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Analysis of Radiation-Induced Cancer Mortality for Korean Using the BEIR V Method

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ABSTRACT

The lifetime radiation-induced cancer mortality for Korean has been estimated for both single and continuous radiation exposure using the BEIR V method. In case of single exposure, a dominant cancer site for young and old ages was digestive and respiratory cancer, respectively. For Korean population, digestive cancer was the most dominant radiation-induced cancer site. In case of 1 mGy/yr continuous exposure from birth to death, the contribution of total radiation-induced cancer mortality was negligible as within 3% in comparison with total natural cancer mortality.

1. Introduction

Exposure to low-linear energy transfer (LET) ionizing radiation may cause cancers. The Fifth Committee on the Biological Effects of Ionizing Radiations of National Research Council, the BEIR V Committee, developed models for radiation-induced cancer mortality based on the study of atomic bomb survivors between 1950 and 1985, and Canadian fluoroscopy study between 1950 and 1980 [1]. The BEIR V Committee believes that the use of constant absolute (additive) risk model is no longer tenable and recommends the use of relative (multiplicative) risk model [2]. In relative risk model, fatal radiation-induced cancer risk is predicted from dose-response relationship, and statistical data for natural cancer mortality and the life expectancy of the relevant population. Since these statistical data are different for different populations and vary with age, fatal radiation-induced cancer risk may represente different results in different populations and for different ages of exposure.

In this study, lifetime radiation-induced cancer mortality for Korean has been investigated using the relative risk model which is recommeded by the BEIR V Committee for the following cases.

(1) 0.1 Gy single (acute) exposure for each age

(2) 0.1 Gy single exposure for population

(3) 1 mGy/yr continuous (chronic) exposure from birth to death

2. Relative Risk Model

In relative risk model, radiation-induced cancer mortality (ε) is expressed as multiple of the natural cancer mortality (ε_0) and dose-response function (R) of relevant cancer type [3].

$$\varepsilon(D, a_0, a, s) = \varepsilon_0(a, s) \times R(D, a_0, a, s) \qquad (1)$$

where, D : exposure dose [Gy]

a_0 : age at exposure

a : ages since exposure

s : sex of the subject

Dose-response functions are a basic element in the estimation of radiation-induced cancer mortality. The BEIR V Committee expressed the dose-response relationships for mortality from a particulate site of cancer in following the form [1].

$$R(D, a_0, a, s) = \alpha(a_0, a, s)\ D + \beta(a_0, a, s)\ D^2 \qquad (2)$$

where, α, β : constants

3. Dose-Response Function

Leukemia. Dose-response function is independent on sex. The latent period is a two-year. A linear-quadratic fit is used, thus a dose-rate effectiveness factor is not required when estimation is made for risk for exposure at low dose and dose rate [1].

$$R(D, a_0, t) = (0.243D+0.271D^2)\ e^{\gamma(a_0, t)} \qquad (3)$$

$\gamma = 4.885$, $t \leq 15$, $a_0 \leq 20$
$\gamma = 2.380$, $15 < t \leq 25$, $a_0 \leq 20$
$\gamma = 4.885$, $t \leq 25$, $a_0 > 20$
$\gamma = 4.885$, $25 < t \leq 30$, $a_0 > 20$

in which, t is elapsed time in year since exposure.

Respiratory cancer. The latent period is a ten-year. A linear fit is used, thus a dose-rate effectiveness factor is required when estimation is made for risk of exposure at low dose and dose rate [1].

$$R(D, a_0, t, s) = 0.636D\, e^{(-1.437 \ln(t/20) + \gamma)} \tag{4}$$

$\gamma = 0$, for male
$\gamma = 0.711$, for female

Breast cancer. The latent period is a ten-year. A linear fit is used, thus a dose-rate effectiveness factor is required when estimation is made for risk of exposure at low dose and dose rate [1].

$$R(D, a_0, t, s) = 1.220D\, e^{(\gamma_1 - 0.104 \ln(t/20) - 2.212 \ln^2(t/20) - \gamma_2(t-20))} \tag{5}$$

$\gamma_1 = 1.385$, $a_0 < 15$
$\gamma_1 = 0$, $a_0 \geq 15$
$\gamma_2 = 0$, $a_0 < 15$
$\gamma_2 = 0.0628$, $a_0 \geq 15$

Digestive cancer. The latent period is a ten-year. A linear fit is used, thus a dose-rate effectiveness factor is required when estimation is made for risk of exposure at low dose and dose rate [1].

$$R(D, a_0, t, s) = 0.809D\, e^{(\gamma_1 - \gamma_2)} \tag{6}$$

$\gamma_1 = 0$, for male
$\gamma_1 = 0.553$, for female

$\gamma_2 = 0$, $a_0 \leq 25$
$\gamma_2 = 0.198(a_0 - 25)$, $25 < a_0 \leq 35$
$\gamma_2 = 1.98$, $a_0 > 35$

All other cancers. The latent period is a ten-year. A linear fit is used, thus a dose-rate effectiveness factor is required when estimation is made for risk of exposure at low dose and dose rate [1].

$$R(D, a_0, t, s) = 1.220D\, e^{-\gamma} \tag{7}$$

$$\gamma = 0, \qquad a_0 \le 10$$
$$\gamma = 0.0464(a_0 - 10), \qquad a_0 > 10$$

4. Lifetime radiation-induced cancer risk

The lifetime radiation-induced cancer mortality (U) due to exposure at an age is estimated by the following equation [3].

$$U(a_0, D) = \sum_a \frac{N(a)}{N(a_0)} \varepsilon_0(a)\ R(D, a_0, a) \tag{8}$$

where, N : aliving number

Average lifetime radiation-induced cancer mortality ($\overline{U}$) for exposure of a particular population may be obtained by multiplication of lifetime radiation-induced cancer mortalities for exposure at ages having same numbers in persons and composition fractions of corresponding ages for population (F) [3].

$$\overline{U}(D) = \sum_{a_0} U(a_0, D) \cdot F(a_0) \tag{9}$$

5. Results and Discussion

The lifetime radiation-induced cancer mortality has been estimated for single and continuous exposure using the life expectancy data for Korean in 1994. For single exposure of low-LET radiation, lifetime radiation-induced cancer mortality was calculated for a dose of 0.1 Gy for each age and population. For the continuous exposure of low-LET radiation, lifetime radiation-induced cancer mortality was calculated for a dose of 1 mGy/yr from birth from death. A dose-rate effectiveness factor of 2 was only applied for continuous exposure.

Figures 1 and 2 show lifetime radiation-induced cancer mortality per 10^5 persons as functions of age at exposure and cancer site for single exposure for Korean male and female, respectively. Genernally, lifetime radiation-induced cancer mortality was high in case of exposure for young age except for respiratory cancer. It is due to the remaining life expectancy of the people involved as a major reason. Especially, the contribution of digestive cancer to total radiation-induced cancer mortality was dominant in case of the exposure for young age because of high natural digestive cancer mortality as shown in Table 1. Respiratory cancer showed very sensitive response in case of exposure for old age.

Figure 3 shows the lifetime radiation-induced cancer mortality per 10^5 persons of male and female in Korean population. The contribution of digestive cancer dominated as predicted in the results of single exposure and population composition in Korean. Table 1 shows comparative results of lifetime radiation-induced cancer mortality estimated between the BEIR V Committee and the this study. The BEIR V Committee used U. S. popualtion data in 1980. Radiation-induced leukemia mortality in Korean population was lower than that in U. S. population, while radiation-induced nonleukemia mortality in Korean population was a little higher than that in U. S. population [4]. Total radiation-induced cancer mortality was similar between Korean and U. S. population, though radiation-induced mortality with cancer type is different.

Figures 4 and 5 show the ratio of lifetime radiation-induced cancer mortality to natural cancer mortality per 10^5 persons in case of 1 mGy/yr continuous exposure from birth to death in Korean male and female, respectively. The contribution of total radiation-induced cancer was within 3% of total natural cancer mortality.

6. Conclusions

The lifetime radiation-induced cancer mortality for Korean has been estimated for single and continuous exposure using the relative risk models which are recommended by the BEIR V Committee. In case of 0.1 Gy single exposure, a dominant cancer site for young and old ages was digestive and respiratory cancer, respectively. Leukemia had relatively high dose-response relationship. In case of 0.1 Gy single exposure of population, the most dominant radiation-induced cancer site was digestive cancer. Total radiation-induced cancer mortality was similar between Korean and U. S. population. In case of 1 mGy/yr continuous exposure from birth to death, the contribution of total radiation-induced cancer mortality was negligible as within 3% in comparison with total natural cancer mortality.

References

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Table 1. Comparison of Radiation-Induced Cancer Mortality per 10^5 Persons between Korean and U. S. Population.

Radiation-induced cancer site	Korean population		U. S. population *	
	Male	Female	Male	Female
Leukemia	70	45	110 (50-280)**	80 (30-190)
Nonleukemia	746	789	660 (420-1040)	730 (550-1020)
Total	816	834	770 (540-1240)	810 (630-1160)

* Reference [3]
** 90% confidence limits are given in parenthsses

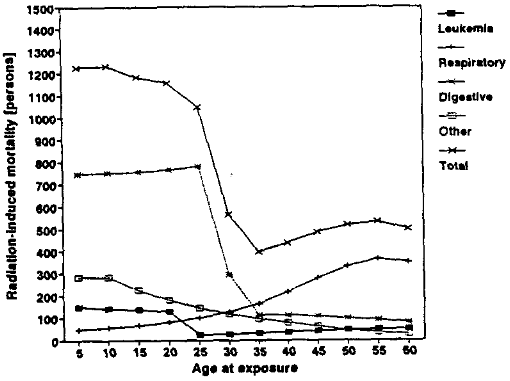

Fig. 1. Lifetime Radiation-Induced Cancer Mortality per 10^5 Males as a Function of Age at Exposure in Case of 0.1 Gy Single Exposure.

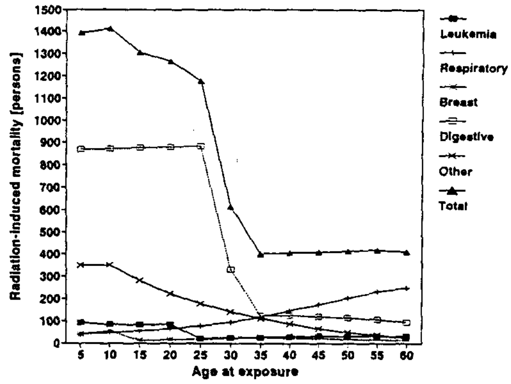

Fig. 2. Lifetime Radiation-Induced Cancer Mortality per 10^5 Females as a Function of Age at Exposure in Case of 0.1 Gy Single Exposure.

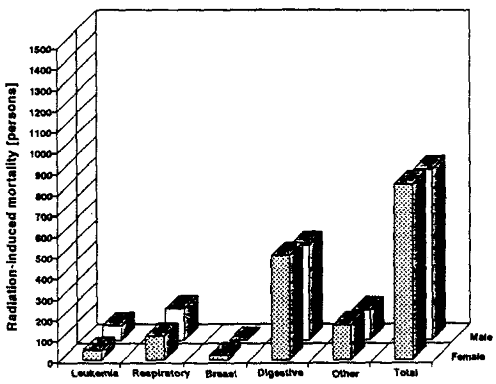

Fig. 3. Lifetime Radiation-Induced Cancer Mortality per 10^5 Males and Females in Population.

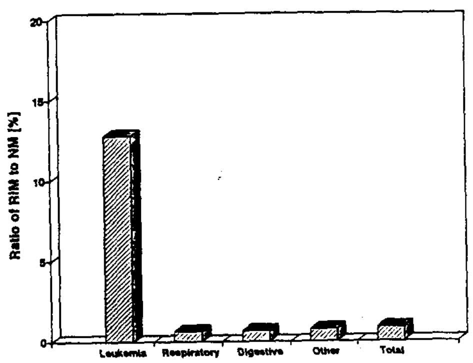

Fig. 4. Ratio of Lifetime Radiation-Induced Cancer Mortality (RIM) to Natural Cancer Mortality (NM) per 10^5 Males in Case of 1 mGy/yr Continuous Exposure from Birth to Death.

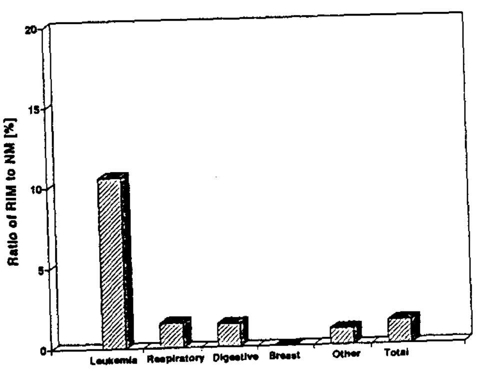

Fig. 5. Ratio of Lifetime Radiation-Induced Cancer Mortality (RIM) to Natural Cancer Mortality (NM) per 10^5 Female in Case of 1 mGy/yr Continuous Exposure from Birth to Death.