HOW SAFE CAN WE BE?

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To live safely does not mean to live without risk. We wish to take some risks in order to enjoy particular benefits. Other risks we cannot avoid. Our death, at some time, is not a "risk", it is a certainty. Our likelihood of dying before age 100 is close to 100 per cent, but also at young ages we run some risk per unit time of dying.

An empirical approximation of the age-specific death probability rate, G(u), as a function of age (u), is known as the Gompertz-Makeham expression. It can be written

$$G(u) = A\ e^{Bu} + C$$

where A and C are constants which differ between populations while the exponent coefficient B is usually about 0.1 per year.

Since we are all certain to die, there is no way in which protection can "save lives". All we can do is to save years of life and to give these years as much of mental and physical well-being as possible. This is a multidimensional objective and can hardly be expressed in terms of a number. We must never forget that saving years of life must be supplemented by commensurable efforts to make these years worth living.

The age-specific mortality may be the best quantity to express the risks in life in a quantitative way. From the objective point of view, it may be said that we have no cause for increased concern about our risk situation as long as G(u) does not change significantly. When asked about our annual risk of dying, we are likely to accept a two-digit answer, e.g. "0.45 per cent", rather than to insist on knowing whether it is, in fact, 0.448 per cent or 0.453 per cent. A total risk increment of the order of G(u)/100 might, therefore, be an objective "de minimis" risk. The lowest values of G(u) are found for ages of about 10 years, at which G(u) may be as low as 0.01-0.02 per cent per year in countries with low risk levels. The corresponding "de minimis" increment of the annual probability of dying would be of the order of one per million.

In countries with a low standard of living, the age-specific annual probability of dying at young ages is quite high, mainly because of malnutrition and infections. It is not unusual that the lowest value is as high as 0.1 per cent per year. It is obvious that priorities must be given to reducing the main causes of death but it would be wrong to set a correspondingly higher "de minimis" value for risks of concern in poor countries if it is agreed that the primary causes of death in these countries are unacceptable.

"Objective" de minimis values for risk increments of individual significance are often misinterpreted. One misconception is that such values could be applied to each source of risk, e.g. to radiation risks or even to a particular source of radiation risk (e.g. by assuming that a source-related annual de minimis dose would therefore be of the order of 100 microsievert). However, it is not a straightforward exercise to derive a source-related de minimis value even if there might be general agreement on a de minimis value of total risk increment.

The problem is even more complicated. It is true that there is an objective de minimis value of risk increment in the sense that a smaller risk increment would not change the individual's overall risk situation significantly. But this does not necessarily mean that he is not concerned about a small risk and is willing to accept it unhesitatingly. Our willingness to accept a risk depends on many factors, such as our prospect of ensuing benefit, our view on the need and value of the source of the risk, our trust in those responsible for risk estimates and protection, and the degree of voluntariness. Few people would accept an unnecessary risk, even if very small, forced upon them for a cause for which they feel no sympathy and by persons they dislike or distrust.

Most people may feel that the loss of a penny or a cent is not worth any further thought, but if all the pennies lost by a large number of persons happened to build up an available asset, they might nevertheless think it worth-while to use it for a good cause rather than throwing it away. In a similar way, a very small risk to a large number of people may mean a mathematical expectation of a finite number of injuries. That number will be small and insignificant in comparison with the total background of harm, but it may not be small in comparison with the effort that could reduce it. It is the latter comparison that matters. If some harm, in the absolute sense, can be avoided at a reasonable cost (including the "cost" of evaluating the situation), why should it then not be avoided? This is the thought behind the ICRP principle of optimization of protection: to keep all exposures as low as it is reasonably achievable, economic and social factors being taken into account (1).

One method for optimization of protection is the differential cost-benefit analysis described in a number of ICRP documents (2). This method is based on minimization of "costs" exclusively related to protection, namely, the cost of protection and a detriment "cost" which is calculated as αS, where S is the collective effective dose equivalent and α is the amount of money that society is willing to pay, marginally, per unit of collective dose eliminated.

The value of α is supposed to be given by national authorities. The two methods usually mentioned for deriving this value are the "human capital" approach and the "willingness to pay" approach. These methods are generally applicable in protection against stochastic harm, not just in radiation protection. In the more universal approach α is replaced by a corresponding value q, which is the marginal sum that society is willing to pay in order to "save" a life in a statistical sense (to save perhaps twenty years). If r is the risk coefficient for radiation detriment (i.e. about 0.02 per mansievert), the implied value of q is α / r. It is often recommended that α be of the order of US$ 10,000 per mansievert, in which case q = $ 500,000.

In the "human capital" approach, q is derived on the assumption that it would be stupid for any government not to pay at least as much per life saved statistically as the per caput gross national product for the years saved. Any lower ambition level would be a direct loss of resources from the economical point of view.

In the "willingness to pay" approach, q is deduced from information on what people might be willing to pay in order to avoid risks to themselves.

Both these approaches have been criticized for setting a price on a human life. This is a valid criticism in the case of the human capital method, which is only defendable as a means of finding a lower limit for q. However, the objective of optimization of protection can also be seen as an attempt to save the maximum number of lives with the resources that have been made available. The fact that society's resources are not infinite does not imply a valuation of life but only a limitation of what is achievable (3).

Conceptually, therefore, there is a third approach for deriving the appropriate value of q. Let us assume that a parliament or a government decides to allocate a sum of money, Q, to be used for statistical life-saving. If protection is optimized on the basis of a very low value of q, the money will not be spent, because very few lives would be saveable on this policy. If, in contrast, the value of q is taken to be very high, for example equal to Q, the whole sum may be spent to save only one life. Between these extremes, there may be a value of q which would save the maximum number of lives. That is the value that should be used, and it would, in fact, be unethical not to use it.

Assume that the saveable number of lives, $N(q)$, is a function of the value of q that is chosen ("saveable" means that a risk source may be eliminated so that individuals who would otherwise have died from that source will have the life expectancy that is normal at their age). If we then save all lives that can be saved with q as the marginal cost per life saved, we shall find that we have, on the average, paid less than q per life. If the average sum that we have paid is $a(q) < q$, the total expense for society is $N(q) \cdot a(q)$. We save the maximum number of lives if that sum is equal to the sum Q that we have at our disposal. This will be when $N(q) \cdot a(q) = Q$. If we knew the function $N(q)$, we would thus be able to calculate q; however, that function is not known.

It is nevertheless possible to make some upper estimate of $N(q)$. There is not an infinite number of lives available to be saved. We may be able to guess what the maximum number, M, may be. We also know that the average cost per life (a) cannot exceed q. We can therefore assume that, at the best choice of q, we have

$$M\,q > Q$$

From the Swedish statistics it can be seen that the parameters A and B in the Gompertz-Makeham expression have not changed much since the beginning of the century, while the parameter C has decreased by more than one order of magnitude (4). This is what one might expect, since the age-independent term would mainly describe the death probability from accidents and infections, i.e. risks that seem to be controllable or "saveable".

One potentially controllable cause of death which is rapidly increasing in many countries is lung cancer. It shows a death probability which is strongly age-dependent. This seems to be masked by a decrease in other age-dependent causes of death. The value of C, therefore, is likely to somewhat underestimate the potentially avoidable risk. The value of C ranges from about 0.0003 per caput and year for males in "safe" countries to about 0.003 per caput and year in those "high-risk" countries for which statistical information is available (5). To "save a life" amounts to different things in these two cases. In a "safe" country it means, on the average, saving 10-20 years of life and in a "high-risk" country 30-40 years in spite of the fact that the mean life expectancy is shorter (the main life-saving in poor countries is in very young years). A more thorough analysis indicates that about 0.1 manyears per caput and year might well be "saveable" for both men and women in many countries, rich as well as poor. This order of magnitude estimate may suffice to give an indication of the implications of the inequality $M q > Q$.

For example, with $q = \$ 500,000$ per life, as implied by the radiation protection practice, which may mean a cost ranging from \$ 10,000 to \$ 50,000 per manyear saved, and with $M = 0.1$ manyear per caput and year, the protection cost expressed per caput in the whole population would be less than a number ranging from \$ 1,000 to \$ 5,000 per year, probably being much less because all potentially "saveable" lives may not be saveable at these values.

If the marginal sum to be paid to save a manyear were chosen on the basis of the human capital method and therefore equal to the per caput annual GNP, the actual protection expense would be less than 1/10 of this GNP, i.e. less than a number ranging from \$ 50 to \$ 1500 per caput and year. The radiation protection ambition for rich countries, therefore, is not much higher than that behind the human capital approach. A rich country should therefore afford to adopt the radiation protection ambition in all fields of protection against stochastic risks, and the cost of doing so may not exceed a few per cent of the GNP. However, a poor country may find that the expenses drawn by such ambitions would be prohibitively high to meet without help. Any ethical problem will not relate to the optimization procedure, but to the political decision to allocate resources (Q), necessarily limited, for lifesaving purposes.

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