

A CHALLENGE TO SCIENTIFIC RISK ESTIMATION ON HEALTH EFFECTS OF LOW DOSE RADIATION – AN OVERVIEW

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ABSTRACT

Although experimental as well as epidemiological studies have revealed the health effects of ionizing radiation, most of our knowledge is for high doses of radiation, while little is known for low doses. For practical purposes, we estimate the risk of low dose radiation by extrapolating the effects at high doses to low doses in a linear relationship. However, several lines of evidence have accumulated in recent years that suggest this linear extrapolation is not necessarily correct and needs further scientific evaluation. Today, many scientists in the field are striving to understand the biological responses to low dose radiation. This work will provide new and perhaps convincing data which are necessary for risk estimation of low dose radiation. Here, I overview the background of the issue.

Keywords: Low dose rate, Radiation, Biological response, Linear extrapolation, Risk estimation, Dose response

1 INTRODUCTION

The hazardous effects of radiation on human health have been recognized since soon after the discovery of X-rays by Röntgen in 1885. In order to prevent negative health effects from radiation, a concept of ‘dose limits,’ or ‘tolerable doses,’ was proposed. These dose limits declined with time as more accurate data became gradually available. Now, international organizations and committees recommend a dose limit of 20 mSv/year for radiation workers and 1 mSv/year for the other people, based on the assumption that carcinogenic effects and genetic effects of radiation at low doses can be extrapolated by linear regression of the effects found at high dose level radiation. This is called linear no-threshold hypothesis (Figure 1). The hazards expected with these dose limits are assumed to be comparable to the risks associated with ordinary work or every day life (Wall, Kendall, Edwards, Bouffler, Muirhead & Meara,

2006).

Although the assumption is admitted to be the best we can do at present, several recent experimental studies on biological responses to low dose radiation have revealed two important phenomena: bystander effect and adaptive response, which raise doubts about the linearity of radiation effects at low doses. Thus, there is an urgent need to elucidate the biological responses to low dose radiation.

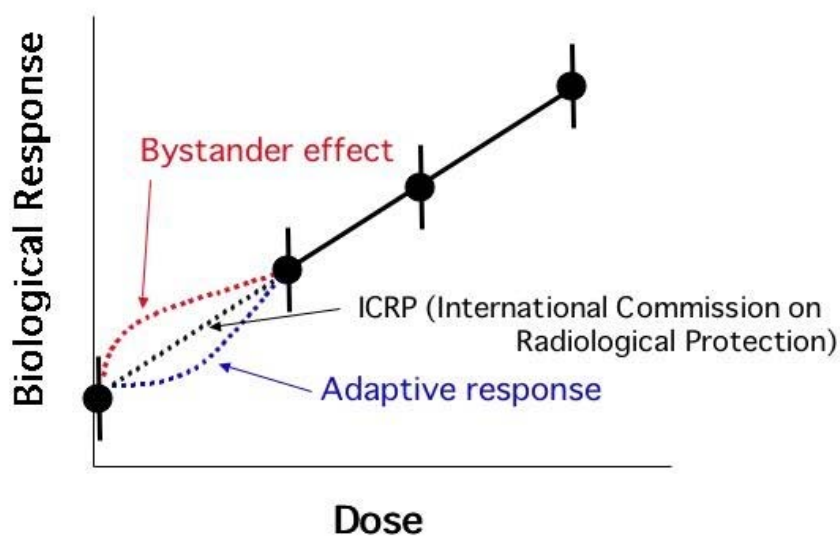


Figure 1. Dose response of cancer induction and genetic effects from high and low level radiation.

Although an international organization such as ICRP (International Committee on Radiological Protection) proposes a linear extrapolation for the estimation of the effects at low doses, the findings of bystander effect and adaptive response suggest that the relationship at low doses could not be linear.

2 BYSTANDER EFFECT AND ADAPTIVE RESPONSE

When a radiation dose is at a low level of a few mGy (or mSv), radiation energy is deposited in some cells, whereas nothing is deposited in others (Booz & Feinendegen, 1988). Under these conditions, the irradiated cells are known to secrete some chemicals that influence the neighboring non-irradiated cells. This is called bystander effect (Figure 2). If this method is active in vivo, the dose response at low doses

could be higher than that assumed by the linear extrapolation (Figure 1) (Hall, 2003; Little, 2003).

The other biological response unique to low dose radiation is adaptive response. When cells are irradiated with a low dose, usually in a dose range of 10 to 500 mGy, they change their own characteristics and become more resistant to later radiation exposure (Kadhim, Moore & Goodwin, 2004; Matsumoto, Takahashi & Ohnishi, 2004). Thus, if the low dose radiation is presented repeatedly or over a long period of time, the effect of the radiation could become less efficient (Figure 1).

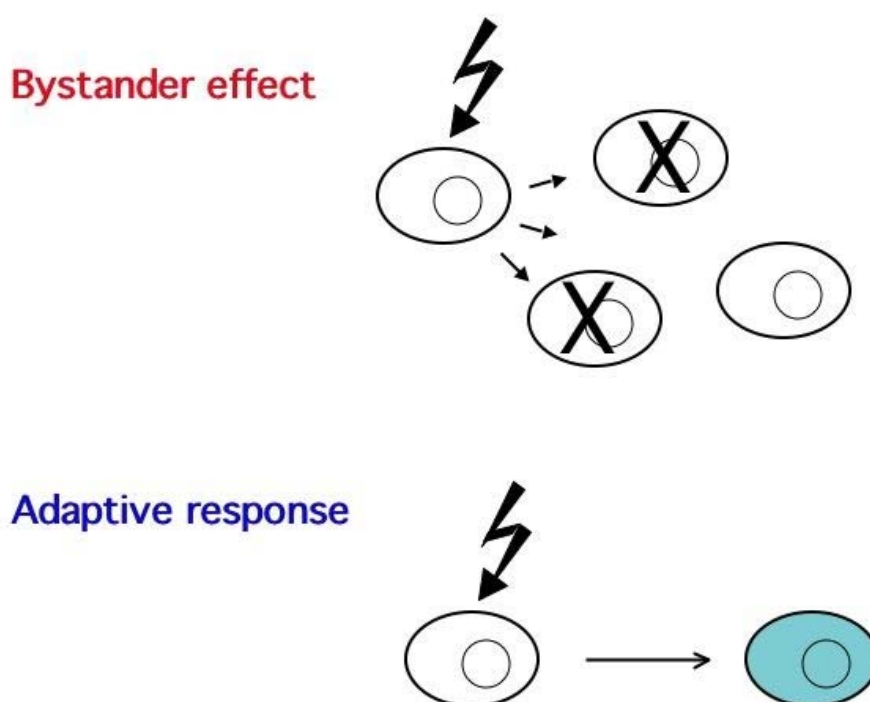


Figure 2. Schematic illustration of bystander effect and adaptive response.

The bystander effect is exerted on un-irradiated cells by chemicals secreted from neighboring irradiated cells. Adaptive response is a cellular change to radio-resistant form after exposure to low dose radiation. If the irradiation is repeated or continued for a long period, the cellular sensitivity drops.

3 DOSE RATE

It is well-established that biological effects of radiation depend on the dose rate of exposure. From a viewpoint of risk estimation, we want to know the biological response to 1 to 500 mGy of radiation

exposed in a period of one year. One mGy/yr is the dose limit for the public and 500 mGy/yr is the dose level expected in space. On the other hand, almost all of the experimental data are derived with a dose rate of 1 Gy/min to 1 mGy/min, which correspond roughly to 0.5 MGy/yr to 0.5 KGy/yr. The difference is as large as 10^3 - to 10^9 -fold. Thus, the biological responses at very low dose rates need to be reexamined experimentally.

In this regard, it is interesting to note that Tanaka et al. examined life-shortening effects of radiation in mice using dose rates of 15.2 μ Gy/min for a total period of 400 days (Tanaka et al., 2003). The life shortening observed at the total dose of 8 Gy was 16 weeks, which was about 1/3 of that induced by high dose rate irradiation (Lindop & Rotblat, 1961). The value corresponds well to the dose rate effect observed in genetic effects of radiation in mice (Russel & Kelly, 1982). Epidemiological studies such as the incidence of chromosomal abnormality in people living in high background areas, as performed by Zhang et al. (2003), provide other important information.

4 CONCLUSION

Biological responses to low level of radiation are important and may represent unique phenomena. They may not be correctly extrapolated from the responses to high dose radiation. It is an important and urgent challenge to measure carefully the biological effects of low dose radiation, using several different vital indices of biological function. The resulting data would be a promising method for evaluation of the risk of low dose radiation on human health.

5 ACKNOWLEDGEMENT

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