QUANTIFICATION OF RADIATION DETRIMENT

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The quantification of the various components of radiation induced detriment has been developed by ICRP in particular over a number of years. In Publication 60 the process reached a level of development such that weighted detriment judgements are a fundamental component of the definition of one of the primary dosimtric quantities, Effective Dose, and were used explicitly in reaching a recommendation on dose limits. There is still some way to go in the further development and application on the concept of quantified detriment and this paper explores both the problems and some possible avenues to solve them.

HISTORICAL INTRODUCTION

The recently revised ICRP recommendations [1] have seen the Commission apply quantitative measures of detriment to several areas in order to support their recommendations. This is clearly a more extensive use of the detriment concept than has hitherto been seen in radiological protection. It has however, taken a number of years to get to this stage as, after all, detriment was initially introduced in ICRP Publication 26 [2]. Here it was defined as the mathematical 'expectation' of the harm incurred from an exposure to radiation, taking into account not only the probability of each type of deleterious effect, but also the severity of the effect. These deleterious effects included both effects on health and other effects.

In practice though, attempts to quantify detriment thereafter were limited. The one area where some progress was made was the monetary costing of detriment for cost-benefit analysis (CBA) and optimisation purposes. [3] We at NRPB used a pragmatic variation of the ICRP recommendations on detriment to derive monetary values of unit collective dose for general use in CBA. The objective health detriment was calculated by estimating the gross economic loss associated with the latent fatal and non-fatal stochastic effects. To this a multiplying factor was added to reflect individual aversion to increasing levels of individual dose. Although the application of CBA is limited to its use in optimisation studies, [4] we have not for some years gone further in accounting for the severity of radiation-induced effects in other formal advice, until recently that is.

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ICRP have clarified that for radiological protection purposes detriment should be taken to include primarily the risk to health, and that a separate allowance within a decision-making process should be made for other forms of detriment. The two principal purposes for which aspects of detriment are now quantified are for the definition of effective dose, and to assess the consequences of continued or cumulative exposure in order to recommend dose limits.

In the definition of Effective Dose, the radiation weighting factors are primarily determined by scientific judgements based on physical or biological observations. For tissue weighting factors, however, the probability of fatal cancer in each organ is weighted for relative loss of life should a cancer occur in that organ. This is adjusted further using the probability of non-fatal effects in each organ weighted by the severity of each cancer type, using a quantified form of the judgement that the relative importance of a non-fatal cancer is inversely proportional to the curability. In addition provision has been made for a more structured weighting of the hereditary consequences although for the present definition a reasonably straightforward judgement has been included. Thus the familiar quantity, Effective Dose, that some might even have considered a 'physical' quantity, is loaded with judgements as to the quantification of detriment.

To assess the consequences of continued exposure at a number of given dose regimes, the Commission quantified these elements together with some others such as years of life lost and the age at which the fatality would occur to construct a multiattribute assessment of the detriment. Based on these measures and further judgements as to their relative importance, a recommendation was made as to suitable dose limits.

CURRENT WORK

The amount of detail on detriment that can be calculated requires commensurately detailed research tools to carry out the analysis, and to examine the implications for standards in different exposure situations. NRPB has developed a PC-based computer code that allows rapid assessments of detriment assuming radiation exposure over a chosen time period to individuals or to a population [5]. This is based on health effects models for the UK [6], currently under revision. The beauty of such tools is that the consequence of varying the weights on the different aspects of health detriment is immediately apparent. The combination of calculational speed and sensitivity analysis, allied to simplicity of use is transforming risk analysis in radiological protection.

However, the danger is that this power becomes addictive. The more detailed the analyses, the more numbers that can be produced without stopping for breath to assess the information. In the context of radiation detriment, there are three clear aspects to be addressed.

1. For what quantities and/or judgements is the quantification of detriment important ?
2. What attributes of detriment are of interest for each of these ? The same attributes, or the same aggregation will not be important in all areas. Indeed, it may be that some quantities are relatively insensitive to the inclusion or the weighting of, certain detriment factors, which therefore are an added complication where simplicity would be preferable.
3. What criteria should components of detriment be assessed against ?

Answering any one of these questions is a formidable task in itself. Here we make no attempt to do so for naturally this represents a long-term work programme. Instead, we focus on two related aspects. Firstly, the final point above, risk criteria, has to be a matter of concern, and is discussed below. Secondly, ICRP 60 introduced the term 'constraint' as

an aid to the optimisation process. We discuss here what attributes of detriment may be important in deriving these.

Risk criteria

The two key reference points for risk criteria in the UK are the study group report of the Royal Society [7] and the Health and Safety Executive's document developing a philosophy of risk control [8]. These bodies have suggested 'acceptable' and 'tolerable' annual levels of death probability for occupational and public circumstances. These criteria are been useful, but for a full consideration based on detriment, additional questions arise.

For example, because the risk rate varies with time, it is necessary to consider whether it is the average or maximum annual risk that is important, or whether it is the age of reaching a particular risk rate that is more relevant to the judgement on acceptability. Another consideration would be whether there is a maximum acceptable lifetime risk irrespective of the time distribution of that risk. Following exposure, most of the risk of additional cancer death arises at older ages. Is there then an argument that risk at different ages should be treated differently ? It could be said that the risk of premature death should be weighted more heavily because, beyond normal life expectancy, the cause of death becomes less relevant. Also in this context, we have tended to concentrate on incremental increases in death rates rather than looking at the relative increase in death and cancer death rates. This aspect may become a more important focus.

So far we have only dealt with fatal effects. We have not started to develop criteria against which one can assess the significance of non-fatal cancer, hereditary effects, years of life lost and impaired, and aggregated detriment. Weighted detriment assumes that acceptability of other effects can be assessed on the same scale as fatal effects, but this is for the moment only a working assumption.

Detriment and Dose Constraints

As noted above a number of aspects of detriment were taken into account by ICRP in making a judgement on appropriate dose limits. The general nature of the dose limits means that fairly broad assumptions are made concerning individuals, and the population groups for whom the limits are intended to apply. Dose constraints are intended to be more sector specific, derived using levels of reasonably achievable individual dose. However, although partitioning of work categories is not straightforward, and inevitably there will be overlaps, this narrowed specification means that considerations other than recorded levels of dose become important. For instance, there is a clear difference in the induced detriment per unit dose between a population of industrial radiographers, and a population of radiotherapy nurses. Moreover, for medical exposure, there are specific procedures, or situations, where solely paediatric, obstetric or geriatric exposure is practiced. For these also the detriment incurred per unit dose will clearly differ. The question is whether, and by how much should this influence the numerical choice of constraint.

What is needed therefore is a thorough review of exposure groups to determine both current levels of recorded dose and the detriment that this implies to average members of each population. This would then be fed into the decision-making process for the setting of a dose constraint. It may be, for example, that some groups of workers may be consistently

older than the average workforce. In this case, because the probability of passing on hereditary effects will be reduced, and because the bulk of the excess risk would occur at very old ages, the annual risk of effects over the remaining life expectancy would be low. Thus if individual doses are already within a nationally set constraint, there would be no need to set an additional more restrictive sector-specific constraint. The employer may, however, choose to set an internal restriction for workers of certain ages.

On the other hand, in paediatric medical exposure, the risk incurred in terms of the additional cancer probability relative to the background rate, in the years following that exposure, is considerably greater than the average in a population and could be deemed excessive, leading to very restrictive constraints.

CONCLUSIONS

There is much work to be done before our ideas on the quantification of radiation detriment can be fully refined. The number of attributes of detriment can proliferate almost indefinitely, and it is necessary to develop clear procedures to decide which are sufficiently useful for their inclusion in radiological protection quantities or as other inputs to decisions. Furthermore, yardsticks against which single or aggregated attributes can be assessed are of prime import.

Not long ago some of these ideas would have seemed too complex as would the number of weighted aspects of detriment included in the ICRP formulation of Effective Dose. However, we must recognise that the real world is complex and ICRP have shown that detriment is not only a more satisfactory measure of the health impact of radiation exposure, but it can be useful and practical. The challenge is to build on this during the next few years.

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