SQUARING AN INFINITE CIRCLE
Radiobiology and the Value of Life

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"We are . . . paying a very heavy price, in the confusion and delay in technical innovations, from having underestimated the depth of biological knowledge that was necessary to support the promulgation of nuclear technology. New directions of policy and research may help to repair not only our administrative and technical lacerations but another priceless good: public confidence that the quality of individual life stands foremost as an aim of government."

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The nuclear power controversy comprises two separate issues related to biological side effects: (a) The biodetriment function, what is the most credible scientific judgement of the biomedical hazards entailed by radiation exposure? (b) What policies can be rationally advocated, taking account of social benefits as well as of biomedical detriment?

The pragmatic framework of this debate has recently been transformed by two important developments. These are the shift of Atomic Energy Commission regulatory and public relations policy away from defense of the Federal Radiation Council (FRC) standard (170 millirems per year) in favor of a quantitative formulation of "the lowest radiation exposure practicable," and the emerging role of an independent authority, the Environmental Protection Agency (EPA, which took over the functions of the FRC). The trend established by the most recent regulatory proposals on the part of AEC, which would in fact limit the effusion of radioactivity from the nuclear power industry to about 1 per cent of the natural radiation background, has mooted much discussion heretofore. To be sure, we require some optimism to believe that a standard proposed for the current generation of light water-cooled reactors will prevail for this and other aspects of the development of nuclear power. However, this action already establishes a political climate that, taken together with the new role of EPA, will surely place a heavy burden of defense on advocates of less restrictive standards. In this new arena we can make policy more confidently in spite of grave uncertainties about the absolute values of the biodetriment. If radiation injury is as grave as painted by the most antagonistic pessimists, we should surely focus our resources and concerns on reducing those sources of radiation which outweigh nuclear power by factors of 10 or 100.

Nevertheless, the problem of radiation hazard remains as an urgent challenge to the development of a axiology of technical innovation. The record to date is no more gratifying than it is in most other fields of technological assessment. A cost benefit analysis of nuclear power must still be perfected, although the challenge is muted; and comparable problems of evaluation of medical X-rays, urban redistribution in relation to altitude and cosmic rays and choices among building materials for construction take higher priority — the principal actual sources of radiation exposure in contemporary life, which have been given less axionomic attention than nuclear power.

The Biodetriment

The principal types of pathology that can reasonably be attributed to radiation exposure at low dose-rates are cancer and gene mutation. In fact the effects that could plausibly be attributed to dose rates of the order of the natural background, 100 millirems per year, are too small to be accessible to experimental or persuasive epidemiological observation. Some theoretical basis can be argued in favor of the expectation that a given dose of radiation will, in general, be more deleterious if delivered within a short period of time than if distributed in continuous ambience. While most parties agree that the evidence for this type of limitation of effect is too tenuous to be relied upon for policy judgment, it undoubtedly plays an important role in setting the level of skepticism with which other allegations about the effects of radiation are assimilated. It would be less insidious to stipulate an efficiency factor of, say, 10 per cent for low dose rate than to allow this potential safety factor to enter unconsciously, as it must often do, in the judgments of some of the protagonists. This facor is, however, excluded from the following calculations.

Gofman and Tamplin, elsewhere in this series, have argued, in effect, that from 5 to 10 per cent of our existing cancer load can be assigned to the natural radiation background. This inference has some support from studies of the effects of large, acute doses of radiation on the incidence of some specific forms of cancer. Many students of radiation carcinogenesis have quarreled with their extrapolations, and even more with the specific theoretical basis propounded for them. However, these do not exceed by a factor of more than about 10 the cancer incidence levels that many analysts have embodied in their recommendations to regulatory authorities. But then, the notion that the background radiation might contribute as much as 1 per cent to the cancer incidence has often been either discounted (1) as a negligible fluctuation in the disease profile, or (2) as an exaggerated upper limit which ignores the probable attentuation of effect at low dose rates. These critics, in effect, either ignore a 1 per cent attribution to background, or believe it to be a much smaller figure.

A 1 per cent fluctuation, of course, looms very much larger when expressed in absolute numbers, for example, 3,000 cancer deaths per year.

Gene Mutation

The situation with respect to gene mutation is quite similar except that there is some greater weight of evidence in favor of a dose-rate-attenuation factor. An attribution of 10 per cent of mutation to background radiation is probably too high, but is posited in further discussions here. The health significance of gene mutation has, however, been undervalued in estimates based upon the frequency of serious, overt genetic disease, which affects about 2 per cent of newborns. If we take into account heritable predisposition to disease, including many very common diseases, we should more appropriately assign about one-fourth to one-half of the total load of ill health to the genetic factors, and some indeterminate fraction of this to recurrent mutation. On this basis we would conclude that some 20 per cent of our overall health bill is of mutational origin.

Our calculation of damage is, however, complicated by the very long time required for mutation to come into equilibrium with natural selection. We can do little better than to suggest that at the present time the human gene pool has retained an accumulation of about 10 generations' worth of deleterious spontaneous mutations. This is to say, given the assumptions already stated, that the natural radiation background worsens our genetic load at the rate of 1/3,000 (10 per cent of mutations x 10 generations x 30 years per generation) of its existing level. (At equilibrium, this is also the rate at which deleterious mutations are cleared by natural selection.) Taking mutational defect at 20 per cent of the health load inculpates the natural background each year to the extent of 1/15,000 of our existing ill health. However this decrement of genetic health, according to the simplified model, remains lodged in the gene pool and is presented for recurrent payment, year after year, for 10 successive generations.

Evaluating the Costs

To take up the genetic costs first, we face a dilemma in judging how far to project costs into the future, the appropriate discount procedure. Much scientific and medical effort will be devoted to ameliorating the existing genetic load (that 10 generations' worth accumulated mutations), and within the next few decades we can reasonably expect to be able to blunt the impact of deleterious mutation on the health of our offspring. This is, after all, one of the strongest arguments against pursuing socially oriented eugenic campaigns. A rather optimistic choice would be to set the present value of these future costs at about 30 years' worth. This attributes 30/15,000 of our annual health bill henceforth to the radiation background, or about 2 per cent per rad.

This estimate is on a scale comparable to that of the consensual cancer load, and subject to the same kind of room for dispute, perhaps tenfold either way.

Translating Health into Dollars

By any rational argument, the health of any individual is a priceless good. This is not to set its value at a mathematical infinity, so much as to point out that it is incommensurable with so-called strictly pecuniary evaluations. If dollar figures are now to be associated with health values, the purpose is only to indicate the kinds of choices that individuals and the body politic have in fact made. One purpose of axiological discussion is to highlight possible inconsistencies within the value framework already postulated. Our existing expenditures on health care amount to some $80 billion per year. This can only set a lower bound to the marginal value of health, on the assumption that the first dollar spent achieves a better return than the last. However, as a nation, we experience a million conceivably deferable deaths per year; but it is unlikely that we could persuade our neighbors to tax themselves to the extent of doubling our health care investment for less than a 20 per cent improvement in our general health standards. That ratio would imply (1) an integrated health "value" of $400 billion per year, (2) an investment of $400,000 per death prevented (assimilating all illness to mortality); this far exceeds most contemporary investments in public health and safety, and (3) if the background worsens health by 0.2 per cent, its health-decremental value is $800,000,000 or $4 per capita. This is equivalent to $40 per man-rad in consequence of the premises given. (If we add in the cancer load, we reach $100, and if we allocate the entire gross national product to health, we will reach $250.)

This does not mean that a citizen would be getting a good bargain if he exposes himself to 1 rad in exchange for a payment of $100; the bargain is merely better than most of the others that he already makes. Alternatively, he would be foolish to spend $1,000 to avoid 1 rad of exposure, but only if this sacrifice distracted him from taking other measures which could offer him a useful return.

This evaluation of the perceived cost of radiation is, I believe, consistent with the expectation of patient benefit envisaged by conscientious physicians in their use of diagnostic X-ray.

These calculations are so crude that they are not significantly altered by factoring in a moderately optimistic value for the incidence of radiation-induced cancer. However, if, as argued by Gofman and Tamplin, the radiation background induces 10 per cent, or some 30,000, of our cancer deaths, this contrived calculus would emerge with a figure of $600 per man-rad. This six-fold inflation of the former figure is less jarring to nuclear energy policy (1 millirem average exposure would imply a figurative tax of 60 cents per capita per year) than it is for any dispensable portion of exposure from medical X-rays.

These pecuniary estimates are hardly to be taken seriously except to suggest the scale of a cost benefit analysis. Many citizens may feel that they value their health and lives more highly than does the multitude; and they may wish to maintain the voluntary option to strike different bargains in areas that exercise their particular anxieties. It is one thing to advertise the merits of a transaction; it is another to impose it willy-nilly on the whole population. We do exchange 1,000 lives per year for the convenience of electric power distribution; but the citizen may feel better able to control his risk of electrocution than of cancer from nuclear pollution. Nor is any safer alternative obvious. (I do not know the marginal costs of reducing electrocution accidents.)

Furthermore, the value calculus so far has given no attention whatever to the redistributive consequencies of a power policy based on nuclear energy as opposed to fossil fuels. Coal miners may be put out of work; but we will also be more evenly distributing the environmental and occupational health costs of power. Yet these distributive effects and other side-effects (like the relationship between our oil-hunger and international policy) may be far more important than a personal tax of 60 cents. Above all the principal argument that appears to have persuaded the utility companies to go nuclear has been the environmental one: the chance to reverse the trend of worsening air pollution from the burning of fossil fuels. This may well have health advantages that would far outweigh the radiation biodetriment.

This argument stands every chance of being the most persuasive to the public as well, but it obviously has not been articulated in a sufficiently detailed, objective and convincing fashion. This would, after all, be in bad taste for a promotional agency, even though a competitor.

Given so many uncertainties about our premises, are we really justified in undertaking a rigorous cost-benefit analysis? It is doubtful that the public interest will be deeply engaged in this type of calculus. Instead its anxieties are aroused by public reference to the qualitative consequences of radiation exposure, the more so because no simple answers can be confidently offered. They had then been sustained for want of an independent evaluative process to which the citizen can confidently relegate his worries. There is no panacea that will surely justify and elicit such confidence, but the recently initiated separation of regulatory from promotional responsibility is the wisest and most constructive step. We are furthermore paying a very heavy price, in the confusion and delay in technical innovations, from having underestimated the depth of biological knowledge that was necessary to support the promulgation of nuclear technology. New directions of policy and research may help to repair not only our administrative and technical lacerations but another priceless good; public confidence that the quality of individual life stands foremost as an aim of government.