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Meeting report

"Scientific Considerations Regarding Radiation Risk" JEMS Open Symposium 2012

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The health effects of low-dose radiation have generated considerable concern after the accident at the Fukushima Daiichi Nuclear Plant. Although the risk of acute direct exposure to high-dose radiation could be avoided, the risk remains for low-level continuous exposure to radiation by long-lived environmental contaminants, such as cesium-137 that is released from the nuclear plant. Scientists have engaged in a contentious debate regarding the actual risk of low-dose radiation. To understand the actual risk of radiation scientifically, the Open Symposium of Japanese Environmental Mutagen Society (JEMS) was held on May 26, 2012 at Keio University in Tokyo. Eight scientists and a special guest from Fukushima were invited to participate in this symposium. We understand that it is difficult to draw a proper conclusion scientifically concerning the actual (absolute) risk of low-dose and low-dose rate radiation from the available data. The risk of radiation exposure can only be estimated in a relative manner if we compare the risk to other confounding risk factors, such as smoking. Being unafraid and controlling risk factors in our lifestyle are important in helping us to cope with the inevitable exposure to low-dose radiation that was caused by the Fukushima accident. It is critical to communicate and to advise people in the nearby environment regarding their risk of radiation exposure and the need to make a rational decision to avoid undue exposure and excess risk concerning radiation emerging from the accident site.

Key words: radiation, risk assessment, nuclear accident, food safety, regulatory science

Introduction

On March 11, 2011, an enormous unexpected tsunami pummeled the northeastern coast of mainland Japan (Tohoku area) after a 9.0 magnitude earthquake. The earthquake itself was not as lethal as the huge tsunami, which killed as many as nineteen thousands people. The tsunami also caused a serious disaster in the Fukushima area by damaging the Fukushima Daiichi Nuclear Plant. Although the nuclear plant was resistant to the earthquake, it was not prepared to withstand the forceful tsunami. Tremendous and powerful waves rolled over the protective wall and penetrated the reactors. Unfortunately, all of the electric power supply had been lost, including the emergency back-up system because the system was not properly designed and situated. The continuous loss of electricity caused the cooling system for the nuclear reactors to cease functioning; the used nuclear fuel pools caused the overheating of these facilities. The plant faced a serious crisis in which the overheating induced a hydrogen gas explosion in multiple reactors, which incurred devastating damage. Consequently, several days after the tsunami, a large amount of radioactive substances, including volatile radioactive iodine and cesium or radioactive water, were released into the surrounding environment. Most of the radioactive substances were released toward the ocean side, but occasional winds from the ocean carried the radioactive substances over the surrounding inland area and caused serious radioactive contamination in the Fukushima area.

In a realistic worst-case scenario, people in the surrounding area were exposed to life-threatening effects caused by the nuclear explosion of the reactor. The Japanese government ordered the residents to evacuate a 20-km area from the nuclear plant. Continuous efforts to cool the reactor and the pool averted additional disaster; however, radioactive contamination from the site, which has remained a central issue, continues to threaten many people in the form of an invisible radiation fear.

From our experiences with the atomic bombs in Hiroshima and Nagasaki and the Chernobyl accident, we know that radiation causes serious health problems in humans. The direct exposure to high-dose radiation has killed many people. We do know about the approximate lethal dose of acute radiation exposure (7 Sv);

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however, we do not have sufficient data to evaluate a risk of low dose/low-dose rate exposure of radiation. In the Chernobyl incident, only radioiodide exposure increased the incidence of thyroid tumor in the young generation by an indirect internal exposure, primarily through contaminated foods. Statistical analysis has shown that the incidence of tumor increased over 100-mSv exposure after the nuclear bomb. Therefore, we do not have a real answer for the health effect by the low-level radiation. After the Fukushima accident, there has been debate between optimistic and pessimistic scientists regarding the actual risk of radiation, which confused residents in the affected area. It may be easy to measure the actual amount of radiation exposure; however, we cannot estimate our risk of exposure.

Radiation is an environmental mutagen; therefore, the JEMS should accept the responsibility of addressing this vital issue. In an initial effort to provide useful information regarding the risk of radiation, we constructed the web site in JEMS HP to provide data on the risk of radiation (http://www.j-ems.org/ray/). Additionally, the radiation risk issue was selected to be the primary theme of the annual JEMS symposium in 2012 to ''scientifically'' discuss the radiation risk and disseminate the pertinent data.

Eight speakers were invited to present their scientific points of view, and a special guest from the Fukushima area was invited to give a talk from her perspective as both a mother and a teacher.

The primary objective of this symposium was to understand the level of radioactive contamination and to estimate the health risk based on scientific data and, more importantly, to direct a proper approach toward considering effective management of radiation risk.

''It is easy to be scared too much or too less, but it is difficult to be afraid properly.''

Torahiko Terada

Opening Address

Hiroshi Kasai, the President of JEMS, delivered the opening remarks and defined the important role that the Society plays in investigating and promoting research on radiation, which is one of the environmental mutagens. From his expert view on the 8-hydroxy guanine, he introduced the contribution of the JEMS to radiation biology and the role of active oxygen species produced by radiation in mutagenesis. He said, ''This symposium can be a good opportunity to re-consider a risk of radiation after one year of struggling debate. In addition, this is also a good opportunity for JEMS to show its relevance as a responsible researchers group who can make a scientific judgment on the risk of radiation in relation to those of other mutagens''.

Session 1 (Chaired by Hiroshi Kasai, University of Occupational and Environmental Health)

Introduction

The introductory presentation was made by Takayoshi Suzuki (National Institute of Health Sciences), organizer of this symposium and a leader of the working group on radiation risk in JEMS. In the presentation titled ''We Have Already Been Exposed to Radiation'', he announced the establishment of the new website concerning information on radiation risk at the JEMS site (http://www.j-ems.org/ray/). The symposium was organized by this working group to disseminate information on radiation risk and provide a forum for the scientific discussion of this subject to gain a better understanding of the actual risk of the current Fukushima disaster. In this issue of Genes and Environment, his opinion is described in the commentary paper titled ''Unconscious Exposure to Radiation''. We must recall an important evidence: We have already been exposed to a much higher nuclear fallout during the 1960s because of the worldwide nuclear bomb experiments; additionally, we are being exposed to potassium-40 radiation derived from our daily food intake. When people think about radiation risk, it is advisable to consider this important evidence before making a rational judgment.

Special Lecture

Yasushi Yamazoe (Food Safety Commissions), the former president of JEMS, presented a special lecture on risk assessment and radioactive nuclides in food. As chairperson of the working group in the Food Safty Commisions, which was established just after the Fukushima nuclear accident, Dr. Yamazoe was able to assess whether radioactive nuclides in food can impact one's health. The risk-assessment report on radioactive nuclides in food was released after an extensive survey of available data and a series of discussions in the working group. An abstract of this report is available in English at (http://www.fsc.go.jp/english/emerg/abstract_risk_assessment_report.pdf). A complete document in Japanese is available at (http://www.fsc.go.jp/sonota/emerg/radio_hyoka_detail.pdf).

Upon a large release of radioactive materials into the environment from the Fukushima Daiichi Nuclear Plant, the Japanese government requested that the Food Safety Commissions conduct an assessment of the situation. An emergency report was quickly released in March 2011 using available information for the evaluation; a continuous effort was made to collect and review 3300 manuscripts to finalize a report that was released in October 2011. The report was evaluated from the following points of view that are described below.

An important principle for evaluation was dealing with both the internal and external exposure to determine the standard limit of exposure because the majority of available data were based on a mixed exposure. The radioactive nuclides of concern were iodide, cesium, uranium, plutonium, americium, curium, and strontium. Epidemiological data based on previous experiences were considered to be more important than animal experiments.

The biological effect of radiation was categorized into the stochastic (without threshold) and the deterministic (with threshold) effects. It was difficult to judge the existence of threshold for the low-level radiation effect based on the current scientific knowledge; therefore, an argument on threshold was avoided. It was important to evaluate the exact level of exposure; in most cases, exposure should be calculated as long-term exposure (both internal and external).

In addition to radiation exposure, confounding factors, such as smoking, made the evaluation difficult. Among many reports, the most reliable data were derived from the atomic bomb exposure in Hiroshima and Nagasaki (1,2). The lowest effective dose of radiation that can increase the incidence of cancer in Hiroshima and Nagasaki was reportedly 200 mSv. Preston *et al.* (1) reported a significant increase of total tumor deaths at 125 mSv but no effect below 100 mSv. Based on these data, the working group set the limit for the level of radiation exposure in a person's lifetime as 100 mSV, although no effect was reported by a lifetime exposure at 500 mSv in the high background area in India.

At the end of his talk, Dr. Yamazoe gave an important message that ''exposure to 100 mSV does not directly mean an increase of cancer incidence and an overall risk for carcinogenesis can be reduced by controlling other confounding factors in life style''.

Session 2 (Chaired by Kazuo Fujikawa, Kinki University)

Nori Nakamura presented data on ''Lessons Learned from Atomic Bomb Survivors in Hiroshima/Nagasaki.'' from the research experience at the Radiation Effects Research Foundation in Hiroshima and Nagasaki. His talk focused on the following points:

- An epidemiological research on approximately 120,000 atomic bomb survivors revealed an early onset of leukemia after the exposure; however, it took more than 20 years to observe an increase in the incidence of solid tumors.
- The relative risk for leukemia increased approximately 5 times after radioactive exposure at 1 Gy.
- In contrast, a relative risk of solid cancers was approximately 1.5 at 1 Gy (1) and the dose response was linear. However, the linearity at the lower dose (<200 mSv) was not clear.
- There is no relationship between increased cancer risks by radiation and incidence of spontaneous cancer of the organ.
- One of the approaches to evaluate the risk of low-dose radiation takes a so-called ''linear non-threshold (LNT) model,'' which extrapolates a linear relationship into lower dose range. This type of safety-margin approach does not underestimate the possible risk.
- There is no evidence of heritable genetic effects in the offspring of the survivors.

In conclusion, Dr. Nakamura proposed a desired operation after the accident as follows: ''Rather than draw a line of evacuation zone on a map, the Government could provide information to the residents on their possible exposure levels and the estimated risks, and let them choose either stay at their home or evacuate. And the maximum support had to be given to their decision.

Jun Takada (Sapporo Medical University), a specialist of radiation protection and hygiene, evaluated individual dose on affected populations and surveyed environments from Sapporo to Tokyo, including the entrance gate of the Fukushima Daiichi Nuclear Plant soon after the accident (April 6–10, 2011). He also performed a recent survey in Namie-cho, which is located within 20 km of the nuclear plant. He reported the results of these radiation hygiene surveys in relation to the Chernobyl accident. Detailed data, as well as his opinions, appeared in the following article, titled ''Low Dose and No Health Risk in Fukushima in Contrast to Chernobyl'', in this issue. His critical view on the political operations in Fukushima after the accidents is also included.

Shizuyo Sutou (Shujitsu University) participated in volunteer work in the radiation monitoring in Fukushima in July 2011, pursuant to a request from the Ministry of Education, Sports, Science and Technology to all Japanese universities. He presented his experience as a volunteer in Minamisouma, Fukushima, in addition to the survey results. He measured the radiation level in the residents who returned to their houses temporarily with permission. As a reference, he discussed measurements of radioactivity in other places. His report, ''The Fukushima Daiichi Nuclear Power Plant Disaster: A Report on Volunteer Activity for Radioactivity Screening of Temporary Returnees to the Evacuation Zone,'' is available in this issue.

Session 3 (Chaired by Chie Furihata, Aoyama Gakuin University/National Institute of Health Sciences)

Takeshi Morita (National Institute of Health Sciences) discussed his paper, ''Radiation Risk in Relation to Risk Evaluation of Chemicals.'' He explained the basic strategy for risk evaluation on chemicals from his expert experiences.

The risk is determined by the hazard level and the incidence (dose of exposure). Outputs from the risk evaluation of chemicals appear as the regulatory standard values, such as the acceptable daily intake (ADI) and the acute reference dose (ARfD). In this process, important factors to be considered are quality of the data, extrapolation to humans, dose-response, and weight of evidence. ADI is calculated by the NOAEL (no observed adverse effect level) in animal experiments, which is multiplied by 1/100 as a safety margin for an extrapolation to humans. The virtual safety dose (VSD) is set for chemicals without the NOAEL (i.e., non-threshold response), such as genotoxic carcinogens. The carcinogenicity of radiation is also considered to be a non-threshold response.

Dr. Morita explained the risks of ethanol, NaCl, and arsenic in foods. People are exposed daily to those chemicals in food; however, they are not afraid of those risks as much as they fear risks of radiation, food additives, or pesticides. However, the former generally tend to bear a higher risk than the latter. Ethanol and NaCl have no regulatory standard values because they are categorized in food, but there is substantial evidence to indicate an association with carcinogenesis. The estimated ADI of ethanol from animal data will be 24 mg/kg, which corresponds to only 30 ml for adults (50-kg). For NaCl, it will be 20 mg/kg, which corresponds to 1 g for adults. An average daily intake of NaCl (10 g) exceeds the estimated ADI. Arsenic is toxic to multiple organs and is considered to be a genotoxic carcinogen; however, it is contained in many foods, such as drinking water, seaweed, and rice at relatively high levels.

MOE (margin of exposure) is calculated by toxicological values, such as NOAEL, divided by the exposure levels in humans. MOE is important for the risk control and communication. Tobacco smoking and diet reportedly correspond to 2/3 of the total risk factors for carcinogenesis and radiation contributes only 2% of the risk factors. The National Cancer Center reported that the carcinogenic risk factor of 100–200 mSv of radiation is estimated to be 1.08-fold, which is lower than smoking (1.6-fold).

Dr. Morita emphasized the importance of the risk trade-off. It happened after the Fukushima accident when people drank a bottle of mineral water, instead of tap water, to avoid the cesium intake. The high arsenic contents in the mineral water became a concern for carcinogenesis. Avoiding a certain risk produced another risk (trade-off).

Akihiro Shima (Institute for Environmental Sciences) presented his data from animal experiments titled ''Considerations on the Risk of the Low Dose-Rate Radiation Based on Experimental Data in Mice.'' He focused on the biological effect of low dose-rate/low dose γ-ray in mice. This presentation is an interim report from the study with 4,000 mice at his institute. As a definition by UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) (2010), the low-dose rate is <0.1 mGy/min and the low dose is <200 mGy. Dose-rates of 0.05 mGy/22 h/d, 1.1 mGy/22 h/d, and 21 mGy/22 h/d for 400 days were used; the total dose went up to 20 mGy, 400 mGy, and 8,000 mGy. A total of 500 male and female B6C3F1 mice per group had been exposed to cesium-137 radiation. A statistically significant shortening of the lifespan was observed at 21 mGy/day in males and 1.1 mGy/day and 21 mGy/day in females. An increased incidence of hemangiosarcoma and myeloid leukemia in males and ovarian neoplasm in females were observed (3). However, the lifetime shortening in mice continuously exposed to a low-dose-rate γ-ray is considered to be attributed to early death from a variety of neoplasms (4).

No change by the lower-dose radiation was observed, which suggested that the effect is too small to be detected even by this size of experiment. Brenner *et al.* (5) suggested that the cohort size required to detect statistically significant increases in overall cancer incidence after 150 mGy of radiation is 10,000.

In the experiment with the *gpt*-delta transgenic mice (6), total doses of 2–8 Gy were exposed at different dose-rates of 0.0125–920 mGy/min. A dose-dependent increase of mutation frequency (MF) in the red/gam gene (primarily by a large deletion) was observed in the spleen and liver. The spleen was more sensitive than the liver. A clear dose-rate effect was observed with the higher MF by the higher dose-rate. It is very important that the biological effect, such as an increased cancer or mutation incidence, was induced by the low dose-rate radiation although the total dose should be high. This finding suggests a likelihood that the lower-dose effect can be detected using a larger number of mice; however, this study seems to be an endless trial.

Suminori Akiba (Kagoshima University) introduced the human epidemiological data in his talk, ''Considerations on the Risk of the Low Dose Radiation from Epidemiological Data in Human.''

Dr. Akiba stated that there are several areas where there is a high level of natural background radiation; e.g., Karunagapally in Kerala, India; Yangjiang in Guangdong, China; and Talesh Mahalleh in Ramsar, Iran. Among these regions, useful epidemiological data were retrieved from Kerala where radioactive monazite sands in the coast released approximately 5–10 mSv gamma ray per year. Dr. Akiba surveyed the radiation level of this area and performed epidemiological analysis in nearly 400,000 residents. There was a small increase in the relative risk of lymphoma; however, this amount was not statistically significant. The results also suggested that the excess relative risk per dose for solid cancer after chronic radiation exposure is significantly lower than that observed among the atomic bomb survivors. There was a statistically significant increase in the incidence of cancer among persons who were exposed to an acute high level of radiation, such as near the Techa River. An increase of mammary tumors was evident among female patients with tuberculosis who were exposed frequently to diagnostic chest radiographs. Therefore, an importance of radiation dose-rate was suggested, which can be confirmed by analysis with workers in nuclear plants. In conclusion, there are no epidemiological data that demonstrate an increase in the incidence of cancer or heritable genetic effects by the low-dose radiation exposure (no evidence does not necessarily mean no effect).

Dr. Akiba's talk was summarized as a review paper titled ''Cancer Risk Associated with Low Dose and Low Dose-Rate Ionizing Radiation Exposure'' in this issue.

General Discussion (Chaired by Takayoshi Suzuki and Masanobu Kawanishi, Osaka Prefecture University)

A general discussion was held at the end of the symposium. Before starting the discussion, a special talk was presented by Maki Momose, a mother who works as a high school teacher in Fukushima (Hanawa Technical High School). It was a good opportunity for scientists to listen directly to a resident from the affected area.

Mrs. Momose suffered essentially from a lack of information on radioactive contamination level and safety. Because of this lack of information, she felt insecure and temporarily evacuated her house with her small children, leaving her husband at home. It had been very stressful for her family; finally, she returned with her children to their home. They live in Nasushiobara (Tochigi Prefecture), where hot spots of radioactive nuclear fallout are found, although the city is not close to the nuclear plant. They were informed about this fact three months after the accident. As a teacher, she reconsidered the risk of the surrounding materials and realized that a similar level of risk of radiation existed, which are considered to be ''not immediately harmful''. She said ''it is important to teach students how to cope with the surrounding risk''. She emphasized that it is critical to make your own decision and to assess the situation based on sufficient data and a long-term vision of the future.

As a mother, she worried that the children's health might be adversely affected by the radioactive contamination, and she felt guilty about staying in that environment if there would be ill side effects in the future.

At the end of her talk, she posed the following questions to challenge scientists:

- How effective is the human defense system against DNA damage?
- Does the low-level radiation cause mental defects, such as a general malaise?
- How different is an individual's susceptibility to radiation?

Additionally, she expected scientists to contribute to the following tasks:

- Evaluation of the radiation effects in combination with other risk factors;
- Collection of data on the health effects induced by a long-term exposure to the low-level radiation; and
- Communication about a health risk of radiation or chemicals in a comprehensible fashion.

These tasks that she proposed are very difficult. Nevertheless, as scientists, we should endeavor to provide useful information with regard to these critical issues.

After her talk, a general discussion with all of the presenters ensued. At the beginning, Dr. Kasai (former ICRP and UNSCER member) explained about a principle of the ICRP report and of the LNT model, which is occasionally misunderstood by researchers. He asked for a proper understanding on the meaning of the reports and a transfer of the correct information.

A question was raised regarding the recent change in food regulation in which the level of maximum acceptable radioactivity had decreased, therefore getting severer. Dr. Yamazoe answered that ''the food regulation is applied for a whole population, therefore the safety level should be higher as much as possible within an achievable range. It is necessarily to avoid the risk, at least immediately after accidents, but it should be reconsidered later from a long term view.''

Finally, in closing, each speaker addressed their issues and proposals for the future risk management of low-level radiation as follows:

- Transparency of information is important for an unbiased risk communication and understanding. (Dr. Yamazoe)
- We should remember the evidence that a forced evacuation of the aged people from their care facility caused death, although no death was reported by a direct exposure to radiation. (Dr. Nakamura)
- Political operations were not properly conducted after the nuclear accident, particularly with respect to monitoring the actual radiation level and human exposure in Fukushima. A lack of information caused confusion among the residents in Fukushima. (Dr. Takada)
- It is important to know the background radiation is not zero on earth. Excess fear caused unnecessary stress, which occasionally leads to a suicide. Therefore, an appropriate understanding about the actual risk is mandatory. (Dr. Sutou)
- Our risk-communication ability should be improved by understanding the actual feelings of the affected residents to better contribute toward a future risk management in Fukushima. (Dr. Morita)
- Experiences in Aomori for an environmental

monitoring of background radiation performed by the Institute for Environmental Sciences, which was built according to an establishment of the Rokkasho Nuclear Reprocessing Plant (not yet operated), before and after the accident in Fukushima, can contribute to a better understanding of the health effect by radiation in Fukushima. (Dr. Shima)
- Verification of operations after the accident is necessary. For example, it would be useful to know why the monitoring of thyroid exposure to radiation in children could not be performed soon after the accident. The Japanese government should contribute to the evaluation of the health effect by low-dose exposure to radiation. (Dr. Akiba)

Take-Home Messages from the Symposium

- It is difficult to draw a conclusion scientifically on a real risk of low-dose radiation.
- The current regulatory standards were set without scientific evidence for the increased risk, including a safety margin.
- The risk of radiation should be considered in conjunction with other confounding factors.
- The increased risk of carcinogenesis by radiation in Fukushima can be a trade-off by controlling the other confounding risk factors in lifestyle.
- The risk communication (education) is important to understand a real risk of low-level radiation exposure and to avoid unnecessary fear among the affected individuals.
- The decision should be made personally whether to accept or avoid the risk of low-level radiation because the level of risk varies depending on the person and his or her situation.

I believe this symposium could provide useful information for the participants. To disseminate this information publicly, all original presentations will be made available as online movies at the radiation risk site in the JEMS homepage.

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