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ARTICLE

Re-establishment of medical and healthcare systems for nuclear emergency workers based on the lessons learned from the 2011 Fukushima nuclear accident

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Abstract – In response to the Fukushima nuclear accident in 2011, the Ministry of Health, Labour and Welfare (MHLW) temporarily increased emergency dose limits from 100 to 250 mSv from March 14 to December 16, 2011, but there were many problems in medical and health care systems. Based on the lessons learned, in 2015, the MHLW deliberated for radiation protection and medical and health care systems to prepare for future nuclear emergencies. The paper aims to describe and share the experience gained in the process of setting medical and healthcare systems. The paper outlines the issues of: (a) on-site medical and health care systems; (b) health care during emergency work and; (c) long-term health care. For the deliberation, the MHLW had to find the way to keep a balance between the protection of the emergency workers and the prompt implementation of crisis response. The MHLW built a consensus among stakeholders by providing lifetime healthcare systems as compensation for the radiation health risks and by enhancing preparedness to eliminate confusion and disorder and improve the level of protection against health risks. The experience gained shows that acceptance of the health risks due to radiation exposure needs not only a scientific basis, but also social acceptance.

Keywords: health effect / safety standard / workplace

1 Introduction

In response to the accident of the Fukushima Daiichi atomic power plant of Tokyo Electric Company (TEPCO) accompanied by the Great East Japan Earthquake on March 11, 2011, the Ministry of Health, Labour and Welfare (MHLW) issued an exemption ordinance to temporarily increase emergency dose limits for emergency workers from 100 to 250 mSv from March 14 to December 16, 2011 (Yasui, 2015). Seven months after the outbreak of the accident, in October 2011, the MHLW established the Ministerial Guidelines (Ministry of Health, Labour and Welfare, 2011) to construct a database of dose records of all emergency workers over their lifetime and to conduct lifetime health care for emergency workers, including cancer screenings, in accordance with the exposed dose (Yasui, 2014). The MHLW and TEPCO experienced the following problems in the early stage of the accident concerning medical and health care of emergency workers;

- it took two months to establish on-site medical care systems, including the 24-hour presence of physicians and medical staff;
- emergency workers had their medical examination items changed several times, and the implementation rate was low until seven months after the occurrence of the accident;
- medium- to long-term dose control for ex-emergency workers exposed beyond the normal dose limits went undecided (Yasui, 2014, 2017).

For preventing the recurrence of similar problems and based on these lessons learned, in December 2015, the MHLW deliberated setting emergency radiation protection standards and medical and health care systems to prepare for future nuclear emergencies (Ministry of Health, Labour and Welfare, 2015a, 2015b).

The MHLW organized an expert meeting, which brought together eight experts from relevant fields, including radiation protection, epidemiology, nuclear medicine and occupational health. Also, the MHLW conducted interviews with nuclear operators and the federation of trade unions of electric power

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companies as well as experts in medical care in nuclear emergencies. The meeting convened and opened five sessions to the public that started in December 2014 to facilitate consensus building among the wide range of stakeholders. The meeting was broadcasted through an internet television network by a NGO. The report of the meeting was provided to the MHLW in May 2015 (Ministry of Health, Labour and Welfare, 2015a).

Based on the recommendations of the report, the MHLW drafted the amendment of the ordinance and the Ministerial guidelines. For building a consensus among the wide range of stakeholders, the MHLW collected opinions from the general public through a public comment scheme (Ministry of Health, Labour and Welfare, 2015c). Then, the MHLW consulted with and got an endorsement from the Labour Policy Council, comprised of the representatives of trade unions and employers' organizations, and from the Radiation Council, which consists of experts on radiation protection and nuclear medicine. Finally, the MHLW publicized its conclusions responding to the public comments on the government website. Following this lengthy process, the MHLW promulgated the amendment of the ordinance in August 2015 and enacted it in April 2016 (Ministry of Health, Labour and Welfare, 2015b).

The paper aims to:

- describe the process of decision-making and social consensus building on setting radiation protection and medical and health care systems for emergency workers;
- share lessons learned for scholars, experts, nuclear operators, and government officials who are responsible for medical and health care of nuclear workers;
- provide guidance for similar kinds of decision making.

The current article focuses on the issues of establishing medical and health care systems for emergency workers and social consensus building, whereas the previous paper focused on setting and application of emergency dose limits (Yasui, 2019). The paper first outlines the scientific background of the standards of:

- on-site medical and health care systems;
- health care during emergency work;
- long-term health care of emergency workers.

A discussion is provided before the conclusions about major issues on consensus building among stakeholders.

2 Methodology

The MHLW summarized and issued the press release of the meeting report in May 2015 (Ministry of Health, Labour and Welfare, 2015a). The factual information described in this article is based on the above-mentioned report and the official meeting transcripts (Labour Policy Council, 2015a, 2015b) and official transcripts of the national councils, unless other references are specified. The observations were also enriched by the author's personal communication with the meeting members and the representatives of relevant stakeholders, as an MHLW officer taking charge of drafting the amendment of the ordinance.

3 Ammended medical/health care systems

3.1 On-site medical and health care systems

In the Labour Policy Council, the trade unions repeatedly requested an establishment of on-site emergency medical care systems (Labour Policy Council, 2015a), based on the experience in the Fukushima accident (Yasui, 2014). The emergency radiation medical care systems designated by the Nuclear Safety Commission in 2008 mainly focused on work-related injury or death accompanying radioactive contamination during normal operation of nuclear plants. The plan did not include continuous on-site medical care systems during severe accidents such as core meltdown (Nuclear Safety Commission, 2008). The role of nuclear facilities is limited to making emergency calls to pre-designated medical institutions for transportation of patients (Tanigawa, 2009).

Immediate medical treatments of occupational accidents have a significant correlation with improving the rate of survival. However, if the evacuation zone is set within 20 km around the affected plant, it takes a few hours to transport the patients to the nearest medical institutions. Medical institutions in the area are to be closed, and local ambulances are not to be allowed to enter the zone. Actually, in the case of the Fukushima accident, it took one to two hours to transport the patients from the affected plant to the nearest medical institution and three hours to advanced medical institutions (Yasui, 2014). Furthermore, emergency work carries a high risk of work-related injury or heat illnesses because emergency workers wear full-face respiratory masks and HAZMAT coveralls. In the first month of the Fukushima accident, the affected plant treated 25 injuries and sick workers and 31 workers in poor physical condition. Forty patients with heat illness were observed from May to September in 2011 (Yasui, 2014).

Immediately after the accident, however, TEPCO was unable to maintain medical staff on-site. After the MHLW had facilitated to dispatching a medical team to the affected plant, TEPCO succeeded in establishing a system of 24-hour on-site physicians. Currently, the medical network, facilitated by Hiroshima University, has coordinated dispatching physicians and medical staff to the affected plant (Yasui, 2014).

3.1.1 On-site medical care systems

Based on the experienced gained in the accident, the basic disaster management plan, based on Basic Act on Disaster Control Measures was revised in January 2014 to require nuclear operators to maintain close relationships with the related government agencies in dispatching and introducing medical staff using a network of medical doctors familiar with emergency medical treatment (p. 236 in [Cabinet Office, Japan, 2017]). To make the plan work, a new medical network needs to be established to respond to future nuclear accidents.

For establishing a new system for dispatching medical teams to the nuclear facilities in case of an accident, the MHLW interviewed and consulted with the experts of emergency medical treatment and the officers of nuclear

operators (Ministry of Health, Labour and Welfare, 2015d). The major issues deliberated were as follows.

3.1.1.1 Facilities

Nuclear operators should designate an area where a makeshift emergency medical room is to be installed after an accident and stock medical supplies and devices to be brought in. The area should be placed in the building located at a sufficient distance from nuclear reactors and equipped with air filtration systems to prevent the inflow of radioactive substances, decontamination chambers provided with a hot shower and equipment for collecting contaminated materials and excrement.

3.1.1.2 Recruitment/training of medical staff

The facilitator of the network should recruit, train and register medical personnel, including physicians, nurses, radiology technologists, public health nurses, and personnel taking charge of radiation protection and logistics, who are assumed to be dispatched to nuclear facilities in the case of nuclear emergencies. The facilitator should directly request the registered personnel to standby or to travel to the site according to the request from nuclear operators. The nuclear operators should be responsible for compensation and insurance for their deployment in the emergency dispatch, including all necessary expenses.

3.1.1.3 Coordination with relevant agencies

The facilitator should convene liaison conferences with medical institutions, fire fighters and local authorities and conduct emergency drills focusing on transportation from the nuclear facilities to the local medical institutions periodically.

3.1.2 Formation of on-site medical teams

The meeting recommended that the composition of medical teams should be changed depending on the phase of emergency situations because it is difficult for a physician to have expertise in all subjects needed. In the chaotic situation in the early stage of an accident, the medical teams need to implement decontamination, triage (the process of determining the priority of patients' treatments based on the severity of their condition), first-aid treatment and selection of medical institutions to transport patients to in response to acute radiation symptoms and occupational injuries accompanying radioactive contamination. On the other hand, after the situation has settled down to some extent, the medical teams need to provide occupational health support, including prevention of accumulating fatigue by providing adequate food and rest and mental health care.

Furthermore, the meeting recommended that training of medical staff should include the knowledge of crisis management and emergency response plans, such as the structure of the nuclear facilities and emergency management systems of the plant. Medical care systems do not work effectively if the dispatched medical staff does not understand the emergency response tasks.

In addition, the safety of medical staff dispatched to the affected plant is also an important issue. In the Labour Policy Council, the representatives of the trade unions demanded compensation for the expected damage to the medical staff (Labour Policy Council, 2015a, 2015b). In response, the MHLW decided to require nuclear operators to provide to medical teams the necessary compensation and insurance, including worker's accident insurance.

3.2 Health care during emergency work

Prior the Fukushima accident, Ordinance on Prevention of Ionizing Radiation Hazard did not prescribe the items of medical checks for emergency workers. Therefore, during the emergency work at the affected plant, the MHLW had to order TEPCO, based on Paragraph 4, Article 66 of Industrial Safety and Health Act, to conduct a special medical examination of emergency workers. The MHLW modified the order several times to change the examination items and subjects of the medical examination in accordance with the progress of the accident.

For preventing the recurrence of the similar problems, the MHLW, based on the recommendation from the meeting, amended the ordinance and obligated nuclear operators to conduct medical examinations of emergency workers once a month and when they leave the emergency work. The items of examinations included:

- medical interviews to check subjective symptoms and objective symptoms;
- white blood cell count and differential count;
- red blood cell count and hemoglobin content or hematocrit value;
- thyroid-stimulating hormone (TSH), free T3 and free T4;
- lenses of eyes;
- skin.

The items of monthly medical examination during emergency work can be omitted for the workers who are exposed no more than 5 mSv, at the discretion of a physician, except inquiries into subjective and objective symptoms. However, all items shall be examined when the workers leave the emergency work. It should be noted that if the radiation exposure dose is controlled within the range of the emergency dose limit, it is unlikely to cause acute radiation syndrome. The examination is rather important for the baseline information for long-term health care. The possible health risks in case of long engagement in emergency work include lack of sleep, reduced appetite, accumulated fatigue, and heat illness. For those risks, subjective and objective symptoms must be investigated once a month.

Furthermore, the amended ordinance obligates nuclear operators to conduct necessary follow-ups on the workers who have abnormal findings, as follows:

- collect medical advice from a physician for necessary adjustment for his/her working conditions;
- describe medical advice on examination records;
- for any worker who was diagnosed as impaired or could possibly be damaged due to radiation exposure, take necessary steps to protect his/her health, such as transferring the worker to another location or task, reducing the hours of radiation work, or changing the work procedure.

Table 1. Items and frequencies of cancer screenings and noncancerous diseases examinations.

Type of examination	Examination items	Frequencies
Gastric cancer screening	a. Gastric fluoroscopy examination or gastric endoscopy examination	a. Once a year
	b. *Helicobacter pylori* antibody test	b. Once for each person
Lung cancer screening	a. Lung X-ray examination	a. Once a year
	b. Sputum cell examination for smokers	b. Once a year
	c. Chest CT examination upon request from physician	c. Once a year for smokers, once every 3 years for non-smokers
Colon cancer screening	a. Fecal occult blood test	a. Once a year
	b. Colonoscopy if a medical doctor judges it necessary from the result of (a) and radiation exposure dose, etc.	b. Approximately once every 10 years
Thyroid examination/ cancer screening	a. Neck ultrasonography b. Measurement of thyroid-stimulating hormone (TSH), free triiodothyronine (free T3) and free thyroxine (free T4) from blood samples in the case that a medical doctor judges them necessary from the result of (a) or radiation exposure dose, etc.	a. Once every 3 to 5 years
Other examinations	a. Hepatitis testing (HBs antigens and HCV antibodies)	a. Once for each person
	b. Renal function tests (urea nitrogen, creatinine, uric acid), blood serum chemistry examination (Na, K, Cl, Ca, P)	b. Once a year

If workers are exposed more than the emergency dose limits (250 mSv), the following examinations should be immediately conducted: (a) chromosomal analysis; (b) white blood cell count and differential count; (c) red blood cell count; and (d) hemoglobin content or hematocrit value. Item (a) should be conducted once immediately after the radiation exposure, while items (b) to (d) should be performed once every 6 to 12 hours starting right after the radiation exposure for the next several days. In cases of internal exposure of alpha-nucleus, radiotoxicological analysis of urine and faeces samples should be implemented as a standard procedure. These tests are necessary to evaluate the degree of acute radiation syndrome and assumed dose exposed, based on experience from previous radiation medicine practices.

3.3 Long-term health care of emergency workers

In the Labour Policy Council, the representatives of the trade unions demanded, as the most critical condition, lifetime healthcare. The most likely health risk is assumed to be stochastic effects, such as cancers, because the emergency dose limits were set as 250 mSv, which are not expected to cause acute radiation syndrome.

The meeting, based on the most recent studies, reviewed and made necessary changes in the examination items of long-term health care systems designated by Ministerial guidelines established in October 2011, seven months after the accident (Ministry of Health, Labour and Welfare, 2011). The guidelines required employers, in addition to the compulsory medical examination for nuclear workers once every six months, to examine the lenses of the eyes with a slit lamp microscope for workers whose effective dose exceeded 50 mSv. The items of compulsory medical examinations includes:

- medical interviews to check subjective symptoms and objective symptoms;
- white blood cell count and differential count;
- red blood cell count and hemoglobin content or hematocrit value;
- lenses of eyes;
- skin.

3.3.1 Cancer screening tests

The original guidelines required to conduct cancer screening tests for workers whose dose exceeded 100 mSv once a year. The amended guidelines strengthened cancer-screening tests. For workers whose dose exceeded 100 mSv, the amended guidelines required nuclear operators providing the following items of cancer screening (Ministry of Health, Labour and Welfare, 2015e):

- gastric cancer screening;
- lung cancer screening;
- colorectal cancer screening;
- thyroid cancer screening.

Detailed examination items and frequencies are shown in Table 1. The meeting recommended adding chest CT and colonoscopy to screen for lung and colorectal cancers, respectively, because the tests are expected to be beneficial to the high-risk groups who are exposed more than 100 mSv.

The meeting also recommended providing neck ultrasound tests once every three to five years for screening thyroid cancers. Whereas the original guidelines required conduct screening tests for gastric, lung and colorectal cancers, which are confirmed to be effective in the general public (Ministry of Health, Labour and Welfare, 2008). Furthermore, the examination of white blood cell count and differential count in the compulsory medical examination is also useful for screening of leukemia.

Furthermore, the meeting recommended not only cancer screening tests but also preventative medicines. The meeting suggested giving antibody tests and eradication of *Helicobacter pylori* to prevent gastric cancers and hepatitis virus screening (HBs antigen and HCV antibody) for avoiding liver cancers. For the prevention of lung cancer, the meeting recommended providing health guidance, including an antismoking education, because joint effects have been observed between radiation exposure and smoking (Richardson & Wing, 2011).

3.3.2 Noncancerous diseases examinations

For noncancerous diseases, the amended guidelines required nuclear operators conducting the following examination item for workers whose dose exceeded 100 mSv:

- thyroid gland screening;
- infectious disease tests;
- chronic kidney disease (Tab. 1).

Regarding to the thyroid disorders, the meeting recommended that the examination of TSH, free T3 and free T4 should be limited to the workers whose equivalent dose to the thyroid is 3 Gy or more for screening thyroid disorders. Whereas the original guidelines required the examination of TSH, free T3 and Free T4 for all emergency workers whose effective dose exceeded 100 mSv because equivalent dose to the thyroid of I-131 was the main contributor to a high-level effective dose at the Fukushima accident.

For the other noncancerous diseases, the meeting recommended providing tests to screen for diseases whose health effects have been observed to be caused by radiation exposure in epidemiological studies. The amended guidelines added renal function tests because some studies suggest, but do not prove, a statistically significant association between chronic kidney diseases and radiation dose at doses under 3 Gy (Adams *et al.*, 2012; Sera *et al.*, 2013).

3.3.3 Mental health screening

The amended guidelines required to conduct stress check once a year, as prescribed in the amendment of Industrial Safety and Health Act in 2015. Although the original guidelines required conducting health guidance in consideration of mental health, the meeting, as a more effective measure, recommended utilizing brief job stress questionnaires because physiological diseases are a concern because emergency workers are assumed to be exposed to significant mental stresses. Based on the recommendation, the amended guidelines require employers to use the format of the checks recommended by the MHLW and demand that primary contractors support their contractors for implementation of the checks (Ministry of Health, Labour and Welfare, 2016).

4 Discussion

In the response to the Fukushima accident, the MHLW faced difficulties in the planning and implementing of medical and health care for the emergency workers of the accident and had to change the examination items and subjects of the special medical examinations in several times through trial and error (Yasui, 2014). The documents of the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), or national legislations of the member countries of the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA) prescribed no detailed information about medical and health care during emergency work and lifetime health care, except treatments of acute radiation syndrome.

The experienced gained in the accident revealed that the most critical issue to build a consensus among stakeholders was how to balance between the protection of the emergency workers and the prompt implementation of a crisis response to prevent the expansion of the accident. The representatives of the trade unions of the nuclear workers repeatedly requested adequate lifetime health care in compensation for emergency work under high-dose-rate radiation. The unions also asked for the establishment of adequate on-site medical and health care systems. Conversely, the NRA and nuclear operators need a prompt emergency response to prevent catastrophic events in nuclear emergencies. The involvement of the MHLW was necessary to facilitate a consensus between nuclear operators and trade unions because the MHLW is required to consult with and get an endorsement from the Labour Policy Council, comprising the representatives of trade unions and employers' organizations.

During the deliberation in the Labour Policy Council, the representative of the federation of the trade unions, which consists of nuclear power plant workers, admitted: "If a nuclear accident occurs, engagement in the emergency response is a responsibility of the workers of nuclear power plants." However, he argued: "We definitely cannot accept the reckless argument that emergency dose limits should simply be raised without any consideration to minimize the risk, or just harmonize our standards to international standards (Labour Policy Council, 2015a, 2015b)." The representative insisted the decision to increase the limits should be a comprehensive package that includes preparedness and implementation of adequate dose control and health care as well as the collection of workers' consent to be assigned as emergency workers and prohibition of disadvantageous changes of working conditions or dismissal by refusing to dispatch them to emergency operations. Thus, the trade unions could not agree with the increase of the limits unless the government ensures special health care systems for emergency workers as compensation to engage in high-risk tasks protecting people's lives and property.

In response to the comments from trade unions, the MHLW tried to build a consensus among stakeholders by providing lifetime health care systems as compensation for the health risks from radiation exposure during emergency work. Furthermore, the MHLW aimed to minimize the health risk of radiation exposure by strengthening lifetime health care systems for emergency workers. The MHLW also intended, by enhancing preparedness, to eliminate confusion and disorder in

the case of a nuclear emergency and improve the level of protection against health risks in actual conditions.

5 Conclusion

The experience gained in Japan shows that acceptance of the health risks of radiation exposure needs not only the scientific basis, but also a broad consensus with stakeholders. The Japanese case can provide useful guidance for establishing medical and health care systems for emergency workers. Thus, further case studies to share the experiences in each country are needed.

Conflict of interest

The author does not have any conflict of interest about this paper.

Disclaimer

The findings and conclusions in this article are those of the author and do not necessarily represent the views of the MHLW.

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