TRANSFER OF RISK COEFFICIENTS ACROSS POPULATIONS[1]

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ABSTRACT

The variation of lifetime risk projections for a Canadian population caused by the uncertainty in the choice of method for transferring excess relative risk coefficients between populations is assessed. Site-specific projections, varied by factors up to 3.5 when excess risk coefficients of the BEIR V relative risk models were transferred to the Canadian population using an additive and multiplicative method. When the risk from all cancers are combined, differences between transfer methods were no longer significant. The Canadian projections were consistent with the ICRP-60 nominal fatal cancer risk estimates.

INTRODUCTION

Current lifetime risk estimates of cancer mortality following exposure to ionizing radiation are based almost entirely on the Life Span Study of the Japanese survivors of the atomic bombings of Hiroshima and Nagasaki. As a result of the latest follow-up of cancer mortality of the cohort (1950-1985), the relative risk model has become preferred over the absolute risk model for projecting lifetime cancer risks following radiation exposure (ICRP 1991, NRC 1990, UNSCEAR 1988, Shimizu et al. 1988). The use of the relative risk model introduces the question of how to transfer excess relative risk coefficients to other populations, such as Canada, where baseline cancer rates are substantially different from those in Japan.

There are two plausible risk transfer methods. The first is a multiplicative method whereby excess relative risk coefficients are transferred directly and applied to the baseline cancer mortality rates of the population of interest. The second is an additive method whereby the excess relative risk coefficients are first applied to the baseline rates of Japan and then the resulting excess absolute risk coefficients transferred to the population of interest. Presently, there is no general agreement on which, if any, transfer method should be used or whether the same method should be used for every cancer site (ICRP 1991).

The purpose of this paper is to assess the variation in the projected lifetime risk of fatal cancer per unit dose for a Canadian population caused by the uncertainty in the choice of risk transfer method. Variations are compared with statistical errors in the excess relative risk coefficients caused by sampling variation. In addition, Canadian projections are compared with the nominal fatal cancer risk coefficients derived in ICRP publication 60, the 1990 Recommendation of the ICRP (ICRP 1991).

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[1] This paper is based on a M.Sc. thesis report (Rasmussen 1991) commissioned by the Atomic Energy Control Board of Canada.

METHODS

Lifetime risk projections for the Canadian population are performed using the excess relative risk coefficients of the modified relative risk models developed by the BEIR V Committee (NRC 1990) of the respiratory tract, female breast, digestive system, and other remaining organs and tissues. Projections are performed for a single hypothetical whole-body exposure of 1 Sv and projections are averaged over the life-table age distribution of a 1982 and 1988 Canadian population with equal number of male and females. A dose and dose rate effectiveness factor of 2 is assumed.

The additive risk transfer method uses the baseline cancer mortality rates of the 1984 Japanese population[2] to compute the conditional absolute excess risks. The multiplicative method uses the baseline cancer rates of 1982 Canada (StatCan 1985) and 1988 Canada[3]. A Canadian life-table is constructed using age-specific mortality rates for all causes of death in Canada for 1980-1982 (StatsCan 1985b) and 1988. Approximate 90 percent confidence intervals representing the uncertainty due to sampling variation are calculated indirectly by multiplying the ratio of the upper and lower 90% confidence interval of the excess lifetime risk point estimate given in the BEIR V report (NRC 1990) to the Canadian projected lifetime fatal cancer risk. The Canadian projections are compared to the ICRP-60 nominal risk factors by combining the ICRP site-specific values to give the corresponding groupings in the BEIR V report.

COMPARISON OF BASELINE CANCER MORTALITY RATES IN CANADA AND JAPAN

Table 1 shows the standardized[4] sex- and site-specific cancer mortality rates for Canada and Japan. The annual background risk of cancer mortality are similar between Canada and Japan for leukemia, Canadian rates being higher by about a factor 1.07. For other cancers, baseline rates differ substantially between the populations. Cancers of the respiratory tract, female breast, and other remaining cancers are greater in Canada than Japan by factors of about 2, 4, and 2 respectively. For digestive cancers, the Canadian baseline mortality rate is about half the rate in Japan. The differences in site-specific baseline rates between Canada and Japan tend to be offsetting so that overall, the rate for all cancers combined is similar between Japan and Canada (Canadian rates higher by a factor of 1.2).

RESULTS

Table 2 shows the age- and sex averaged[5] site-specific risks of fatal cancer per Sv for the Canadian population. Given is the lifetime fatal

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[2] Supplied by Dale Preston of the Radiation Effects Research Foundation

[3] The 1988 Canadian rates were calculated using data from 1988 causes of death tables and population estimates supplied by Statistics Canada

[4] Standardized to the age distribution of the 1988 Canadian population.

[5] Averaged over a Canadian life-table population (ages 0-85) and equal number of males and female

cancer risk averaged over transfer methods (the nominal risk estimates) the variation with transfer method, the 90% confidence interval of the nominal estimates, and the nominal values given by the ICRP. For cancers of the respiratory tract, female breast, and other remaining cancers the multiplicative transfer method gives a significantly higher projected risk than additive method by factors of 1.8, 3.5, and 2.4, respectively. For digestive cancer, the fatal cancer risk projected by the multiplicative method is almost half that of the additive method. These variations are comparable to the uncertainty caused by sampling variation (i.e. 90% confidence intervals). The projected lifetime risk for radiation-induced leukemia is similar between transfer methods, differ by a factor of 1.14. The site-specific differences between transfer methods tends to be offsetting so that when the lifetime risk from all radiation-induced cancers are combined, there is little difference between transfer methods (transfer methods differing by a factor of 1.18).

The site-specific lifetime risk projections for the Canadian population are in good agreement with the nominal fatal cancer risk factors given in ICRP publication 60 (ICRP 1991). For specific cancer except leukemia, the ICRP risk factors within the range projected by the two transfer methods for Canada. The ICRP risk factor for radiation-induced leukemia mortality is lower than that for Canada (ICRP: 50×10^{-4} per Sv, Canada: 70 to 80×10^{-4} per Sv). However, this is not significant in view of the uncertainty due to sampling variation and the ICRP do not use the BEIR V risk coefficients.

CONCLUSION

The choice of method for transferring excess relative risk coefficients is a significant source of uncertainty in lifetime risk projections of fatal cancer resulting from radiation exposure. Canadian site-specific projections can be expected to vary up to a factor 3 or more, depending on the transfer method and cancer site. In view of the difficulty in choosing between transfer methods and the significant effect on site-specific risks, it would seem the appropriate approach is to to carry out lifetime risk projections using both methods and then average the results.

TABLE 1

NATIONAL CANADIAN AND JAPANESE STANDARDIZED[a] MORTALITY RATES BY CANCER SITE (DEATHS PER 100,000 PERSONS PER YEAR)

CANCER GROUP	MALES			FEMALES		
	Canada	Japan	Ratio Can/Jap	Canada	Japan	Ratio Can/Jap
Leukemia	5.4	5.0	1.08	3.6	3.4	1.06
Respiratory	73	39	1.87	22	11	2.00
Breast	--	--	--	28	7	4.00
Digestive	61	120	0.50	36	59	0.60
Other	73	28	2.60	42	23	1.83
All Cancers	212	192	1.10	132	103	1.28

(a) Standardized to the age distribution of a 1988 Canadian population

TABLE 2

VARIATION OF THE PROJECTED LIFETIME RISK OF FATAL CANCER PER UNIT DOSE FOR GENERAL CANADIAN POPULATION CAUSED BY THE UNCERTAINTY IN RISK TRANSFER METHOD AND SAMPLING VARIATION.

Lifetime Risk of Fatal Cancer
(10^{-4} per Sv)

CANCER	CANADA (a)	ICRP-60 (b)	SOURCE OF UNCERTAINTY	
			RISK TRANSFER TRANSFER (c)	SAMPLING VARIATION (d)
Leukemia	75	50	70 - 80	30 - 185
Respiratory	90	85	65 - 115	60 - 135
Breast	25	20	10 - 35	20 - 35
Digestive	220	240	275 - 165	155 - 325
Other	130	105	75 - 180	90 - 190
All Cancers	540	500	495 - 575	390 - 805

(a) Average over risk transfer method, sex, and age distribution of a 1982 and 1988 Canadian life-table population (ages 0-85)
(b) ICRP site-specific risk estimates grouped to represent the equivalent BEIR V cancer groupings
(c) Range of Canadian lifetime fatal cancer risk per Sv projected by additive and multiplicative risk transfer method.
(d) 90% confidence interval of Canadian projected lifetime fatal cancer risk per Sv.

REFERENCES

ICRP 1991. "The 1990 Recommendations of the International Commission on Radiological Protection." ICRP Publication 60. Pergamon Press, Oxford (1991).

NRC 1990. National Research Council, Committee on Biological Effects of Ionizing Radiation (BEIR V), "Health Effects of Exposure to Low Levels of Ionizing Radiation". National Academy Press, Washington, D.C. (1990).

Rasmussen, L.R. 1991. "Uncertainties in Lifetime Risk Projections For Radiation-induced Cancer and an Assessment of the Applicability of the ICRP-60 Fatal Cancer Risk Estimates to the Canadian Population". Thesis report. McMaster University, Hamilton Ontario, Canada (1991).

Shimizu, Y, H. Kato, and W.J. Schull. 1988. "Life Span Study Report 11, Part 2. Cancer mortality in the years 1950-1985, based on the recently revised doses". RERF TR5-88, Hiroshima: Radiation Effects Research Foundation.

StatCan 1985. "1982 Canada Cancer Statistics". Statistics Canada 1985.

StatsCan 1985b. "Canada 1980-82 Current Life Tables". Statistics Canada 1985.

UNSCEAR 1988. "Sources, Effects, and Risk of Ionizing Radiations". United Nations Scientific Committee of the Effects of Atomic Radiations, 1988 Report to the General Assembly. U.N. Publication E.88.IX.7. United Nations, New York (1988).