as in the present extensive epidemiological study.

The prevalence rate of hypothyroidism including subclinical hypothyroidism in the exposed group of both sexes was found to be higher than that of the control group. In general, most of the cases of acquired primary hypothyroidism are attributable to injury of the thyroid tissue due to chronic thyroiditis. When the antithyroid antibody (MCHA) in the blood is positive, it is assumed that the patient has chronic thyroiditis with infiltration of lymphocytes in the thyroid tissue¹⁵⁾. In comparing the prevalence rate of positive MCHA among hypothyroidism cases of both groups, in males the prevalence of positive MCHA was 16.4% in the exposed group and 88.9% in the control group, while in females it was 25.3% and 63.3%, respectively. In both sexes the prevalence rate was remarkably lower in the exposed group.

In view of the foregoing, the possibility may be considered strong that hypothyroidism observed in atomic bomb survivors was not caused by injury of the thyroid tissue due to chronic thyroiditis but by the involvement of a different developmental mechanism. Hypothyroidism is mostly mild and subclinical hypothyroidism diagnosed by TSH value has been observed at a high rate in the exposed group. Analysis by exposure dose has also suggested a dose response in the prevalence of hypothyroidism. Furthermore, in the exposed group an increase in hypothyroidism was observed with age and in

particular the rate was remarkably high in both sexes at 70 years or above, but in the control group, no increase was observed in hypothyroidism at 70 years or above when compared to that of those in the sixties.

The present analysis was based on TSH level. Orimo et al⁸⁾ who studied the changes in TSH level with aging have not observed any elevation of TSH level with aging and have reported that the number of non-TSH responders was greater in elderly cases. The present authors have not noted any elevation of TSH level with aging in the control group. Morimoto et al⁶⁾ have not observed any elevation of TSH level in heavily exposed young survivors which is different from the results of the present authors. This may be because the age of their subjects at time of examination was lower, being less than 49 years. The correlation between the prevalence of positive antithyroid antibody among hypothyroidism has not been elucidated. The prevalence of positive antithyroid antibody among hypothyroidism cases in the exposed group is remarkably lower than that of the control group and it is difficult to assume that most of the cases of hypothyroidism in the exposed group is attributable to chronic thyroiditis. It has been reported that the radiosensitivity of the thyroid tissue is high and that clinical hypothyroidism can be induced by external exposure⁴⁾. As for the relationship between radiation and acceleration of the aging process from the experimental approach, it is regarded that this is attributable to decrease in regenerative activity of cells caused by radiation¹²⁾. To date the number of reports on thyroid weight and volume in autopsy cases of atomic survivors has been extremely few. Nakashima et al⁵⁾ have reported a decrease in thyroid weight among atomic bomb survivors and suggested acceleration of aging of the thyroid tissue due to radiation exposure. The results of the present authors also suggest the possibility of hypothyroidism being induced by atrophy of the thyroid tissue by exposure to atomic bomb radiation. At any rate, there is a need for detailed studies on the thyroid gland.

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REFERENCES

1. **Hollingsworth, D.R., Hamilton, H.B., Tamagaki, H. and Beebe, G.W.** 1966. Thyroid diseases. ABCC-JNIH Adult Health Study, Hiroshima, 1958-59. *J. Hiroshima Med. Ass.* **19**: 167-196.
2. **Irie, M., Enomoto, K., Nemoto, H., Umeda, M. and Naruse, H.** 1976. Determination of thyroid stimulating hormones in blood using dried filter paper blood. *Folia Endocrinol. Jap.* **52**: 243-247.
3. **Irie, M.** 1982. A discussion of diagnosis of endocrine diseases. *Folia Endocrinol. Jap.* **58**: 1385-91.
4. **Maxon, H.R., Thomas, S.R., Sanger, E.L., Buncher, C.R. and Kereiakes, J.G.** 1977. Ionizing irradiation and the induction of clinically significant diseases in human thyroid gland. *Amer. J. Med.* **63**: 967-978.
5. **Nakashima, E., Yoshimoto, Y. and Fujikura, T.** 1983. Effects of aging on organ weight of A-bomb survivors. *Jap. J. Behaviormetrics* **10**: 55.
6. **Morimoto, I., Yoshimoto, Y., Sato, K. Kawamoto, S., Izumi, M. and Nagataki, S.** 1985. Serum TSH, thyroglobulin, and thyroid disorders in atomic bomb survivors exposed in youth: A study 30 years after exposure. *RERF TR* 20-85.
7. **Okano, Y., Ohno, Y., Nagatani, Y., Tsuruhara, T. and Oura, T.** 1982. Cretinism mass-screening study by solid phase TSH-RIA method. *Clinical Endocrinology* **30**: 81-85.
8. **Orimo, H., Yamada, H., Ito, H., Shiraki, M. and Nakao, S.** 1982. Normal values and abnormal values of test findings in the elderly. 5. *Endocrine function. Jap. J. Geriat.* **19**: 459-464.
9. **Oshiumi, Y., Kamoi, I., Takahashi, S., Ishida, S., Inoue, S. and Kuramoto, K.** 1972. Thyroid function in atomic bomb survivors. *Proceedings of the 13th Late Atomic Bomb Effect Research Meeting*, p.69-75.
10. **Parker, L.N., Belsky, J.L., Yamamoto, T., Kawamoto, S. and Keehn, R.J.** 1973. Thyroid carcinoma diagnosed between 13 and 26 years after exposure to atomic radiation. *ABCC TR* 5-73.
11. **Socolow, E.L., Hashizume, A., Neriishi, S. and Niitani, R.** 1963. Thyroid carcinoma in man after exposure to ionizing radiation. A summary of the findings in Hiroshima and Nagasaki. *New Engl. J. Med.* **268**: 406-410.
12. **Tauchi, H. and Kuroda, Y.** 1981. Aging of cells. p.201-206, *Kyoritsu Shuppan, Tokyo.*
13. **Wood, J.W., Tamagaki, H., Neriishi, S., Sato, T., Sheldon, W.F., Archer, P.C., Hamilton,**

- H.B. and Johnson, K.G.** 1969. Thyroid carcinoma in atomic bomb survivors, Hiroshima and Nagasaki. *Amer. J. Epidemiol.* **89**: 4–14.
14. **Yokota, M., Matsuzaka, K., Anpi, S., Yokouchi, H. and Mukae, H.** 1960. Thyroid disorders in atomic bomb survivors. *Nagasaki Med. J.* **36 Special Edition**: 202–205.
15. **Yoshida, H. Amino, N., Yagawa, K. Uemura, K., Satou, M., Miyai, K. and Kumahara, Y.** 1978. Association of serum antithyroid antibodies with lymphocytic infiltration of the thyroid gland. Studies on seventy autopsied cases. *J. Clin. Endocrinol. Metab.* **46**: 859–862.