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Biological Dosimetry Measurement Using ESR Spectroscopy

Teruaki Maeda

The applicability of ESR (electron spin resonance) spectroscopy for measurement of dosimetry at low doses of ionizing radiation was evaluated in granulated sugars, teeth of field mice, human fingernails, human hair, and scallop shells irradiated with X-rays. DPPH (1, 1-diphenyl-2-picrylhydrazyl) diluted to 1.2×10^{14} spins in 200 mg of glycine powder was used as a standard to estimate the amount of free radicals induced in the irradiated samples. After 200 mg of each sample was exposed to X-rays at 0-20 Gy, ESR spectra were recorded with JEOL JFS-RE1X ESR spectrometer under the following conditions: 5-mW microwave power, 100-kHz field modulation, and 0.4-mT amplitude. In addition, ESR spectrum of Mn++ powder was simultaneously measured using a specially designed ESR cavity to adjust the ESR signal intensity and the magnetic field. Signals were observed even in unirradiated control samples except for granulated sugars using ESR. These signals of unirradiated samples were subtracted from those of irradiated samples, and the residual signal was doubly integrated by WINRAD computer software (Radical Research Company, ver. 1.20) to derive the actual signal intensity. The amount of free radicals in X-irradiated samples was calculated by comparing the doubly integrated signal values of irradiated samples with that of DPPH samples. Linear relationship between the amount of free radicals and irradiation dose was achieved in the range of 0-20 Gy in granulated sugars and teeth of field mice; however, no quantitative measurements could be made in samples irradiated with doses less than 0.5 Gy because of considerably lower intensities of signals. From the slopes of these linear relationships, free radical production efficiencies of irradiated granulated sugars and teeth of field mice were estimated to be 4.0×10^{14}/g/Gy and 2.06×10^{14}/g/Gy, respectively. These results indicated that ESR-based dosimetry for both samples were applicable to ionizing radiation at doses > 0.5 Gy. Precise estimation of the amount of free radicals could not be performed in fingernails, hair of head, and scallop shells because these samples were contaminated by large amounts of free radicals in the unirradiated state.

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Radiation Exposure Dose in X-ray Computed Tomographic Examination

Hideki Obara

X-ray computed tomography (CT) is a medical imaging technique that uses computer-processed X-rays to produce tomographic images or "slices" of specific areas of the body. These cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines. In 2004, Berrington et al. reported that a large number of CT examinations were performed in Japan, which resulted in high radiation exposures and high attributable risks. Particular care should be exercised when exposing fetuses and infants to radiation because this group is more radiosensitive compared with adults. Of the children examined by CT at our institution, the number of infants aged ≤ 5 years were determined, and their radiation exposures were calculated. The results of CT examinations performed at the Department of Radiology, Hirosaki University Hospital, between January 2011 and December 2011 were analyzed. The conversion factors from International Commission on Radiological Protection (ICRP) Publication 102 and the dose-length product obtained from the CT scanner were used to calculate the radiation dose. The regions examined were the head, neck, chest, abdomen, and pelvis. The number of children aged ≤ 5 years was 191, which was 1.1% of the total 17,476 patients examined by CT. The 191 children examined were grouped by age, and the number of examinations in descending order was: newborns, 63 (32.8%); 1-year-olds, 36 (18.8%); 3-year-olds, 32 (16.7%); 5-year-olds, 23 (12.0%); 2-year-olds, 20 (10.4%); and 4-year-olds, 18 (9.4%). The number of regions examined, in order of descending prevalence, was the head, chest, and abdomen. The average effective dose of a child patient who underwent a single CT examination was 4.89 mSv. Newborns received a dose of 5.91 ± 2.72 mSv, which was the highest among infants. The heads of newborns received a dose of 4.62 ± 1.73 mSv, which was the highest value among all regions. In newborns, this value was obtained after applying the largest conversion factor from ICRP Publication 102.

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Response of the Nrf2 Protection System in Human Monocytic Cells after Ionizing Irradiation

Hironori Yoshino

In response to reactive oxygen species (ROS) or electrophiles, the transcription factor nuclear factor erythroid 2 (NF-E2)-related factor 2 (Nrf2) rapidly translocates into the nucleus and induces the expression of various antioxidant genes, such as heme oxygenase-1 (HO-1). Low linear energy transfer (LET) ionizing radiations such as X-rays generate ROS which cause biological damage. However, little is known about whether the Nrf2 system in human monocytic cells is activated by low LET ionizing irradiation. Therefore, in this study, we investigated the response of the Nrf2 system to X-irradiation in human monocytic THP1 cells. Following exposure of THP1 cells to X-rays (1–5 Gy), intracellular ROS levels and mitochondrial superoxide were measured using 2′, 7′-dichlorodihydrofluorescein diacetate and MitoSOX™ Red, respectively. Nrf2 localization was determined using immunofluorescence staining, and HO-1 mRNA and protein expression were examined. Although ROS were generated by irradiation in a dose-dependent manner, they disappeared immediately after irradiation. However, secondary intracellular ROS generation was observed 24 h after irradiation. On the other hand, mitochondrial superoxide generation in X-irradiated THP1 cells increased 3 h after X-irradiation, thus showing a possibility that mitochondria are the source of the X-irradiation-induced secondary peak of intracellular ROS generation in human monocytic THP1 cells. In terms of Nrf2 translocation into the nucleus, it was observed 6 h after 5 Gy X-irradiation but was not detected following 1–2 Gy irradiation or in non-irradiated controls. HO-1 expression was significantly higher in 5 Gy-irradiated cells after 24 h than in non-irradiated controls. Furthermore, the treatment with N-acetyl-L-cysteine, a precursor of glutathione, significantly reduced the up-regulation of HO-1 expression after 5 Gy-irradiation, which showing that ROS is associated with radiation-induced HO-1 up-regulation. These results indicate that high-dose irradiation (5 Gy) activates Nrf2 and that the Nrf2 protection system may function from 24 h after irradiation in human monocytic cells. Given that the kinetics of ROS and antioxidant system are important factors for the cellular response in irradiated cells, these results will be helpful for not only cancer radiotherapy but also treatment for radiation-induced injury, such as acute radiation syndrome.

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Education Program for Radiation Emergency Medicine: Evaluation and Management

Junko Mikami

Background: This study investigated the effectiveness of the current education program for radiation emergency medicine at our institute, a tertiary medical care center.
Methods: Thirty-six nurses were enrolled in this study. They were working at the Emergency and Disaster Center, Hirosaki University Hospital, and attended workshops that conveyed the fundamental knowledge about radiation, radiation emergency medicine in practice, and how to wear and remove a radiation protection suit. For the purpose of this analysis, examinations were conducted 3 times: before (baseline), just after, and 3 months after completion of the workshops. The results were calculated as a percentage of the full score and compared at each time point. Interviews were also conducted using a questionnaire regarding the participants' feelings about the program.
Results: The average scores of the examinations were 29.2±14.6, 69.4±17.8, and 57.9±22.9 at baseline, just after, and 3 months after the workshops, respectively. Although the average score was significantly higher 3 months after the workshops compared to the scores at baseline ($P < 0.001$), it was lower than those just after completion of the workshops ($P < 0.001$). According to the results of the questionnaire, 30 participants (94%) felt satisfied with the program, whereas only 2 respondents (6%) answered that they were neither satisfied nor unsatisfied. In response to the question, "Are you able to apply the knowledge gained from the program in practice"? , 8 participants (25%) indicated that they were able to apply the knowledge in practice, 23 (72%) predicted that they would be able to do so in future, and 1 (3%) responded that the knowledge would not be useful in practice.
Conclusions: Almost all participants indicated that they were satisfied with the current educational program for radiation emergency medicine, and were confident that they would be able to apply the knowledge gained from the program in a practical way. Examination scores showed that participants had difficulty retaining the knowledge they had gained about radiation emergency medicine. This was true even for skilled staff working at a highly equipped medical center because radiation emergency medicine requires additional knowledge about general emergency and disaster medicine. A continuous education program may provide better education on radiation emergency medicine. Better educational materials may also help program participants to retain the knowledge and techniques gained in the workshops. The current program may be helpful in the short term, but long-term education is necessary. Thus, a more effective system for training nurses in radiation emergency medicine needs to be developed.

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Evaluation of Human Resource Development Program in Radiation Emergency Medicine. Covering and Detachable of Protective Clothing.

Misato Kasai

Objective: The aims of this study were to evaluate the efficacy of current education programs on radiation emergency medicine and to determine areas requiring further development. These programs are part of a human resources development initiative to train personnel to deal with unexpected radiation accidents.

Methods: Thirty-six nurses were enrolled this study. They were working at the Emergency and Disaster Center, Hirosaki University Hospital, a tertiary medical care center of Aomori Prefecture, which has a few nuclear power plants and related facilities. The nurses took knowledge test about radiation and practical valuation of techniques to wear and remove radiation protection clothing at before, just after, and 3 months after completions of the study sessions, and scores at each time point were compared. They also filled out a questionnaire survey on the educational program.

Results: The average scores of the knowledge-based examinations were significantly higher just after and 3 months after the study session compared to those before the session ($P < 0.001$). No significant difference was observed between the results just after and 3 months after the session. The score of the practical examinations on the removal of protective clothing at 3 months after completion of program was significantly higher than that just after the session ($P < 0.001$). Thirty-two subjects responded to the questionnaire survey. Their responses indicated that about 94% of them were satisfied with the program. Approximately 90% indicated that once a year was the desirable frequency to conduct the program.

Discussion: Some important points were suggested to develop the radiation emergency medicine program at the Emergency and Disaster Center, Hirosaki University Hospital. The results of the knowledge-based examinations clearly demonstrated the effectiveness of the study session, and the knowledge was well maintained until 3 months after the session. Gaining an understanding of the practical aspects of disaster response may require more time, based on the results of the practical examinations. Some additional elements may need to be added to the program in order to satisfy all participants. Although the frequency at which the program is conducted should be evaluated, continued annual implementation and evaluation of the educational program for training in radiation emergency medicine will satisfy the needs of the majority of participants.

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A Consciousness Survey and Stress Evaluation of the Staff at a Radiation Emergency Medicine Facility after the Great East Japan Earthquake

Daishi Sato

Objective: Several nuclear-power-related facilities are located in Aomori Prefecture in Japan. Hirosaki University School of Medicine Hospital is a tertiary medical center in Aomori Prefecture. The equipment for radiation-related medical emergencies is located in the Critical Care and Emergency Center at this hospital. Corresponding trained staff must maintain this
equipment and be prepared to respond in case of emergency. This study investigated the psychological influence of radiation-related medical emergencies on staff working at the Critical Care and Emergency Center of the Hirosaki University School of Medicine Hospital and clarified problems associated in this medical institution.

Methods: With the help of staff from the critical care medical center, 46 potential candidates for this study were identified. There were 13 people mainly workers who attended to victims of the Great East Japan Earthquake and nuclear power plant accident in Fukushima. The K6/K10 questionnaire (Japanese version) was used to evaluate their experiences and investigate the resulting psychological changes.

Results: Eighty percent of respondents felt uneasiness and a sense of resistance to radiation exposure, while 76% were interested in medical treatment of disaster and radiation exposure victims. Furthermore, 89% respondents felt that they had limited knowledge of the medical treatment required after radiation exposure. Pregnancies, births, and overall health were influenced in 80% respondents. Fear of radiation poisoning greatly influenced the judgment and decision-making of those providing support services. Of the 13 participants who responded to the K6/K10 questionnaire, the influence of providing disaster support on psychological state had decreased in 12. In addition, the stress reaction had decreased as time passed since the earthquake.

Discussion: Doctors and nurses working at radiation emergency medicine facilities should have exclusive knowledge about medical treatment required after radiation exposure and the associated equipment. The staff evaluated in this study felt uneasy about the strong probability of radiation exposure, and they were concerned about offering medical treatment to victims of radiation. Education about radiation exposure and appropriate medical treatment is important to maintain adequate health care in times of radiation-related emergencies. In addition, manpower in such facilities must be increased and supported in the future.

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Problems in the Medical Treatment of Victims Involved in the Great East Japan Earthquake and Subsequent Radioactive Disaster

Akiyoshi Yamada

This study aimed to investigate problems about the Great East Japan earthquake (March 11, 2011) and the subsequent radiation disaster at the Tokyo Electric Power Company Fukushima Daiichi nuclear power plant. Three major questions were addressed:

(1) How did the victims act about an obstacle caused by the radioactivity?

(2) How did hospitals, health centers and other organizations cope with the disaster?

(3) What were the effects of gasoline shortage, lack of goods, rolling blackouts, and other consequences of the disaster?

The study showed these three questions and performed questionnaire, interviews and documentation. And considerations were performed for the activity of the fire brigade and the medical care for radioactivity and disaster.

All supplies are short by the large, complicated disaster such as Great East Japan Earthquake.

Furthermore, a nuclear, biological, or chemical disaster also requires many staffs and equipment compared with other kinds of disaster. If equipment is lost or disappears as a result of the disaster, as it did after the great earthquake, recovery activity is considerably restricted. In addition, the emergency intelligence network was not maintained, too. The shortage of staff and lack of equipment parts and basic amenities of life immediately after the disaster were particularly matters.

Many victims of disaster had not yet recovered completely from the disasters; therefore, responding to the questionnaire was very difficult for them.

The study suggested that the most important thing was to obtain much information from the disaster.

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Suggestions for Improving Firefighter Protocols for Emergencies Involving Radiation

Kenichiro Watanabe

On March 11, 2011, the Great East Japan Earthquake occurred. As a result, a wide area of northeastern Japan was affected by a massive earthquake. At the Fukushima Daiichi nuclear power plant, all reactors were damaged because of the associated tsunami disaster, resulting in a nuclear disaster with the release of a huge amount of radioactive material. The myth of safety of nuclear power in Japan was destroyed by this disaster.
As of December 2012, 2 nuclear power plants were still operating, whereas the remaining 52 plants had suspended operation. In addition, because many facilities converting radioactive material to industrial use exist nowadays, emergency staff find it difficult to identify whether the accident involves the release of radioactive material. Sometimes emergency staff members have to visit the scene of accidents with insufficient information (e.g., "there' s an injured person"). They may also be unaware about the causes of that accident until they arrive at the accident site.
Two solutions to this problem are presented below:

(A) Radioscope deployment for ambulance teams
Radioscopes can provide a more complete picture of the accident even if the ambulance team is unaware whether the release of radioactive material is involved.

(B) Distribute dosimeters to all staff
Guessing the working time from air dose rate is difficult for non-specialists.
Evacuation based on alarms of dosimeters will make rescue activities safer and smoother.
Revision of manuals and systems on the basis of these suggestions will help in protecting firefighters from radiation accidents. In addition, regular, sustained education of firefighters about radiation accidents will improve the safety and security of all citizens.

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Exposure of a Monitoring Staff Member to Radiation after the Fukushima Dai-ichi Nuclear Power Plant Accident

Kumiko Sasaki

On March 11, 2011, the nuclear accident at the Fukushima Dai-ichi Nuclear Power Plant (FDNPP) occurred as a consequence of the massive earthquake and subsequent tsunami that struck the Higashi Nihon area of Japan. The accident caused the release of a large number of radionuclides into the environment. In the subsequent weeks, Japanese government authorities conducted emergency monitoring of the radiation levels.

In this study, radiation exposure of a monitoring staff member who did not wear a protective mask was estimated. Outside a 20-km radius from the FDNPP, the radiation distribution was measured from March 15 to 20, 2011, and from March 25 to 28, 2011, from a monitoring car. On March 15, the highest dose rate of >200 μSv/h was observed at a point approximately 30 km northwest of the FDNPP. The data may have been affected by a radioactive plume from the FDNPP and radioactive deposition by rainfall. The dose because of external irradiation from March 15 to 20 was estimated to be 0.67 mSv based on the dose rate calculated over time and from records of the monitoring team member's behavior. This value was similar to the measured value of 0.72 mSv. The thyroid equivalent dose as a result of internal irradiation was estimated to be 5.0 mSv using a whole-body counter. It was similar to the thyroid dose in Dr. Tokonami's report (median adult dose: 3.5 mSv; maximum adult dose: 33 mSv). The mean effective dose was estimated to be 1.1 mSv, which was much lower than the mean effective dose in the Chernobyl accident (31 mSv in evacuees).

This member of the emergency monitoring team measured radiation levels just after the release of radionuclides from the FDNPP without wearing a protective mask by his own choice. These exposure data provide a useful reference for residents of the highly contaminated area of Fukushima.