ICRP COMMITTEE 1: THE CONTINUING SAGA OF ESTIMATES OF RISK FOR RADIATION INDUCED CANCER

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ABSTRACT

The estimates of fatal cancer risk which ICRP used in recommending more restrictive exposure limits for workers and for the public in 1990, were derived from the study of atomic bomb survivors. The many uncertainties in these estimates will be reduced with time as future data accrues in the Japanese study. Recent low dose studies in the Soviet Union, in the U.K. and in the U.S.A. provide tests, within broad limits, of the estimates of risk derived from the atomic bomb survivors. These form part of the continuing saga of cancer risk estimation.

INTRODUCTION

ICRP Committee 1 is responsible for advising the Main Commission of ICRP concerning the biological effects of exposure. In the 1990 recommendations of the ICRP (ICRP, 1991a) these responsibilities included reviewing Chapter 3 on Biological Effects in the main text of Publication 60, preparing the background material on biological effects used by the Commission, *i.e.*, Annex B of ICRP Publication 60 (ICRP, 1991a), and reviewing the selected papers of the Risk Task Group of Committee 1, which supported Annex B (ICRP, 1991b).

ICRP Committee 1 continues surveillance over developments in our knowledge of the biological effects of radiation and sets up working groups and task groups in selected areas as needed. This surveillance embraces all aspects of radiation-induced cancer risk, including the examination of low dose epidemiological studies for possible confirmation of risks from high dose, high dose rate studies.

NOMINAL VALUES OF CANCER RISK

ICRP appraised, for radiation protection purposes (ICRP, 1991a), recent evaluations of cancer risk from all human sources by both the UNSCEAR (1988) and the BEIR V Committee (NAS/NRC, 1990) as well as providing some additional analyses of their own. ICRP concluded that for the general public (*i.e.*, a population of all ages) the nominal risk of fatal cancer following high dose, high dose rate exposure is 10%/Sv, while for an adult (working) population it is about 8%/Sv. ICRP then applied a dose rate effectiveness factor of 2 to these numbers

to obtain the risk for low dose or low dose rate exposure, yielding 5%/Sv and 4%/Sv respectively.

SIGNIFICANT ASPECTS OF NOMINAL VALUES OF CANCER RISK

Certain features of these nominal values need to be emphasized. These include supporting estimates from other studies, projection to lifetime risk, age and sex variations and transfer between populations.

Comparison of cancer risks between different studies

The important study of the survivors of the atomic bombs has limitations, consequently confirmation would be useful. UNSCEAR (1988), (see ICRP, 1991a, Annex B, Table B-4), compared risk estimates for the ankylosing spondylitis in the U.K., and the international cervix series with those for the atomic bomb survivors. The estimates for the ankylosing spondylitis series are lower than for the atomic bomb survivors by a factor of about 2. Given the wide differences in sample, in age, in exposure circumstances, etc. (see Upton, 1991) this difference is small. For the cervical cancer series the agreement is less satisfactory, but the circumstances of exposure are even more different.

Projection of observed results to lifetime risk estimates

To estimate lifetime risk, observations of the survivors in Japan must be projected to the end of the life span of those individuals comprising over 60% of the original population who were alive in 1985. The time course of the increase in induced cancers in a number of sites has followed a multiplicative pattern well so far, consequently, the multiplicative model has been used for projection (UNSCEAR, 1988; Preston & Pierce, 1988). However for some cancer sites the multiplicative model may overestimate the risk, at least slightly. BEIR V (NAS/NRC, 1990) included a term involving time since exposure which enabled the model to be fit separately to the data for individual cancers and thus allow for a small fall-off in some cases. If this trend in the data were to continue, current estimates of lifetime risk based on multiplicative projection would be over projected. The ankylosing spondylitic study already shows a substantial fall off at longer times (Darby *et al*, 1987).

Recently Kellerer & Barclay (1991) have shown that if the multiplicative projection is based on attained age instead of age at exposure (and the data fit reasonably well), the projected risk is only about a half. Again, this implies over projection for current models.

Age and sex variations

Both UNSCEAR and BEIR V give substantial information on variations in cancer risk with age at exposure and sex, and still more detail, especially for individual organ risks, is available in Land & Sinclair (1991) and in summary form in Sinclair, 1992. The cancer risk is 10 times greater for the 0 to 19y ages than for the 65 to 90y age group. The sex difference is of the order of 10 to 50% depending on age, females having the larger induced cancer risk especially at young ages.

Transfer between populations

When populations other than the Japanese are considered, estimated risks must be transferred to the new population either multiplicatively using the base cancer rates in the new population or additively, independent of the spontaneous rates in the population, as in the NIH model (Rall *et al*, 1985). Presently it is not known which is the preferred method (Land, 1991; UNSCEAR, 1988; NAS/NRC, 1990) or whether there is a preferred method for all sites. Consequently, in deriving the contributions of the individual organs to the overall detriment, results have been averaged between the two models (Annex B, ICRP, 1991a). The total risks by the two transfer methods also differ somewhat as do results for some other national populations considered in the ICRP evaluation. ICRP averaged results for the two transfer models and for five national populations as well as for age and sex.

DETRIMENT AND ORGAN WEIGHTING FACTORS

ICRP's effective dose is based on the total detriment from a radiation exposure which includes fatal cancer in individual organs and tissues, severe hereditary effects, a weighting of each for length of life lost and a contribution for each organ or tissue from nonfatal cancer. These are listed in Table 1.

The relative contribution of the organs to this total detriment are determined as outlined in Annex B (ICRP, 1991a, Table B-20) and are then rounded to obtain tissue weighting factors. Only four weights are used (Table 2). Uncertainties due to transfer model and to characteristics of national populations have been reduced by averaging and the same weights can be used for all ages, sex and national population.

Table 1 - *Nominal probability coefficients (from ICRP, 1991a)*

Exposed Population	Detriment 10^{-2} Sv^{-1} Fatal Cancer	Nonfatal Cancer	Severe Hereditary Effects	Total
Adult workers	4.0	0.8	0.8	5.6
Whole population	5.0	1.0	1.3	7.3

Table 2 - *Tissue weighting factors*

w_T =	0.01		0.05		0.12		0.20	
	Skin Bone surface		Bladder Breast Liver Oesophagus Thyroid "Remainder"		Bone marrow Colon Lung Stomach		Gonads	
Σw_T =	0.02	+	0.30	+	0.48	+	0.20	= 1.00

UNCERTAINTIES IN RISK ESTIMATES

The main uncertainties in the estimates of risk for high dose, high dose rate exposure include:

1. uncertainties in the epidemiological data,
2. dosimetric uncertainties, neutron RBE, etc.
3. uncertainty in projection to lifetime
4. uncertainties due to transfer model and
5. variations due to specific age groups or sex.

Some committees have attempted to assign magnitudes to these uncertainties (Rall *et al.*, 1985; NAS/NRC, 1990).

Risk coefficients for low dose or low dose rate exposure are subject to these uncertainties plus those arising from the application of a dose response model or a dose and dose rate effectiveness factor, DDREF. The uncertainty in the DDREF is probably not greater than a factor of two, because the value applied by ICRP is two and the factor that could be assigned is probably not less than one nor more than about four.

FUTURE EXPECTATIONS IN THE STUDY OF THE ATOMIC BOMB SURVIVORS IN JAPAN

The study of the atomic bomb survivors will continue to acquire additional data. By the turn of the century, less than half (44%) of the study population will be surviving, four more cycles of data will have accumulated, time relationships will be better defined and the younger age groups will be further into the ages when cancer is more prevalent. Questions of fall-off (from constant relative risk) with time and overprojection of lifetime risks should be much clearer.

Significant excess of various cancer sites should extend to lower doses, to the group at 0.1 Gy to 0.19 Gy, or even to 0.06 Gy to 0.09 Gy. This will greatly influence the choice of DDREF and if the dose response curve is established at low enough doses perhaps eliminate the need for a choice.

In dosimetry, extension of the DS86 sample from 76,000 to 86,000 is expected in the 1985-89 evaluation. It may subsequently be extended a little further. Small improvements in the dosimetry can be expected and possibly a resolution of the worrisome discrepancy between calculation and measurement with distance for thermal neutrons. Further studies in high-LET radiation biology might provide additional information on neutron RBEs at low doses and permit more precise evaluation of the neutron component.

Incidence data from the tumor registries at Hiroshima and Nagasaki is just becoming available. The greater number of excess tumors, fatal and nonfatal, will improve estimates of the excess and establish better the dose response curve free of complications from treated cases. Incidence data may, in time, take over from mortality, as a superior index of the excess tumors due to radiation induction.

Overall, within not much more than a decade, improved (less uncertain) risk estimates from the atomic bomb survivors should be possible.

LOW DOSE STUDIES

In radiation protection the risk after low doses is paramount and thus direct low dose studies seem to be more relevant than high dose studies. However, most low dose studies suffer from methodological flaws which render the results questionable. Modan, in addressing this question (Modan, 1991), examined studies of fallout, occupational exposure, fetal (medical) exposure, therapeutic experience and natural background studies. Among the principal problems he identified were inadequate dosimetry, limitations on sample size and composition, lack of adequate controls, extraneous effects and sociogeographic confounders. Additional problems include the fact that studies are of too low a statistical power to demonstrate an effect, small numbers tend to increase chance associations and there is often no clear association between radiation dose and effect. Care in interpretation is also necessary if the time relationships involved are not those usually found or the cancers detected in excess are not those usually associated with radiation.

Given all these difficulties few low dose studies have been able to provide quantitative estimates of risk. Nevertheless, some have aspired to describe a range of risk and some of these are becoming of increasing importance as tests of estimates of risk derived from high dose studies.

Recent "quantitative" low dose studies

An early study of U.K. atomic energy workers (Beral *et al.*, 1985) resulted in a broad range of risk estimates which included both the old and the new ICRP estimates. A more recent study of these workers (NRPB, 1991) is more definitive. It obtained a specific risk estimate for leukemia of 0.8×10^{-2} Sv^{-1}, about twice the ICRP value for workers, with broad confidence limits extending to six times the ICRP value. A nonsignificant risk value for all cancers was also derived which had even broader limits.

In the U.S.A. (Gilbert *et al.*, 1989) a study of some nuclear workers did not yield a significant association of leukemia or of all cancer with dose. The estimates ranged from below zero to an upper limit which was about the same value as that derived from the Japanese atomic bomb survivors. An initial report (Matanoski, 1991) on nuclear shipyard workers also lacked a definitive answer. Nuclear workers with exposures above 5 mSv had more leukemia and more hematopoietic cancers than those exposed below 5 mSv. However, both groups were less than for non-nuclear workers. Furthermore, within those above 5 mSv no clear association with dose was found. Further follow-up in this study may yield some more definitive contribution.

Two recent studies from the Soviet Union appear to be of greater intrinsic value, partly because the exposures in early atomic energy work were higher. The first involved workers in the atomic energy program exposed in the period 1947-58. Workers with total exposure above 1 Sv had greater cancer excess than workers below 1 Sv, from which Shlyakhter & Wilson (1991) derived a risk of all cancer expressed as $>3 \times 10^{-2}$ Sv^{-1} similar to the 4×10^{-2} Sv^{-1} for workers of ICRP. In a study of residents in an area of Chelyabinsk (Degteva & Kosenko, 1990), people were exposed via their drinking water from the Techa River which for three years, 1949-52, was used for the disposal of fission products. Modeling the dosimetry appropriately, a risk estimate was derived of about 0.2×10^{-2} Sv^{-1} for leukemia, half the ICRP value for workers. More information on these studies would be most welcome.

Thus, in spite of the broad ranges only that can be defined, these low dose studies are within about a factor of two of the estimates derived from the atomic bomb survivors.

Possible future low dose studies

From Chernobyl useful data may emerge eventually (perhaps on leukemia only) from evacuated groups or from those in "hotspot" areas of the Ukraine, Byelorussia and Russia.

Also, a comprehensive study has been proposed of all nuclear workers in the U.S.A., possibly to include U.K. and European nuclear workers. A more positive result than any to date could result from such a comprehensive study.

CONCLUSIONS

The study of the atomic bomb survivors will continue to provide more and more data and thus to improve lifetime risk estimates. Some present and future low dose studies may help materially in testing the risk estimates from the atomic bomb survivors.

ICRP Committee 1 will continue to evaluate the situation as new information appears and relate it to radiation protection circumstances.

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