Estimation of Life-Span Shortening in Man Exposed With Maximum Permissible Dose of Ionizing Radiation

By Yori Ueno*

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Putting on the base of previously reported data on life-span shortening in irradiated mammals, life-span shortenings were estimated in man exposed with the dose rate of 5 R/year calculated from the present maximum permissible dose during 18 to 60 years old and with the dose rate of 0.2 R/day during 20 to 60 years old. The calculated values of life-span shortening were nil to 4,070 day at 60 years old in man exposed with 0.2 R/day and nil to 1,690 days in man exposed with 5 R/year. The possibility of life-span shortening in man exposed with the present maximum permissible dose could not be denied by the present estimation. The calculated results that radio-sensitivity responsible to life-span shortening was depending on the age, suggested that the age to start radiation works had better to be limited more than 25 years old under the condition to end radiation works at 60 years old.

Introduction

In the late effects of ionizing radiation to mammals is a phenomenon of life-span shortening besides neoplastic and nonneoplastic changes or the disorders in functions. Life-span shortening could be classified into three kinds, that is, the first kind of shortening is one induced by parallel shortening in whole processes of life from the first cell formed by the sperm and the ovum to the death of whole body, the second kind is a shortening in a given part of life processes and the third is a shortening in all or partial processes of life after a given chronological time. Life-span shortening after exposure of ionizing radiation probably belongs in the last kind. A true aging and an aging-induced pathological change would be two factors affecting life-span. It is unclear which process is mainly accelerated by ionizing radiation. The data in the present report was only treated mathematically, apart from the biological aspect, on which the author discussed previously (Ueno & Kano, 1967).

The object of the present report is to estimate life-span shortening in man exposed with the present maximum permissible dose under the assumption that ionizing radiation induces always life-span shortening and to reappraise the present maximum permissible dose from the point of view of life-span shortening.

Methods and procedure

Various data reported previously on life-span shortening induced by ionizing radiation were corrected to data under two conditions of man exposed with daily dose of 0.2 R from 20 to 60 years old (Shortening I in Table 1) and of man exposed with dose calculated from the equation $5(N-18)$ from 18 to 60 years old (Shortening II in Table 1). The value of shortening was given in man at 60 years old. The rates of aging in mice and rats were assumed to be twenty times larger than in man (Failla & McClement, 1959).

* 上野 陽里，京都大学医学部放射線基陈医学教室 (Department of Experimental Radiology, Faculty of Medicine, Kyoto University, Kyoto)
The procedures of calculations were described in appendices.

Results

The calculated results were summarized in Table 1. On the four lines of Table 1 from the top were given the results which were estimated from the amount of changes depending upon age in some organs. Warren's data (1965) was used to calculated Forssberg's results (1964). Shortening I was 108-1,825 days and Shortening II was 2.2-850 days. On fifth to tenth lines from the top, the results calculated from the remove of Gompertz's line, survival time, $ET_{50}$ (days of age at which 50% are dead), that is, the changes in whole body, were given. Shortening I were 0-4,070 days and Shortening II was 0-1,690 days. The results on eleventh to thirteenth lines from the top were calculated according to the method of each author's own presenting. Shortening I was 219-3,070 days and Shortening II was 0-210 days. On the last line was Warren's results, which was observed in man in radiation works till 1965. The value in Shortening I of Warren's data was assumed by the author as the value in man exposed with daily dose of 0.2 R.

Table 1. Life-span shortening of irradiated man at sixty years old, estimated from previously reported data

<table>
<thead>
<tr>
<th>Biological index</th>
<th>Shortening (day) I</th>
<th>Shortening II</th>
<th>References</th>
<th>Animal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Intercapillary glomerulosclerosis</td>
<td>108</td>
<td>5.8</td>
<td>Guttman &amp; Kohn, 1960</td>
<td>mouse</td>
</tr>
<tr>
<td>2. Chromosome aberration in the liver</td>
<td>166</td>
<td>2.2</td>
<td>Curtis &amp; Crowley, 1963</td>
<td>mouse</td>
</tr>
<tr>
<td>3. Abnormal cells in CNS</td>
<td>376</td>
<td>16.8</td>
<td>Diller et al., 1964</td>
<td>mouse</td>
</tr>
<tr>
<td>4. Abnormal blood cells</td>
<td>1,825</td>
<td>850</td>
<td>Forsberg, 1964</td>
<td>man</td>
</tr>
<tr>
<td>5. Mortality rate</td>
<td>2,670</td>
<td>1,400</td>
<td>Sacher, 1956</td>
<td>mouse</td>
</tr>
<tr>
<td>6. Mortality rate</td>
<td>4,070</td>
<td>1,690</td>
<td>Failla &amp; McClement, 1957</td>
<td>mouse</td>
</tr>
<tr>
<td>7. $ET_{50}$</td>
<td>0</td>
<td>0</td>
<td>Carlson &amp; Jackson, 1959</td>
<td>rat</td>
</tr>
<tr>
<td>8. Survival time</td>
<td>438</td>
<td>9.5</td>
<td>Vogel et al., 1961</td>
<td>mouse</td>
</tr>
<tr>
<td>10. Mortality</td>
<td>3,410</td>
<td>235</td>
<td>Trujillo et al., 1962</td>
<td>mouse</td>
</tr>
<tr>
<td>11. Calculation</td>
<td>452</td>
<td>1.7</td>
<td>Hursh et al., 1955</td>
<td>rat</td>
</tr>
<tr>
<td>13. Calculation</td>
<td>219</td>
<td>0</td>
<td>Mole, 1957</td>
<td>mouse</td>
</tr>
<tr>
<td>14. Survival time</td>
<td>1,825</td>
<td>0</td>
<td>Warren et al., 1965</td>
<td>man</td>
</tr>
</tbody>
</table>

Discussion

In comparison to the results from the calculations using the changes in one organ as the index of aging, the results from the calculation using the change in whole body appears to be slightly large. As the most critical organ to life-span shortening is not found in mammals, it seems to be somewhat unreasonable to extend the results from one organ to whole body.

It was shown that there was neither similarity or relationship among values in Table 1. Though an estimation reported in some work was adequate one to explain each own data, it was inadequate method to explain other data. The calculation under the assumptions and corrections neglecting the differences in fine biological conditions of various experiments would be one of causes to
induce such a random values.

According to Warren's results (1965), it appears that there is no life-span shortening in 1965 under the present maximum permissible dose. The fact, however, is not able to present the conclusion that the present maximum permissible dose does not induce any life-span shortening, since there is yet no person who had worked till 60 years old from 18 years old under the present maximum permissible dose and the dose of exposure in radiation work may be less than the present maximum permissible dose in fact, except accidents.

The problem on the age to start radiation works has to be view with caution. According to Figure 1 drawn by the author using Table 1 in Mole's report (1963) under the conditions that the person exposed with 5 R/year stayed till 60 years old from each age in radiation works, to start the works at 18 years old seems to be slightly early, from the point of view of life-span shortening and more than 25 years old seems to be reasonable. The results present the necessity to reappraise the age to start and to end radiation works.

The data in Figure 1 is remarkably interested in radiation biology as will, because it shows that there is one process seemed to be the critical time responsible to radiation induced life-span shortening. The data should be investigated to analyse the mechanism of radiation induced life-span shortening in future.

Being induced from the data in population of mammals, the results had rather be understood as an index for the risk of life-span shortening responsible to each person, The results presented here do not be directly responsible to each person.

On the base of present results, it is very difficult to conclude that there is no life-span shortening under conditions of the present maximum permissible dose. It seems to be neccessary in future to reappraise the present maximum permissible dose under consideration of the results from more experimental and practical researches on life-span shortening induced by ionizing radiation.

Appendix

1. The calculation to induce the value given on the second line in Table 1 from the top. The accumulated dose calculated according to the equation 5(N-18) from 18 to 60 years old equals 5 × (60-18)−210 R. Using the lines in Figure 2, which was drawn by the author using Figure 1 in the report given by Curtis and Crowley (1963), the accumulated dose of 210 R is converted to life-span shortening of 0.32 days/R and therefore 75 days. The value of 75 days given in mice is corresponding to 70 × 20 = 1,500 days in man. The data being results from the original experiment using dose rate on 7.5 R/day, the value of 1,500 days was converted to 3 days under the condition of the dose rate of 13.6 mR/day (approximately 5 R/year) using Figure 3 drawn the author using Figure 5 in Storer's report (1959). As mice were irradiated from 60 days old to their death in the original experiment, the condition was recorrected to man exposed from 18 to 60 years old, that is, $3 \times \frac{42}{(60-3,3)} = 2.2$ days. The value in Shortening II on the second line was given according to this procedure.
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2. The calculation to induce the value given on the fifth line in Table 1 from the top. The age of mice exposed continuously with the dose rate of 13.6 mR/day to show the mortality rate of 0.0100/day, is 1,70 days according to Figure 4 drawn by the author using Figure 5 in Sacher's report (1956). The age of unirradiated mice to present the same mortality rate being 1,170 days, the difference in both results is 100 days. Therefore, life-span shortening is \((1,170 \times 100 = 8.55\) 

%.

Life-span shortening at 60 years old is 60 \times 365 \times 8.55/100 = 1,880 days. The mice being irradiated from 70 days old in the original experiment, the condition was converted to man exposed from 18 to 60 years old, that is, \(1880 \times 42/(60 - 3.85) = 1,500\) (days), where 3.85 years was induced from \(70 \times 20/365\). The value in Shortening II in fifth line was given according to this procedure.

References


Mole, R.H. (1963) Cellular basis and etiology of late...