SCIENTIFIC RISK ESTIMATION OF THE HEALTH EFFECTS OF LOW DOSE AND LOW DOSE-RATE RADIATION – AN OVERVIEW

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ABSTRACT

Estimation of the scientific risks of high dose radiation has been successfully quantified by many studies using several different approaches. However, the risk for low and low dose-rate radiation is obscure because of a lack of evidence. This risk is currently estimated by extrapolating the radiation response at high doses into low dose ranges for practical purposes. Recent challenges to examine directly the biological responses to low dose radiation using newly developed technologies are unveiling interesting alterations at the molecular level. The interpretation of these data, however, needs careful consideration because they may not be related to any change in biological functions.

Keywords: Low dose, Low dose-rate, Radiation, Biological response, Risk estimation

1 INTRODUCTION

We are surrounded with natural and man-made ionizing radiation and know at the same time that this radiation elicits health hazards at least when the dose of radiation is high. Figure 1 roughly depicts the relationship between radiation dose and health effects together with the radiation levels we face in real life. Thanks to studies in the last 100 years, we now understand quantitatively the risk of radiation, especially when the dose is high. However, the risk of low dose or low dose-rate radiation is obscure because scientific evidence is quite limited.

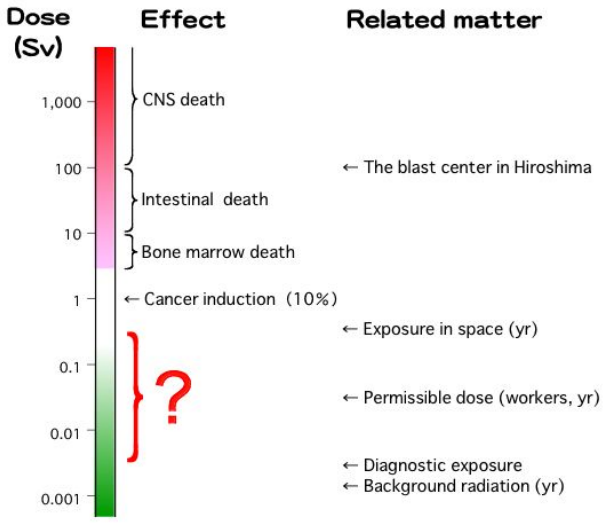

Figure 1. The relationship between radiation dose and health effects. Radiation levels in real life are also indicated. CNS means central nervous system. The question mark shows that the health effects of low dose radiation are not well understood.

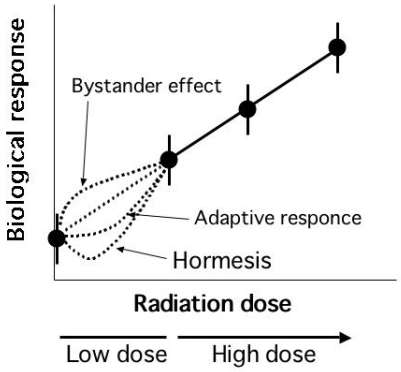

Figure 2. Biological responses to high dose and low dose radiation. At low doses, the dose-response could not be extrapolated from the responses observed at high dose ranges because biological systems respond to low dose radiation in unique ways. The known responses are bystander effect, adaptive response, and hormesis.

Extrapolation of risks at high doses to low doses is not adequate in biological systems because the response to low dose radiation is different from that to high dose. It is now known that creatures recognize low dose radiation as a kind of stress that changes their characteristics in different ways and eventually alters their radiosensitivity. This change is called adaptive response or hormesis. Further, irradiated cells produce some chemicals that influence neighboring non-irradiated cells, a phenomenon called bystander effect. Biological responses to low dose radiation are complicated by another factor called dose-rate effect. These responses are unique to low dose radiation and make it difficult to estimate dose response by extrapolation from the responses to high dose radiation effects (Figure 2). Thus, it is of vital importance to collect evidence on biological responses to low dose radiation (Brenner et al., 2003; Ono, 2007).

Most biological indices show reduced radiation effects if the dose is delivered at a low dose-rate or in a protracted way. This is assumed to be a reflection of the limit of cellular capacity to repair radiation damage. Many radiation-induced lesions cannot be repaired if they are produced in a short period of time, such as in the case of acute irradiation, whereas most are repaired if the lesions are delivered at a slow rate, such as in the case of low dose-rate irradiation. Although the precise mechanisms are yet to be solved, the dose rate effect is an important factor in risk estimation of radiation because we can be exposed to both of these irradiation modalities (Sorensen et al., 2000). Above all, the dose-rates of about 20 mGy/yr and 200 mGy/yr are of critical interest because they correspond to the dose limit for radiation workers and the dose level in space stations, respectively (Figure 1). Studies on the biological responses to these very low dose-rates are extremely limited.

For evaluating the risk of low dose-rate irradiation in humans, epidemiological studies on people exposed in the Chernobyl nuclear accident play a pivotal role because most of them were exposed for a long period of time to a very low dose-rate (Ron, 2007). In contrast, the victims of atomic bombs in Hiroshima and Nagasaki were exposed to high dose-rate radiation. Comparative studies of these two populations will provide a clue to understanding dose-rate effects in humans.

In the following sections, we introduce two recent topics on the effects of low dose and low dose-rate irradiation. They provide new views in estimating the risk of low dose radiation.