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# Mortality Statistics of Major Causes of Death among Atomic Bomb Survivors in Hiroshima Prefecture from 1968 to 1982

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## ABSTRACT

A comparative study was made on mortality during a 15-year period from 1968 to 1982 between atomic bomb survivors resident in Hiroshima Prefecture and non-exposed controls.

The mortality rate for all causes of death was lower in atomic bomb survivors than in the non-exposed, but the rate was higher among those directly exposed within about 1 km than in the non-exposed. The mortality rate for malignant neoplasms was higher in atomic bomb survivors than in the non-exposed, but that for cerebrovascular disease and heart disease was lower. In examining the rate for malignant neoplasms by site, the sites showing a high mortality rate among atomic bomb survivors were almost identical to the results of the Life Span Study. For these sites, the shorter the exposure distance the higher was the mortality rate. The rate for malignant neoplasms of the uterus and stomach, and leukemia was unnaturally high among early entrants whose period after issuance of atomic bomb survivor's health handbook was short. In observing the atomic bomb survivors by the level of family destruction due to the bombing as a socio-economic factor, a tendency was observed for the mortality rate for malignant neoplasms, diseases of blood and blood-forming organs, and peptic ulcer, to be higher among survivors with severe family destruction.

**Key words:** *Atomic bomb survivors, Late effect, Mortality, Major causes of death*

Atomic Bomb Casualty Commission (ABCC) and its successor, Radiation Effects Research Foundation (RERF), in their attempt to ascertain whether or not there is any shortening of life span among atomic bomb survivors, have been engaged in a Life Span Study and have released a series of reports[1,2,5,14], but inasmuch as the primary purpose of their study is to observe the biological effects of radiation on a fixed population, a large number of reports of much value on the relation between radiation and malignant neoplasms have been released, but little analysis has been made on other causes of death[2]. Oho[12] has made a painstaking study on mortality for malignant neoplasms among Hiroshima atomic bomb survivors. From 1975 the staffs of the Department of Epidemiology and Social Medicine and of the Department of Biometrics of our Research Institute have been jointly engaged in an important research project of studying the mortality statistics of atomic bomb survivors resident in Hiroshima Prefecture in comparison with those of non-exposed residents of Hiroshima Prefecture and have published to date a series of reports

of their findings[4,6,7]. A similar study, mainly concerned with all causes of death, has been made on Nagasaki atomic bomb survivors resident in Nagasaki City[11,13].

As the eighth revised population[8] of atomic bomb survivors has been recently compiled by the Research Institute for Nuclear Medicine and Biology and as the mortality statistics of this population for a 15-year period extending from 1968 to 1982 became available, an analysis on malignant neoplasms by major sites and other major causes of death observed in this population was conducted by exposure status, place of residence (Hiroshima City and others), period after issuance of atomic bomb survivor's health handbook, and level of family destruction due to the atomic bomb. The results of this analysis will be presented.

## MATERIALS AND METHODS

As the study population, the eighth revised population[8] of atomic bomb survivors of the Research Institute for Nuclear Medicine and Biology was used. The person year at risk was that as

of July 1 of each calendar year and death information was based on vital statistics death schedules whose approved use other than their original purpose was secured from the agency concerned.

The non-exposed population for the period 1968 to 1982 was obtained by subtracting from the estimated population of Hiroshima Prefecture of these years based on the national census conducted in 1965, 1970, 1975, 1980 and 1985 the enumerated number of atomic bomb survivors as of these respective years. The study population and deaths were restricted to only Japanese and as place of residence the administrative geographic division as of the end of 1982 was employed.

Exposure status was classified as indicated in Table 1. Because the exposure distance from the hypocenter of those directly exposed to the atomic bomb was based on the name of "machi", that is, a Japanese administrative district where the individual lived at the bombing, the distance is not exact. "Early entrants" refers to those who entered Hiroshima City within about 2 km from the hypocenter within 2 weeks after the bombing. In-utero exposed cases were classified according to the exposure status of the mother.

In order to take into account the difference in sex-age composition between the atomic bomb survivors and the non-exposed, the expected deaths adjusted for sex, age and period was calculated in the following way. The observed 15 years were divided into three periods of 1968—72, 1973—77, and 1978—82. The expected deaths ($E_{i,j}$) were calculated on the basis of the mortality rate ($r_{i,j,k}$) of all Japan by period (i), sex (j) and 5-year age-group (k) and the person years at risk ($p_{i,j,k}$) using the following equation

$$E_{i,j} = \sum_k P_{i,j,k} \cdot r_{i,j,k}.$$

And the ratio of observed deaths ($D_{i,j}$) to expected deaths ($E_{i,j}$) was used as standardized mortality ratio.

The relative risk defined by the ratio of atomic bomb survivors' to the non-exposed population's standardized mortality ratio was computed and observation was primarily based on this relative risk. In the following results of analysis, in order to simplify the observations, the expected deaths (E) of both sexes combined for the 15 year period and the observed deaths (D) were calculated by the following:

$$E = \sum_{i,j} E_{i,j} \quad , \quad D = \sum_{i,j} D_{i,j}.$$

Therefore, the relative risk was obtained as follows:

$$\text{Relative risk} = \frac{(D \,/\, E)}{(D' \,/\, E')} \quad ,$$

where D : number of deaths among the survivors,
D': number of deaths among the non-exposed,
E : expected deaths among the survivors,
E': expected deaths among the non-exposed.

Test of significance of relative risk was made by binomial test[15]. As level of significance, 5%, 1%, and 0.1% have been employed, but as suggestive level 10% has also been indicated.

In the classification of causes of death, the eighth revision of the International Statistical Classification of Diseases, Injuries, and Causes of Death was used for 1968—78 and the ninth revision for 1979—82. For those items for which the classifications were almost identical, those for a period for 15 years were totalled and the nomenclatures given in the eighth revision were employed. As for malignant neoplasms, observation was made by the detailed list and as for other causes of death only the major causes of death based on the simplified list were examined.

## RESULTS

### 1. Relative risk by exposure status

Table 1 shows the relative risk of all causes of death, malignant neoplasms, and other causes of death by detailed exposure classification status. The risk of all causes of death in the survivors combined was significantly low being 92% of the non-exposed, but that of those directly exposed within about 1 km was significantly higher than that of the non-exposed which was 6% higher. The risk of those exposed about 1—1.5 km was slightly lower and not significant and that of other exposure groups was significantly lower. The risk of malignant neoplasms in the survivors combined was about 10% higher than that of the non-exposed and, in particular, that of those directly exposed within about 1 km was 47% higher, that of those exposed about 1—1.5 km 27% higher, that of those about 1.5—2 km 14% higher, that of those directly exposed more than 2 km who either entered or did not enter the city within 3 days about 10% higher, and those of other categories was of the same level as or lower than that of the non-exposed. The risk of causes of death other than malignant neoplasms among the survivors combined was 88% of the non-exposed and significantly low, but that among survivors directly exposed within about 1 km was 96%, being closest to the non-exposed with the level of significance of 10%. The ratio of those belonging to other exposure categories was very significantly low.

### 2. Relative risk of malignant neoplasms by site

Table 2 shows the relative risk of malignant neoplasms by site according to five exposure classifications (three classifications for the directly exposed within about 2 km). For the exposed combined, the risk of malignant neoplasm of the testis was the

Table 1. Relative risk[a] of mortality for all causes, malignant neoplasms and other causes of death by detailed exposure status (Both sexes, 1968—1982, Hiroshima Prefecture)

| Exposure status | All causes | Malignant neoplasms | Other causes |
|---|---|---|---|
| Atomic bomb survivors (Total) | 0.918 *** | 1.098 *** | 0.875 *** |
| Proximally exposed (Subtotal) | 0.976 ** | 1.244 *** | 0.910 *** |
| Within about 1 km from the hypocenter | 1.063 ** | 1.466 *** | 0.959 sug. |
| About 1 to 1.5 km from the hypocenter | 0.983 | 1.275 *** | 0.915 *** |
| About 1.5 to 2 km from the hypocenter | 0.941 *** | 1.143 *** | 0.891 *** |
| Early entrants within 3 days after the bombing (Subtotal) | 0.895 *** | 1.032 * | 0.862 *** |
| Distally exposed about 2 km and over | 0.929 *** | 1.120 *** | 0.880 *** |
| Not exposed | 0.885 *** | 1.002 | 0.857 *** |
| Other survivors (Subtotal) | 0.901 *** | 1.065 * | 0.862 *** |
| Distally exposed about 2 km and over and entrants on and after 4 days after the bombing | 0.877 * | 0.999 | 0.847 ** |
| Distally exposed about 2 km and over and not exposed | 0.935 *** | 1.102 *** | 0.897 *** |
| Entrants on and after 4 days after the bombing and not exposed | 0.841 *** | 1.004 | 0.798 *** |
| Others | 0.807 *** | 0.981 | 0.763 *** |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.

highest, being 2.1-fold that of the non-exposed, which was followed by lymphosarcoma and reticulum-cell sarcoma (1.7), malignant neoplasm of the salivary gland (1.6), leukemia (1.5), and malignant neoplasm of the breast (1.5). Other sites which showed a significantly high risk were larynx, ovary, multiple myeloma, bladder, uterus, lung, esophagus, large intestine except rectum, and liver and intrahepatic bile duct.

In examining these malignant neoplasms by three exposure groups, the relative risk among those directly exposed within about 2 km was highest in malignant neoplasm of the testis, followed by lymphosarcoma and reticulum-cell sarcoma, leukemia, breast, ovary, bladder, uterus, lung, large intestine, and liver and intrahepatic bile duct. Of these malignant neoplasms, the relative risk of leukemia was also significantly increased in the other exposed groups. Though the risk of malignant neoplasms of the stomach and thyroid gland was not significantly high in the exposed groups combined, it was significantly high when confined to those directly exposed within about 2 km. In examining those directly exposed within about 2 km by exposure distance, a tendency was observed for the risk to be higher the shorter the distance for malignant neoplasms of sites such as stomach, large intestine, liver and intrahepatic bile duct, breast, ovary, and bladder, and for leukemia. The risk of malignant neoplasms of the esophagus and larynx was the highest in other survivors, and also the risk of malignant neoplasms of the testis, ovary, and lymphosarcoma and reticulum-cell sarcoma was relatively high in other survivors. The risk of malignant neoplasm of the skin was significantly low for the exposed groups combined.

## 3. Relative risk of other major causes of death

As can be seen in Table 2, in the exposed groups combined the risk was significantly high for diseases of blood and blood-forming organs, cirrhosis of the liver, diabetes mellitus, hypertensive disease, benign and unspecified neoplasms, nephritis and nephrosis, while the risk of senility, gastro-enteritis, cerebrovascular diseases, accidents, suicide, and heart disease was significantly low. In examining these risks by three exposure classification, hardly any difference by exposure classification could be observed.

## 4. Relative risk by place of residence (Hiroshima City and others)

That these causes of death may be affected by living environment, that is, the difference between urban and rural area, the place of residence of the survivors was classified into Hiroshima City and others and then comparison was made with the non-exposed in each place. The results are presented in Table 3. In examining all causes of death and malignant neoplasms by exposure status, the relative risk was found to be higher in Hiroshima City. The risk of all causes of death was significantly lower in all three exposure groups outside of Hiroshima City, but the risk of those directly exposed within about 2 km was almost of the same level as that of the non-exposed in Hiroshima City. The risk of malignant neoplasms was higher in all three exposure groups in Hiroshima City with the risk being the highest among those directly exposed within about 2 km. Outside of Hiroshima City, the risk of malignant neoplasms was slightly high in the exposed groups combined and significantly high only in those directly exposed within about 2 km.

In examining the major sites of malignant ne-

**Table 2.** Relative risk[a] of mortality for selected causes of death by exposure status (5 categories)
(Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death | Atomic bomb survivors (Total) | Proximally exposed | | | | Early entrants within 3 days after the bombing | Other survivors |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | Subtotal | Within about 1 km from the hypocenter | About 1 to 1.5 km from the hypocenter | About 1.5 to 2 km from the hypocenter | | |
| Malignant neoplasms | | | | | | | |
|   Salivary gland | 1.571 * | 1.460 | 2.301 sug. | 1.918 sug. | 0.792 | 1.928 * | 1.081 |
|   Esophagus | 1.165 ** | 1.278 * | 1.319 | 1.429 * | 1.140 | 0.977 | 1.438 *** |
|   Stomach | 1.019 | 1.140 *** | 1.274 *** | 1.133 ** | 1.100 * | 0.983 | 0.958 |
|   Large intestine, except rectum | 1.149 ** | 1.242 ** | 1.455 * | 1.294 * | 1.129 | 1.081 | 1.161 * |
|   Rectum and rectosigmoid junction | 1.011 | 0.908 | 0.742 | 1.070 | 0.826 sug. | 0.989 | 1.144 sug. |
|   Liver and intrahepatic bile duct, specified as primary | 1.087 ** | 1.260 *** | 1.591 *** | 1.235 * | 1.166 * | 0.985 | 1.086 sug. |
|   Gallbladder and bile ducts | 1.062 | 1.075 | 1.512 sug. | 0.880 | 1.103 | 1.121 | 0.966 |
|   Pancreas | 0.995 | 1.013 | 0.916 | 1.049 | 1.016 | 1.028 | 0.923 |
|   Larynx | 1.406 ** | 1.206 | 1.609 | 0.766 | 1.408 | 1.310 sug. | 1.859 ** |
|   Trachea, bronchus and lung | 1.162 *** | 1.347 *** | 1.287 * | 1.579 *** | 1.179 * | 1.088 * | 1.114 * |
|   Skin | 0.713 * | 0.577 * | 0.550 | 0.418 * | 0.723 | 0.745 | 0.794 |
|   Breast | 1.506 *** | 2.082 *** | 4.722 *** | 1.816 *** | 1.593 ** | 1.143 | 1.353 ** |
|   Uterus | 1.209 *** | 1.434 *** | 1.223 | 1.177 | 1.725 *** | 1.141 sug. | 1.085 |
|   Ovary, fallopian tube, and broad ligament | 1.336 ** | 1.466 * | 1.792 sug. | 1.631 * | 1.227 | 1.075 | 1.448 ** |
|   Prostate | 1.094 | 1.198 | 1.773 * | 0.886 | 1.213 | 1.061 | 1.062 |
|   Testis | 2.111 * | 3.641 ** | — | 7.420 *** | 1.886 | 0.616 | 2.808 * |
|   Bladder | 1.251 ** | 1.616 *** | 2.094 ** | 1.895 *** | 1.208 | 1.089 | 1.196 |
|   Thyroid gland | 1.106 | 1.392 sug. | 3.145 * | 1.057 | 1.167 | 0.903 | 1.109 |
|   Lymphosarcoma and reticulum-cell sarcoma | 1.664 *** | 2.090 *** | 2.308 * | 2.624 ** | 1.575 sug. | 1.261 | 1.886 ** |
|   Multiple myeloma | 1.326 * | 1.026 | 0.882 | 1.247 | 0.890 | 1.574 ** | 1.223 |
|   Leukemia | 1.524 *** | 1.956 *** | 5.864 *** | 1.383 sug. | 1.179 | 1.362 ** | 1.334 * |
|   Myeloid leukemia | 1.887 *** | 2.677 *** | 7.863 *** | 1.749 * | 1.803 ** | 1.592 ** | 1.530 ** |
| Benign and unspecified neoplasms | 1.107 * | 1.319 *** | 1.434 * | 1.267 * | 1.325 ** | 1.072 | 1.177 |
| Tuberculosis | 0.992 | 1.360 *** | 1.287 sug. | 1.426 *** | 1.332 ** | 0.824 ** | 0.919 |
| Diabetes mellitus | 1.198 *** | 1.200 ** | 1.292 sug. | 1.208 * | 1.164 sug. | 1.196 ** | 1.198 ** |
| Diseases of blood and blood-forming organs | 1.378 *** | 1.303 * | 1.097 | 1.409 sug. | 1.277 | 1.403 ** | 1.409 ** |
| Heart disease | 0.906 *** | 0.968 sug. | 0.918 sug. | 1.030 | 0.929 * | 0.882 *** | 0.886 *** |
| Hypertensive disease | 1.126 *** | 1.223 *** | 1.089 | 1.296 *** | 1.198 * | 1.071 sug. | 1.124 * |
| Cerebrovascular disease | 0.837 *** | 0.826 *** | 0.916 * | 0.802 *** | 0.817 *** | 0.837 *** | 0.849 *** |
| Pneumonia | 1.011 | 1.098 * | 0.944 | 1.139 * | 1.113 * | 0.977 | 0.987 |
| Peptic ulcer | 0.927 sug. | 0.934 | 1.174 | 0.797 sug. | 0.968 | 0.910 sug. | 0.952 |
| Cirrhosis of liver | 1.225 *** | 1.386 *** | 1.174 | 1.389 *** | 1.455 *** | 1.114 ** | 1.245 *** |
| Nephritis and nephrosis | 1.103 * | 1.093 | 1.585 ** | 1.042 | 0.980 | 1.070 | 1.163 * |
| Senility without mention of psychosis | 0.502 *** | 0.476 *** | 0.600 *** | 0.465 *** | 0.451 *** | 0.521 *** | 0.499 *** |
| Gastro-enteritis | 0.629 *** | 0.577 *** | 0.207 *** | 0.515 *** | 0.746 * | 0.608 *** | 0.706 *** |
| Accidents | 0.852 *** | 0.845 *** | 0.908 | 0.905 | 0.774 *** | 0.907 ** | 0.777 *** |
| Suicide | 0.883 ** | 0.797 ** | 0.893 | 0.832 sug. | 0.739 ** | 0.945 | 0.883 * |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
Symbol "—" denotes no death.
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.

**Table 3.** Relative risk[a] of mortality for selected causes of death by exposure status (3 categories) in Hiroshima City and others (Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death | Atomic bomb survivors (Total) | | Proximally exposed within about 2 km from the hypocenter | | Early entrants within 3 days after the bombing | | Other survivors | |
|---|---|---|---|---|---|---|---|---|
| | Hiroshima City | Others | Hiroshima City | Others | Hiroshima City | Others | Hiroshima City | Others |
| All causes | 0.941 *** | 0.903 *** | 0.992 | 0.965 * | 0.906 *** | 0.894 *** | 0.924 *** | 0.873 *** |
| Malignant neoplasms | 1.128 *** | 1.026 sug. | 1.265 *** | 1.126 *** | 1.070 ** | 0.992 | 1.050 * | 1.042 |
| Esophagus | 1.194 * | 0.969 | 1.135 | 1.276 sug. | 1.020 | 0.890 | 1.459 ** | 0.959 |
| Stomach | 1.084 ** | 0.983 | 1.209 *** | 1.085 sug. | 1.039 | 0.965 | 1.002 | 0.940 |
| Large intestine, except rectum | 1.305 *** | 1.065 | 1.378 ** | 1.173 | 1.333 ** | 0.961 | 1.212 sug. | 1.255 sug. |
| Rectum and recto-sigmoid junction | 1.044 | 1.003 | 0.950 | 0.870 | 0.993 | 1.001 | 1.183 sug. | 1.128 |
| Liver and intra-hepatic bile duct, specified as primary | 1.196 *** | 0.967 | 1.426 *** | 0.935 | 1.135 sug. | 0.891 * | 1.026 | 1.249 * |
| Trachea, bronchus and lung | 1.072 sug. | 1.110 * | 1.225 ** | 1.237 * | 1.005 | 1.079 sug. | 0.986 | 1.095 |
| Breast | 1.657 *** | 1.287 * | 2.210 *** | 1.874 ** | 1.369 * | 0.900 | 1.384 * | 1.358 sug. |
| Uterus | 0.990 | 1.328 *** | 1.261 * | 1.281 sug. | 0.856 | 1.352 * | 0.849 sug. | 1.328 * |
| Ovary, fallopian tub, and broad ligament | 1.331 * | 1.070 | 1.451 * | 1.051 | 1.146 | 0.838 | 1.353 * | 1.348 |
| Testis | 3.214 ** | 1.212 | 4.714 ** | 2.803 sug. | — | 0.982 | 4.445 ** | — |
| Bladder | 1.407 ** | 1.043 | 1.529 ** | 1.770 ** | 1.330 sug. | 0.930 | 1.364 * | 0.776 |
| Multiple myeloma | 1.553 * | 1.420 * | 1.524 sug. | 0.644 | 1.413 | 1.827 ** | 1.713 * | 0.960 |
| Leukemia | 1.648 *** | 1.377 ** | 2.118 *** | 1.660 * | 1.386 * | 1.356 * | 1.431 * | 1.158 |
| Benign and unspecified neoplasms | 1.058 | 1.125 * | 1.116 | 1.719 *** | 1.130 | 1.006 | 0.933 | 0.934 |
| Tuberculosis | 1.039 | 0.841 | 1.317 ** | 1.219 sug. | 0.881 | 0.754 *** | 0.907 | 0.768 sug. |
| Diabetes mellitus | 1.237 *** | 1.215 *** | 1.271 ** | 1.166 | 1.136 sug. | 1.267 *** | 1.297 ** | 1.103 |
| Diseases of blood and blood-forming organs | 1.403 ** | 1.303 * | 1.370 * | 1.059 | 1.514 * | 1.301 * | 1.337 * | 1.523 * |
| Heart disease | 0.938 ** | 0.887 *** | 0.981 | 0.989 | 0.923 ** | 0.864 *** | 0.910 ** | 0.873 *** |
| Hypertensive disease | 1.007 | 1.125 ** | 1.105 sug. | 1.151 sug. | 0.888 sug. | 1.140 * | 1.021 | 1.053 |
| Cerebrovascular disease | 0.862 *** | 0.849 *** | 0.861 *** | 0.825 *** | 0.815 *** | 0.870 *** | 0.907 *** | 0.797 *** |
| Pneumonia | 0.898 ** | 0.976 | 0.944 | 1.089 | 0.880 * | 0.964 | 0.869 ** | 0.921 |
| Peptic ulcer | 0.916 | 0.933 | 0.929 | 0.929 | 0.858 | 0.940 | 0.963 | 0.909 |
| Cirrhosis of liver | 1.324 *** | 1.066 sug. | 1.501 *** | 1.072 | 1.155 * | 1.074 | 1.312 *** | 1.031 |
| Nephritis and nephrosis | 1.099 sug. | 1.031 | 1.019 | 1.145 | 1.147 sug. | 0.976 | 1.132 | 1.090 |
| Senility without mention of psychosis | 0.582 *** | 0.524 *** | 0.540 *** | 0.563 *** | 0.616 *** | 0.517 *** | 0.591 *** | 0.515 *** |
| Gastro-enteritis | 0.566 *** | 0.647 *** | 0.510 *** | 0.634 * | 0.537 *** | 0.630 *** | 0.642 *** | 0.711 * |
| Accidents | 0.964 | 0.884 ** | 0.968 | 0.899 | 1.046 | 0.891 * | 0.888 * | 0.843 * |
| Suicide | 0.888 * | 0.970 | 0.886 sug. | 0.746 * | 0.923 | 1.003 | 0.862 * | 1.102 |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
Symbol "—" denotes no death.
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.

oplasms in the exposed groups combined, the risk of most of the sites was higher in Hiroshima City, with the risk only being significant in sites such as esophagus, stomach, large intestine, liver and intrahepatic bile duct, ovary, testis, and bladder. The risk of malignant neoplasm of the breast, multiple myeloma, and leukemia was significantly high in both areas, but the risk was higher in Hiroshima City. However, the risk of only malignant ne-oplasms of the lung and uterus was significantly high outside of Hiroshima City. By exposure status, due to the number of available cases the findings were not necessarily consistent, but the ratio of malignant neoplasms of the stomach, breast, and ovary, and leukemia was higher in Hiroshima City in all exposure categories. The risk of malignant neoplasms of the lung and uterus was higher outside of Hiroshima City in all exposure categories.

As for other major causes of death excluding malignant neoplasms, the risk of the exposure groups combined was higher in Hiroshima City for tuberculosis, diabetes mellitus, diseases of blood and blood-forming organs, heart disease, cirrhosis of the liver, nephritis and nephrosis, senility, and accidents, while the risk was higher outside of Hiroshima City for benign and unspecified neoplasms, hypertensive disease, pneumonia, and gastro-enteritis, but no difference in risk between the two areas could be demonstrated for cerebrovascular disease and peptic ulcer. By exposure status, the risk of tuberculosis, cirrhosis of the liver, and accidents was higher in Hiroshima City for all three exposure groups, but the risk of pneumonia and gastro-enteritis was higher in all three exposure groups outside of Hiroshima City.

## 5. Relative risk by period after issuance of atomic bomb survivor's health handbook

Even during the period of 1968—82, a considerable number of atomic bomb survivor's health handbooks were newly issued. If the application for benefits under the Atomic Bomb Survivors Medical Treatment Law upon contraction of disease is an important motive for request for issuance of the health handbook, the mortality rate during a short period after handbook issuance should be high. In order to confirm whether such a phenomenon exists or not, the standardized mortality ratios for five different periods, that is, less than one year, 1—2 years, 2—3 years, 3—5 years, and more than 5 years were computed and these were compared with those of the non-exposed.

Table 4. Relative risk[a] of mortality for all causes, malignant neoplasms and other causes of death by period after issuance of atomic bomb survivor's health handbook and exposure status (3 categories)

(Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death | Period after issuance of atomic bomb survivor's health handbook | Atomic bomb survivors (Total) | Proximally exposed within about 2 km from the hypocenter | Early entrants within 3 days after the bombing | Other survivors |
|---|---|---|---|---|---|
| All causes | Total | 0.918 *** | 0.976 ** | 0.895 *** | 0.901 *** |
| | −1 yr | 1.276 *** | 2.244 *** | 1.306 *** | 1.161 ** |
| | 1—2 yrs | 0.979 | 1.211 | 0.951 | 1.002 |
| | 2—3 yrs | 0.938 * | 1.269 * | 0.943 sug. | 0.889 * |
| | 3—5 yrs | 0.869 *** | 1.044 | 0.842 *** | 0.899 ** |
| | 5 yrs and over | 0.913 *** | 0.971 *** | 0.886 *** | 0.891 *** |
| Malignant neoplasms | Total | 1.098 *** | 1.244 *** | 1.032 * | 1.065 ** |
| | −1 yr | 2.154 *** | 3.829 *** | 2.033 *** | 2.167 *** |
| | 1—2 yrs | 1.319 *** | 0.869 | 1.278 ** | 1.421 *** |
| | 2—3 yrs | 1.088 sug. | 1.878 ** | 1.162 * | 0.858 sug. |
| | 3—5 yrs | 1.040 | 1.495 ** | 1.005 | 1.040 |
| | 5 yrs and over | 1.074 *** | 1.234 *** | 0.995 | 1.023 |
| Other causes | Total | 0.875 *** | 0.910 *** | 0.862 *** | 0.862 *** |
| | −1 yr | 1.032 | 1.771 *** | 1.113 * | 0.867 * |
| | 1—2 yrs | 0.886 ** | 1.315 sug. | 0.866 ** | 0.880 * |
| | 2—3 yrs | 0.899 ** | 1.093 | 0.888 ** | 0.898 * |
| | 3—5 yrs | 0.825 *** | 0.922 | 0.802 *** | 0.860 *** |
| | 5 yrs and over | 0.874 *** | 0.907 *** | 0.860 *** | 0.861 *** |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.

Table 4 shows the relative risk of all causes of death, malignant neoplasms, and other causes of death by period from issuance of health handbook by each exposure group. All the relative risks were higher for the period of less than one year and with lapse of time after handbook issuance, the risk generally declined. Even for all causes of death whose relative risk was significantly low for the total period, the risk was significantly high for all exposure groups for the period of less than one year after issuance of the health handbook.

The risk of malignant neoplasms was remarkably high particularly for the period of less than one

year, being 3.8 fold higher in those directly exposed within less than 2 km than that of the non-exposed. Furthermore, the risk was significantly higher even for the period of more than 5 years. The risk in cases of early entrants within 3 days after the bombing was significantly high for the periods of less than 3 years, and that of the other survivors was significantly high for the periods of less than 1 year and of 1—2 years, but thereafter the risk was almost equivalent to that of the non-exposed.

As shown in Table 5, the relative risk of malignant neoplasms of the major sites for the exposed groups combined was remarkably high for almost

**Table 5.** Relative risk[a] of mortality for selected causes of death by period after issuance of atomic bomb survivor's health handbook (All exposure groups, Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death | Period after issuance of atomic bomb survivor's health handbook | | | | |
| --- | --- | --- | --- | --- | --- |
| | −1 yr | 1—2 yrs | 2—3 yrs | 3—5 yrs | 5 yrs and over |
| Malignant neoplasms | | | | | |
| Esophagus | 2.193 ** | 1.024 | 0.703 | 1.473 * | 1.142 * |
| Stomach | 2.127 *** | 1.058 | 1.077 | 1.015 | 0.991 |
| Large intestine, except rectum | 1.572 sug. | 1.106 | 1.899 ** | 1.060 | 1.128 * |
| Rectum and rectosigmoid junction | 1.288 | 2.255 *** | 0.851 | 0.958 | 0.984 |
| Liver and intrahepatic bile duct specified as primary | 1.670 ** | 1.415 * | 1.067 | 0.895 | 1.078 * |
| Trachea, bronchus and lung | 2.084 *** | 1.482 * | 0.891 | 1.277 * | 1.138 *** |
| Breast | 2.534 ** | 1.302 | 2.877 *** | 1.063 | 1.469 *** |
| Uterus | 2.431 *** | 1.649 * | 1.281 | 1.381 * | 1.149 ** |
| Ovary, fallopian tube, and broad ligament | 2.424 * | 2.685 ** | 0.413 sug. | 0.607 | 1.344 ** |
| Testis | 12.536 ** | — | — | — | 2.119 * |
| Bladder | 2.947 ** | 1.078 | 0.591 | 0.963 | 1.257 ** |
| Multiple myeloma | 2.100 sug. | — | 2.404 * | 1.142 | 1.323 * |
| Leukemia | 5.073 *** | 3.154 *** | 1.523 | 0.375 * | 1.466 *** |
| Benign and unspecified neoplasms | 1.552 * | 1.252 | 0.884 | 1.311 sug. | 1.088 sug. |
| Tuberculosis | 1.066 | 0.655 sug. | 0.647 * | 1.210 sug. | 0.997 |
| Diabetes mellitus | 1.271 | 1.493 * | 1.059 | 1.377 *** | 1.183 *** |
| Diseases of blood and blood-forming organs | 4.390 *** | 1.404 | 2.701 ** | 1.441 sug. | 1.274 ** |
| Heart disease | 0.967 | 0.933 | 0.850 * | 0.772 * | 0.912 *** |
| Hypertensive disease | 1.090 | 1.432 * | 1.075 | 0.996 | 1.129 *** |
| Cerebrovascular disease | 0.910 | 0.792 *** | 0.878 * | 0.776 *** | 0.839 *** |
| Pneumonia | 1.038 | 0.788 sug. | 0.815 | 0.702 ** | 1.033 sug. |
| Peptic ulcer | 1.648 * | 0.699 | 1.135 | 0.729 sug. | 0.924 sug. |
| Cirrhosis of liver | 1.767 *** | 1.362 * | 1.272 sug. | 1.400 ** | 1.197 *** |
| Nephritis and nephrosis | 2.697 *** | 0.928 | 1.399 sug. | 1.634 ** | 1.039 |
| Senility without mention of psychosis | 0.413 *** | 0.535 *** | 0.493 *** | 0.302 *** | 0.512 *** |
| Gastro-enteritis | 1.411 | 0.665 | 0.851 | 0.534 ** | 0.613 *** |
| Accidents | 0.811 | 1.103 | 0.937 | 0.923 | 0.839 *** |
| Suicide | 0.848 | 1.170 | 1.281 sug. | 1.231 sug. | 0.842 *** |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
Symbol "—" denotes no death.
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.

all sites for the period of less than one year. However, the risk of the malignant neoplasms of the rectum and ovary was the highest for the period of 1—2 years after issuance, that of large intestine, breast, and multiple myeloma for the period of 2—3 years. However, the sites of malignant neoplasms which showed a significantly high relative risk for the total period continued to show a similarly significantly high level even after a period of more than five years.

As shown in Table 6 by three exposure groups, the tendency for the relative risk of malignant neoplasms of some sites to be higher the shorter the period after issuance of health handbook was similarly observed even by exposure status. In particular, the relative risk of those directly exposed within about 2 km was high for the periods of within less than one year and 1—2 years after handbook issuance, this being particularly remarkable for malignant neoplasms of the uterus, and liver and intrahepatic bile duct. The relative risk of

malignant neoplasms of the sites indicated in this table at a period of more than 5 years after issuance was almost equivalent to the relative risk for the entire period combined and the level of significance did not change among the proximally exposed, but it was common for the relative risk at a period of more than 5 years after issuance to be lower than that for the entire period combined among early entrants within 3 days after the bombing and other survivors. The relative risk of malignant neoplasm of the lung and leukemia in the early entrants within 3 days after the bombing and that of malignant neoplasms of the liver and intrahepatic bile duct and lung in other survivors were significantly high for the period combined, but these significance disappeared when the period after issuance was more than five years. The relative risk of malignant neoplasm of the stomach at a period of more than five years after handbook issuance was low in early entrants within 3 days after the bombing and other survivors, the risk being signifi-

**Table 6.** Relative risk[a] of mortality for malignant neoplasms of some sites by exposure status (3 categories) and period after issuance of atomic bomb survivor's health handbook.

(Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death and exposure status | Period after issuance of atomic bomb survivor's health handbook | | | | |
|---|---|---|---|---|---|
| | −1 yr | 1—2 yrs | 2—3 yrs | 3—5 yrs | 5 yrs and over |
| Malignant neoplasm of stomach | | | | | |
| Proximally exposed within about 2 km from the hypocenter | 3.677 *** | 0.756 | 1.717 sug. | 1.762 * | 1.126 *** |
| Early entrants within 3 days after the bombing | 1.817 *** | 1.021 | 1.194 sug. | 0.920 | 0.954 sug. |
| Other survivors | 2.425 *** | 1.152 | 0.737 sug. | 1.101 | 0.898 ** |
| Malignant neoplasm of liver and intrahepatic bile duct, specified as primary | | | | | |
| Proximally exposed within about 2 km from the hypocenter | 4.892 ** | — | 3.134 * | 1.630 | 1.243 *** |
| Early entrants within 3 days after the bombing | 1.645 * | 1.253 | 0.635 sug. | 0.667 * | 1.001 |
| Other survivors | 1.422 | 1.812 * | 1.629 * | 1.245 | 1.017 |
| Malignant neoplasm of trachea, bronchus and lung | | | | | |
| Proximally exposed within about 2 km from the hypocenter | 3.101 * | — | 1.003 | 2.700 ** | 1.335 *** |
| Early entrants within 3 days after the bombing | 2.276 *** | 1.541 * | 1.019 | 1.304 * | 1.036 |
| Other survivors | 1.728 * | 1.528 sug. | 0.615 sug. | 0.990 | 1.107 sug. |
| Malignant neoplasm of uterus | | | | | |
| Proximally exposed within about 2 km from the hypocenter | 8.434 ** | 6.878 ** | — | 1.029 | 1.410 *** |
| Early entrants within 3 days after the bombing | 3.042 ** | 1.403 | 1.389 | 1.670 * | 1.002 |
| Other survivors | 1.732 * | 1.510 sug. | 1.285 | 1.126 | 1.024 |
| Leukemia | | | | | |
| Proximally exposed within about 2 km from the hypocenter | 7.097 ** | 6.013 * | — | — | 1.956 *** |
| Early entrants within 3 days after the bombing | 6.867 *** | 3.464 ** | 1.891 sug. | 0.228 * | 1.213 sug. |
| Other survivors | 3.212 ** | 2.518 * | 1.238 | 0.644 | 1.269 * |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
Symbol "—" denotes no death.
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.

cant in the latter and nearly significant in the former.

As for other major causes of death, the relative risk of diseases of blood and blood-forming organs, nephritis and nephrosis, cirrhosis of the liver, benign and unspecified neoplasms, peptic ulcer, and gastro-enteritis was the highest at a period of less than one year after issuance as shown in Table 5. However, such a tendency could not be observed in the other causes of death and the relative risk of heart disease, cerebrovascular disease, senility, and accidents did not hardly show any relation to period after issuance of the handbook. The relative risk of diabetes mellitus was high at periods of 1—2 years and 3—5 years after issuance, that of suicide was slightly high at periods of 1—2 years, 2—3 years, and 3—5 years after issuance and that of tuberculosis was low at periods of 1—2 years and

2—3 years after issuance. The relative risk of individual causes of death at a period of more than 5 years after issuance was almost equal to that of the risk of the total period.

## 6. Relative risk by level of family destruction

Earlier reports[8,9] have shown that the level of family destruction through the loss of important family members in the atomic bombing is severe in the proximally exposed individuals and is parallel to the magnitude of radiation exposure dose.

In order to confirm whether family destruction through the atomic bomb affects the mortality rate by cause of death, the standardized mortality ratio by level of family destruction was determined and compared with that of the non-exposed. The level of family destruction was classified as severe when an individual was applicable to any one of the following: (1) Death of the head of the family by

bombing ("Death by the bombing" is defined as death by the end of October 1945 following direct exposure to the bomb); (2) Death of either the father or mother by the bombing when the individual was younger than 20 years of age; (3) Death of the husband by the bombing; (4) Death of first son by the bombing when the individual was more than

45 years of age; and (5) Death of one-third or more of the family members by the bombing. Individuals not applicable to any of the foregoing conditions were classified as slight. However, it should be noted that in about one-third of the individuals the circumstances of the family members at the time of the bomb were unknown.

**Table 7.** Relative risk[a] of mortality for all causes, malignant neoplasms and other causes of death by level[b] of family destruction and exposure status (3 categories) (Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death | Level[b] of family destruction | Atomic bomb survivors (Total) | Proximally exposed within about 2 km from the hypocenter | Early entrants within 3 days after the bombing | Other survivors |
|---|---|---|---|---|---|
| All causes | Severe | 0.763 *** | 0.799 *** | 0.682 *** | 0.787 *** |
| | Slight | 0.751 *** | 0.831 *** | 0.673 *** | 0.785 *** |
| | Unknown | 1.282 *** | 1.552 *** | 1.257 *** | 1.158 *** |
| Malignant neoplasms | Severe | 1.062 sug. | 1.203 *** | 0.851 * | 1.026 |
| | Slight | 0.898 *** | 1.064 ** | 0.769 *** | 0.923 ** |
| | Unknown | 1.495 *** | 1.832 *** | 1.455 *** | 1.351 *** |
| Other causes | Severe | 0.694 *** | 0.707 *** | 0.643 *** | 0.729 *** |
| | Slight | 0.715 *** | 0.774 *** | 0.650 *** | 0.752 *** |
| | Unknown | 1.230 *** | 1.481 *** | 1.210 *** | 1.111 *** |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.
b) The level of family destruction due to atomic bomb was classified as severe when an individual was applicable to any one of the following: (1) Death of head of the family by the bombing ("Death by the bombing" is defined as death by the end of October 1945 following direct exposure to the bomb); (2) Death of either the father or mother by the bombing when the individual was younger than 20 years of age; (3) Death of the husband by the bombing; (4) Death of first son by the bombing when the individual was more than 45 years of age; and (5) Death of one-third or more of the family members by the bombing.
Individuals not applicable to any of the foregoing were classified as slight.

Shown in Table 7 was the relative risk of all causes of death, malignant neoplasms, and other causes of death by level of family destruction of the three exposure groups. The relative risk in each category was remarkably high and significant for those whose level of family destruction was unknown. The relative risk of all causes of death was significantly low in all exposure groups whose level of family destruction was either severe or slight with hardly any difference between the two.

The risk of malignant neoplasms in all exposure groups was higher in those whose level of family destruction was severe than in those whose level was slight. For the survivors combined, the risk of those with severe family destruction was high with suggestive significance, but that of those with slight family destruction was significantly low. The risk among those exposed within about 2 km was significantly high when the level of family destruction was either severe or slight. The risk of early entrants within 3 days was significantly low at both levels and that of the other survivors was somewhat but not significantly high when the level of family destruction was severe and was significantly low when the level of family destruction was slight.

The risk of causes of death other than malignant neoplasms was significantly low in all exposure groups regardless of whether the level of family destruction was severe or slight.

Table 8 shows the relative risk of malignant neoplasms of selected sites and of major causes of death for the exposed groups combined. The risk of malignant neoplasms of many sites and of almost all major causes of death was significantly higher in those whose level of family destruction was unknown than that in the non-exposed (However, the risk was low for senility and gastro-enteritis.). The relative risk of those whose level of family destruction was severe was nearly significantly high for malignant neoplasms of sites such as esophagus, and liver and intrahepatic bile duct, and was almost significantly low for malignant neoplasm of the rectum, and as for major causes of death it was significantly high for diseases of blood and blood-forming organs and significantly low for gastro-enteritis, senility, accidents, suicide, cerebrovascular disease, pneumonia, and heart disease. The relative risk of many major causes of death observed in those with slight level of family destruction was significantly low.

In order to compare severe family destruction

**Table 8.** Relative risk[a] of mortality for selected causes of death by level[b] of family destruction (All exposure groups, Both sexes, 1968—1982, Hiroshima Prefecture)

| Causes of death | Level[b] of family destruction | | |
| --- | --- | --- | --- |
| | Severe | Slight | Unkown |
| Malignant neoplasms | | | |
|   Esophagus | 1.347 sug. | 0.968 | 1.522 *** |
|   Stomach | 1.017 | 0.782 | 1.484 *** |
|   Large intestine, except rectum | 1.149 | 1.024 | 1.391 *** |
|   Rectum and rectosigmoid junction | 0.745 sug. | 0.804 | 1.472 *** |
|   Liver and intrahepatic bile duct, specified as primary | 1.196 sug. | 0.906 * | 1.409 *** |
|   Trachea, bronchus and lung | 1.029 | 1.034 | 1.439 *** |
|   Breast | 1.302 | 1.150 sug. | 2.137 *** |
|   Uterus | 1.137 | 0.837 * | 1.943 *** |
|   Ovary, fallopian tube, and broad ligament | 1.221 | 1.154 | 1.666 *** |
|   Testis | — | 2.633 * | 1.615 |
|   Bladder | 1.322 | 1.138 sug. | 1.467 ** |
|   Multiple myeloma | 0.823 | 1.134 | 1.810 ** |
|   Leukemia | 1.326 | 1.476 *** | 1.654 *** |
| Benign and unspecified neoplasms | 1.117 | 0.975 | 1.363 *** |
| Tuberculosis | 0.792 sug. | 0.733 *** | 1.534 *** |
| Diabetes mellitus | 1.066 | 0.901 * | 1.838 *** |
| Diseases of blood and blood-forming organs | 1.798 ** | 0.906 | 2.208 *** |
| Heart disease | 0.738 *** | 0.781 *** | 1.191 *** |
| Hypertensive disease | 1.080 | 0.892 ** | 1.607 *** |
| Cerebrovascular disease | 0.623 *** | 0.682 *** | 1.196 *** |
| Pneumonia | 0.710 *** | 0.886 *** | 1.326 *** |
| Peptic ulcer | 1.016 | 0.660 *** | 1.437 *** |
| Cirrhosis of liver | 1.013 | 0.977 | 1.731 *** |
| Nephritis and nephrosis | 1.137 | 0.877 * | 1.539 *** |
| Senility without mention of psychosis | 0.455 *** | 0.423 *** | 0.656 *** |
| Gastro-enteritis | 0.415 *** | 0.497 *** | 0.923 |
| Accidents | 0.478 *** | 0.622 *** | 1.365 *** |
| Suicide | 0.554 *** | 0.635 *** | 1.410 *** |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%
Symbol "—" denotes no death.
a) The ratio of the atomic bomb survivors' to the non-exposed population's standardized mortality ratio.
b) See the Table 7.

with slight family destruction, the ratio of standardized mortality ratio of the two was computed for some causes of death. As shown in Table 9, no significant difference could be observed for all causes of death by exposure status, but the ratio of malignant neoplasms of all sites was significantly high for the exposed groups combined and for those exposed within about 2 km. And in examining some of the sites, the risk was higher in those with severe family destruction for sites such as stomach, liver and intrahepatic bile duct, and uterus, being either significant or nearly significant. As for other major causes of death, the ratio was significantly high for diseases of blood and blood-forming organs, and peptic ulcer, while that of pneumonia and accidents was significantly low.

## DISCUSSION

Many of the reports published to date on mortality statistics of atomic bomb survivors have been confined to survivors resident in Hiroshima City or Nagasaki City and the majority of the study subjects belonging to the Life Span Study of ABCC-

RERF are residents of the two cities. The survivors resident in the two cities are biased as samples of atomic bomb survivors as a whole from the standpoint of being urban residents. Furthermore, concern has been directed in recent years to diseases of low incidence and thus there is a need to employ a study population of the largest size possible. The Life Span Study is a valuable project in that detailed exposure dose data are available for its population, but inasmuch as the primary purpose of that study is to measure the biological effects of radiation on man, it is unable to respond to administrative need of identifying the difference between the entire atomic bomb survivor population and the general population. And the status of early entrants and distantly exposed survivors has yet to be elucidated. From these standpoints, our study covering all atomic bomb survivors resident in Hiroshima Prefecture is regarded as having much significance. It should also be noted that inasmuch as the subjects of the present study are deaths occurring from 1968 to 1982, it presents the status of the population more than 20 years after ex-

**Table 9.** Ratio of standardized mortality ratio among survivors of severe family destruction to among survivors of slight family destruction for some causes of death by exposure status (3 categories)
(Both sexes, 1968—1982, Hiroshima Prefecture)

| | |
|---|---|
| **All causes** | |
| Atomic bomb survivors (Total) | 1.017 |
| Proximally exposed within about 2 km from the hypocenter | 0.962 |
| Early entrants within 3 days after the bombing | 1.013 |
| Other survivors | 1.003 |
| **Malignant neoplasms** | |
| Atomic bomb survivors (Total) | 1.183 *** |
| Proximally exposed within about 2 km from the hypocenter | 1.130 * |
| Early entrants within 3 days after the bombing | 1.107 |
| Other survivors | 1.112 |
| Esophagus | 1.391 |
| Stomach | 1.301 *** |
| Large intestine, except rectum | 1.122 |
| Liver and intrahepatic bile duct, specified as primary | 1.321 * |
| Trachea, bronchus and lung | 0.995 |
| Breast | 1.132 |
| Uterus | 1.358 sug. |
| Leukemia | 0.898 |
| Tuberculosis | 1.081 |
| Diabetes mellitus | 1.183 |
| Diseases of blood and blood-forming organs | 1.984 ** |
| Heart disease | 0.945 |
| Hypertensive disease | 1.211 sug. |
| Cerebrovascular disease | 0.913 |
| Pneumonia | 0.802 * |
| Peptic ulcer | 1.539 * |
| Nephritis and nephrosis | 1.296 sug. |
| Accidents | 0.769 * |
| Suicide | 0.873 |

Level of significance: sug. 10%, * 5%, ** 1%, *** 0.1%

posure to the atomic bomb.

## Low mortality rate of all causes of death

The results of the present study showed that the standardized mortality ratio of all causes of death in the survivors was about 8% lower than that of the non-exposed, but that of the directly exposed within about 1 km from the hypocenter was significantly higher. According to the cumulative death rate for 1950—78 observed in the Life Span Study[5], the higher the exposure dose the higher was the rate in the survivors less than 50 years of age at time of the bomb, but this is not a comparison with the non-exposed. In our study, in examining the directly exposed by distance from the hypocenter, the shorter the distance from the hypocenter the higher was the relative risk, a finding in agreement with the results of the Life Span

Study.

## Malignant neoplasms

The mortality rate for malignant neoplasms of all sites combined in the directly exposed within about 2 km was 24% higher than that for the non-exposed. When this was examined by exposure distance, the rate was 47% higher among those exposed within about 1 km, 27% higher among those exposed at 1—1.5 km, and 14% higher among those exposed at 1.5—2 km. This is in agreement with the results of the Life Span Study that excess deaths increase with exposure dose. However, even among those exposed beyond about 2 km, the rate in those who entered the city within 3 days and that in those who did not enter the city were high, being 12% and 10%, respectively, higher than the non-exposed. As our exposure distance is based on the "machi" where the individual was exposed, the distance is not accurate and there is a possibility that those exposed within 2 km may be included in the group exposed beyond about 2 km.

Many reports have been published on malignant neoplasms by site among atomic bomb survivors. According to the results of the latest report of the Life Span Study[5], the sites of malignant neoplasms which show a significant excess risk with radiation dose are leukemia, esophagus, stomach, colon, lung, breast, ovary, bladder, and multiple myeloma. Oho[12] has given malignant neoplasm of the uterus in addition. And our results have shown in addition a high relative risk of mailgnant neoplasms of sites such as salivary gland, liver and intrahepatic bile duct, larynx, testis, and lymphosarcoma and reticulum-cell sarcoma. However, malignant neoplasms of the salivary gland and larynx did not show a significantly high risk in those directly exposed within about 2 km, but the risk was significantly high among the early entrants who entered the city within 3 days and other survivors. When the directly exposed were observed by exposure distance, the risk of malignant neoplasms of the stomach, large intestine, liver and intrahepatic bile duct, breast, ovary, and bladder, and leukemia was higher the shorter the distance and malignant neoplasm of the lung, and lymphosarcoma and reticulum-cell sarcoma showed a similar tendency. These findings are almost consistent with the results of the foregoing Life Span Study. However, the relation of some sites to exposure distance is not necessarily consistent and there is thus a need to undertake a review based on accurate exposure distance measurements and to take into account factors other than radiation.

## Other major causes of death

In examining all causes of death combined excluding cancers, the mortality rate is lower than in the non-exposed, but in the directly exposed, the rate increased with decrease in exposure distance and

tended to approach the rate of the non-exposed. By major causes of death, the rate of benign and unspecified neoplasms, tuberculosis, hypertensive disease, pneumonia and cirrhosis of the liver was significantly elevated among those directly exposed within about 2 km, but the rate of diseases of blood and blood-forming organs was elevated to almost the same level in every exposure group. the rate of heart disease was lower than in the non-exposed with that in those exposed within about 2 km who were closest to the non-exposed. The rate of cerebrovascular disease, peptic ulcer, senility, gastro-enteritis, and accidents was generally low with no difference observable by exposure status. The rate of suicide was also generally low with the rate being the lowest among those directly exposed within about 2 km.

The findings of the Life Span Study[5] have shown that tuberculosis is not related to radiation, but as a result of medical examination of a fixed population, Belsky et al[3] have pointed out that in some cycles of health examination the prevalence of tuberculosis was high among males with exposure dose exceeding 100 rad and suggested that this was attributable to poor health among male survivors in the military conscription age. This phenomenon might have influenced the mortality statistics more that 20 years thereafter. However, this does not explain the absence of high risk of tuberculosis among those distally exposed.

If one were to exclude malignant neoplasms, diseases of blood and blood-forming organs showed the highest relative risk. An increase in mortality rate for this disease has also been observed in the Life Span Study[5] among the heavily exposed group, but the accuracy of diagnosis of this disease entered in the death certificate has been questioned. In also our study, the risk was elevated regardless of exposure status, indicating a need to take into consideration factors other than radiation, for example the question of diagnosis given in death certificate as cause of death.

According to the findings of the Life Span Study[1], cerebrovascular disease is not related to radiation, but this is not in comparison with residents in general. It has been reported in Nagasaki that the mortality rate of this disease is lower than in the non-exposed[11]. Despite the finding that the mortality rate of malignant neoplasms is high among atomic bomb survivors, the mortality rate of all causes of death is lower than in the non-exposed. This is primarily attributable to the low mortality rate of this disease and heart disease.

It has often been speculated that the suicide rate among the exposed might be higher than the non-exposed, but this could not be confirmed at least during this period of observation and in particular the rate among those exposed within about 2 km was about 80% that of the non-exposed. The Life Span Study[1] reported that the rate for this cause

of death showed an inverse relationship with radiation dose and also in our study the rate among early entrants within 3 days and other survivors was higher than that in those directly exposed within about 2 km, a finding consistent with that of the Life Span Study.

Of the major causes of death whose rate was lower than in the non-exposed, senility showed the largest difference, being only about one-half that of the non-exposed, and was low with hardly any relation with exposure status. In Japan, senility is one of the major causes of death and even in 1986 it was ranked 6th place among the causes of death of the people. A high frequency of senility as a cause of death is considered to be one evidence of inaccuracy of death certificate diagnosis. It is expected that with improved accuracy in the diagnosis of diseases, senility as cause of death in death certificate will decrease. From this standpoint, it may be interpreted that accuracy of diagnosis among atomic bomb survivors is higher than people in general due to the higher rate in which medical care is received by the survivors in light of the availability of free medical care. If so, a tendency should be observed for the mortality rate due to diseases relatively difficult to diagnose to increase. This point should be taken into account in considering their high mortality rate due to various malignant neoplasms, diabetes mellitus, and blood disease.

A discussion will be made of the effect of low frequency of senility as cause of death among atomic bomb survivors on the relative risk of malignant neoplasms. If the death rate for senility among the non-exposed is assumed to be as low as that among atomic bomb survivors, that decreased portion due to the smaller number of deaths of senility will be occupied by other diagnoses. Other diagnoses would naturally include of malignant neoplasms and if it is assumed that the proportion to be occupied by malignant neoplasms is similar to the proportion occupied by malignant neoplasms among all causes of death excluding senility, and if this number is calculated in each age group and then added to the number of deaths, the standardized mortality ratio can be computed. During this period of observation, of the number of deaths among the non-exposed due to all causes of death excluding senility, 17% was due to malignant neoplasms. Based on the standardized mortality ratio of the non-exposed with the foregoing addition, the relative risk of malignant neoplasms among the exposed was estimated and the relative risk of the survivors combined would be 1.080, that of the directly exposed within about 2 km would be 1.224, that of the early entrants within 3 days would be 1.015, and that of other survivors would be 1.047. The significance of the relative risk of the early entrants within 3 days would disappear. As the possibility of malignant neoplasms being diagnosed as senility is con-

sidered to be stronger than that of other diseases being diagnosed as senility, the true relative risk might be larger than the foregoing estimates. It may be reasonable to assume that there is hardly any difference in malignant neoplasms mortality between the non-exposed, and early entrants within 3 days and other survivors.

**Place of residence (Hiroshima City and others)**

It has been stated earlier that the low mortality rate of cerebrovascular disease and heart disease in atomic bomb survivors is an important factor in the low mortality rate of all causes of death. There is a geographic difference within Hiroshima Prefecture in both of these diseases and all causes of death. When Hiroshima Prefecture is divided into Hiroshima City and others, the rate is definitely higher in the latter[10]. On the other hand, many of the atomic bomb survivors live in Hiroshima City to account for about two-thirds of the total[8]. This concentration of atomic bomb survivors in Hiroshima City which has a low mortality rate may be the reason why the mortality rate of atomic bomb survivors is lower than the non-exposed when viewed from the total of Hiroshima Prefecture. The relative risk of standardized mortality ratio was therefore computed by Hiroshima City and others. The results as described previously showed the relative risk of all causes of death, cerebrovascular disease and heart disease to be low in both localities to refute the foregoing supposition. In addition, our results showed that the relative risk of many sites of malignant neoplasms was higher in Hiroshima City than in the rest of Hiroshima Prefecture and similar results were obtained when observed by exposure status. This is not attributable to the fact that the proportion occupied by the directly exposed is larger among the exposed residing in Hiroshima City nor to the fact that the proportion of proximally exposed is larger among the directly exposed residing in Hiroshima City. The necessity is suggested that consideration be made of factors other than radiation such as urban factors.

**Reasons for the low mortality rate among atomic bomb survivors**

As described above, the death rate in the exposed for cerebrovascular disease and heart disease which are the major causes of death in Japan is lower than in the non-exposed and thus it may not be a mistake to state that the mortality rate for all causes of death is lower. As a cause for this low rate, it may be interpreted that with improved health management of atomic bomb survivors following the enforcement of the Atomic Bomb Survivors Medical Treatment Law enacted in 1957, a high health examination rate has been maintained and the medical examination, medical treatment, and living guidance provided particularly for circulatory disease have been effective. "Selection the-

ory" has been postulated for this unexpectedly low mortality rate among atomic bomb survivors. For example, Stewart et al[16] have criticized that the results of the Life Span Study have undervalued the true effects of radiation inasmuch as only those with strong immunity selectively survived after being exposed to the atomic bomb and scarred bone marrow must have persisted for an extended period. However, according to our study, among the proximally exposed whose mortality rate immediately after the bomb was high, the distally exposed with lower mortality, and the early entrants, the mortality rate for major causes of death excluding malignant neoplasms is almost comparable in the observed period of this report, and when examined by all causes of death excluding malignant neoplasms, the rate has been higher the shorter the exposure distance. The assumption that the cause of the low mortality rate observed among the exposed in recent years is "selection" attributable to high mortality at the time of bombing exposure does not appear to be reasonable.

**Effect of period after issuance of atomic bomb survivor's health handbook**

It is natural to assume that after contracting disease a survivor would apply for issuance of atomic bomb survivor's health handbook particularly if the medical care fees to be borne increase following retirement on reaching retirement age. If such cases increase, the effect on mortality rate can no longer be ignored. Even during the period of this mortality statistics from 1968 to 1982, the number of atomic bomb survivors who were newly issued such handbooks in Hiroshima Prefecture reached a total of about 62,000. An examination was attempted by period after handbook issuance and a tendency was observed for the risk of many sites of malignant neoplasms to be higher the shorter the period after handbook issuance and in particular the risk was remarkably elevated within one year after issuance. It should be noted that the risk of leukemia and lung cancer is high among the early entrants within 3 days and other survivors in whom the effects of radiation are assumed to be fairly small. The risk is definitely high at periods of within one year and 1—2 years after issuance and the significance of the risk among early entrants within 3 days disappears after 5 or more years.

The directly exposed within about 2 km from the hypocenter similarly showed a remarkably high risk within a short period after handbook issuance, but even after 5 or more years after issuance the relative risk has persisted at a comparable level. Among the proximally exposed, the high risk observed during the short period after issuance did not necessarily influence the entire mortality rate, but in other exposed cases, there are instances in which such effect cannot be ignored. The high mortality rate for leukemia and some other malignant

neoplasms among early entrants should also be examined from such a standpoint.

## Effect of family destruction

It is obvious that the poor health experienced by atomic bomb survivors is attributable to the biological effects of radiation, but other factors should be taken into account. One of these is the socio-economic factor and as one of the leads we have made a number of analysis from the standpoint of family destruction attributable to death of family members by the atomic bombing[8,9]. In examining the relative risk of standardized mortality ratio after classifying the level of family destruction into severe and slight, it was found that the relative risk of those for whom we were not able to obtain information regarding their family members or, in other words, the unknown category was remarkably high. Our information regarding families of atomic bomb survivors is based on the so-called restoration survey[17] which was commenced in 1968, but a part of this information is dependent on the various family surveys conducted after 1973. The survey of the latter is as a rule based on those who survived at the time of survey and thus for those who had deceased prior to the conduct of the survey family information could not be obtained. Thus, the level of family destruction of some portion of those who had died prior to 1972 is listed as unknown. In order to advance analysis of this aspect, it has been pointed out that survey must be conducted not only the living atomic bomb survivors but also retrospectively into the past.

The mortality rate of those whose family circumstances could be ascertained by the foregoing survey to date is remarkably low and cannot be said to reflect the actual condition. Despite these restrictions, analysis was conducted by classifying the level of family destruction into severe and slight. Though no difference could be demonstrated for all causes of death, a tendency was observed for the risk to be higher in the severe category for many sites of malignant neoplasms, diseases of blood and blood-forming organs, and peptic ulcer, suggesting the possibility that socio-economic factors represented by the level of family destruction affect various types of diseases in atomic comb survivors. Further detailed studies should be made on their interaction with exposure distance directly associated with radiation dose.

## REFERENCES

1. **Beebe, G. W., Kato, H. and Land, C. E.** 1977. Life Span Study Report 8, Mortality experience of atomic bomb survivors, 1950—1974. RERF TR: 1—77.
2. **Beebe, G. W., Kato, H. and Land, C. E.** 1979. Studies of mortality of A-bomb survivors. 6. Mortality and radiation dose. 1950—74. J. Hiroshima Med. Ass. **32**: 842—861. (in Japanese)
3. **Belsky, J. L., Tachikawa, K. and Jablon, S.** 1974. The health of atomic bomb survivors : A decade of examinations in a fixed population. J. Hiroshima Med. Ass. **27**: 813—822. (in Japanese)
4. **Hayakawa, N., Munaka, M., Kurihara, M., Yamamoto, H., Ueoka, H., Ohtaki, M., Watanabe, S., Ubuki, S., Oride, M., Matsuura, M., Sumida, H. and Hiraoka, M.** 1985. Mortality statistics by causes of death among A-bomb survivors in Hiroshima Prefecture, 1973—1977. Proc. Hiroshima Univ. RINMB, **26**: 134—147. (in Japanese)
5. **Kato, H., Brown, C. C., Hoel, D. G. and Schull, W. J.** 1981. Life Span Study Report 9, Part 2. Mortality from causes other than cancer among atomic bomb survivors, 1950—78. RERF TR : 5—81.
6. **Kurihara, M., Munaka, M., Hayakawa, N., Yuzaki, M., Yamamoto, H., Ueoka, H., Ohtaki, M., Watanabe, S., Ubuki, S., Ikeuchi, M., Shimizu, Y., Sumida, H. and Hiraoka, M.** 1981. Mortality statistics among A-bomb survivors in Hiroshima Prefecture, 1968—1972. 1981 Proc. Hiroshima Univ. RINMB, **22**: 235—255. (in Japanese)
7. **Kurihara, M., Munaka, M., Hayakawa, N., Yamamoto, H., Ueoka, H. and Ohtaki, M.** 1981. Mortality statistics among atomic bomb survivors in Hiroshima Prefecture, 1968—1972. J. Radiat. Res. **22**: 456—471.
8. **Kurihara, M., Munaka, M., Hayakawa, N., Ohtaki, M., Ubuki, S., Matsuura, M., Hiraoka, M. and Sumida. H.** 1989. The eighth revised population of atomic bomb survivors of RINMB and state of family destruction of the survivors. Proc. Hiroshima Univ. RINMB, **30** (submitted). (in Japanese)
9. **Kurihara, M., Ueoka, H., Munaka, M., Hayakawa, N., Hiraoka, M. and Sumida, H.** 1988. The effects of family destruction in the atomic bomb survivors in Hiroshima Prefecture. Report 2. Observation by exposure status. J. Hiroshima Med. Ass. **41**: 480—483. (in Japanese)
10. **Kurihara, M. and Ohtaki, M.** 1978. Regional investigation of mortality for selected causes in Hiroshima Prefecture. J. Hiroshima Med. Ass. **31**: 1331—1353. (in Japanese)
11. **Mine, M., Nakamura, T., Mori, H., Kondo, H. and Okajima, S.** 1981. The current mortality rates of A-bomb survivors in Nagasaki City. J.J.P.H. **28**: 337—342. (in Japanese)
12. **Oho, G.** 1963. Statistical observation on deaths due to malignant neoplasm in A-bomb survivors (4th report). Nagasaki igk. Z. **38 (Supple.)**: 117—130. (in Japanese)
13. **Okajima, S., Mine, M. and Nakamura, T.** 1985. Mortality of registered A-bomb survivors in Nagasaki, Japan, 1970—1984. Radiation Res. **103**: 419—431.
14. **Shimizu, Y., Kato, H. and Schull, W. J.** 1988. Life Span Study Report 11, Part 2. Cancer mortality in the years 1950—85 based on the recently revised doses (DS86). RERF TR: 5—88.
15. **Siegel, S.** 1956. Nonparametric statistics : For the behavioral sciences, p. 36—42. McGraw-Hill Book Company, Inc., New York.
16. **Stewart, A. M. and Kneale, G. W.** 1984. Non-

cancer effects of exposure to A-bomb radiation. J. Epidemiol. Community Health **38**: 108—112.

17. **Yuzaki, M., Shimizu, K., Kurihara, M., Munaka, M., Hayakawa, N., Yamamoto, H., Watanabe, S., Ueoka, H., Ubuki, S. and Ohtaki, M.** 1981. Family destruction due to the atomic bombing ; Though the resulting of the "Restoration survey" in atomic bomb disaster in Hiroshima. Proc. Hiroshima Univ. RINMB, **22**: 359—383. (in Japanese)