

Fukushima Daiichi Nuclear Accident and Radiation Exposure

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I would like to talk about the topic that physicians should have correct knowledge about radiation at the accident of the Fukushima Daiichi Nuclear Power Plant (NPP) and the effect of radiation on health.

Introduction

We consider that the Great East Japan Earthquake was a combined disaster involving earthquake and tsunami as well as the release of radioactive materials into the environment (**Fig. 1**).

Something I would like you to notice here is that among various disasters, a radiation nuclear disaster cannot be seen; it cannot be felt; in fact it cannot be detected without special devices. Because of that, the fact that you cannot understand what is happening even on the disaster site is a peculiarity of this kind of disaster. This is an important point.

Unlike Clinical Medicine Based on Experiences, Those With Accidental Radiation Exposure Do Not Accumulate, Since It Rarely Occurs

Why is there a need for special knowledge about radiation exposure? Clinical medicine is a field based on experience. But, radiation exposure accidents extremely rarely occur, and we don't know if we are being exposed. For example, we might feel that radiation is being emitted if we

could feel a prick of pain when a radiological technologist says, “Take a breath and hold it” for the chest X-rays examination at the hospital. But, since there is no pain, we don't know when we are being exposed.

Another thing we often hear is that it takes a time until symptoms/signs appear. One example is carcinogenesis. It could take, at least 2 years or longer after radiation exposure depending on type of cancer. With the overlap of these kinds of problems, it is no wonder that even medical staff members become quite uneasy about radiation and its exposure.

Unlike Viruses or Chemicals, Techniques Such as Sterilization and Neutralization Do Not Change Radioactive Materials

There are so many technical terms regarding radiation such as Becquerel (Bq), Sievert (Sv), Gray (Gy), effective dose, and others, that even health personnel get tired of it. However, compared to viruses/bacterias and chemicals, the measurement techniques for radiation have been extremely developed. For instance, the rapid detection kits for influenza antigen sometimes give false positive or negative results. For radiation, on the other hand, the detection capabilities are quite high and most of γ -rays can be measured in real time.

Nonetheless, it is not all good. Even if you

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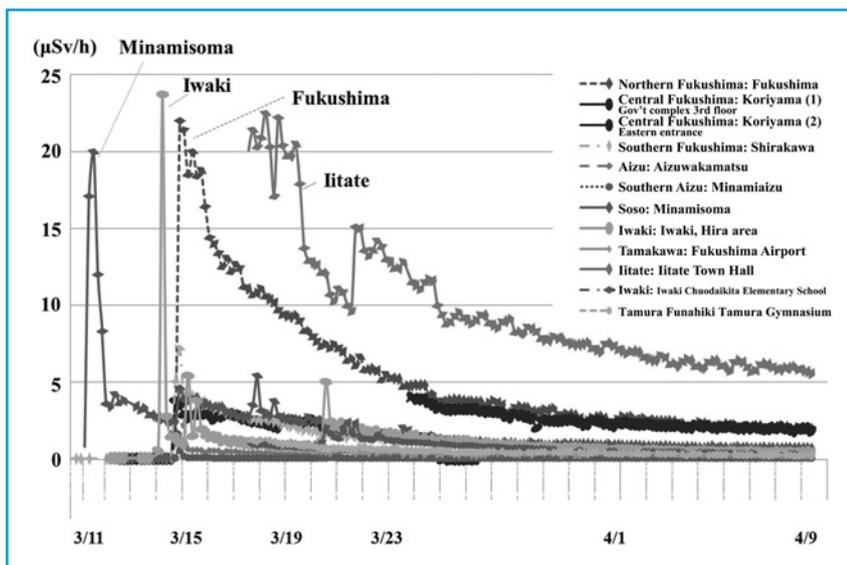


Fig. 4 Daily ambient dose rates in Fukushima

Tokyo. This higher dose rate of radiation is caused by that from outer space.

Something I would definitely like you to know is the dose rate of radiation exposure on an airplane—from Tokyo to San Francisco; of course it would be almost the same from Tokyo to Europe. Since the exposure rate is about $7 \mu\text{Sv}$ per hour, if you fly round-trip for 20 hours between Tokyo and San Francisco, that would be $140 \mu\text{Sv}$ of exposure. If you did that 10 times it would be more than 1 mSv of exposure. Remember, this is radiation from nature. It is even higher inside the International Space Station— $24 \mu\text{Sv/h}$ —and $67 \mu\text{Sv/h}$ of radiation outside the International Space Station. This is the level of radiation in nature.

Can You Correctly Explain the Ambient Dose Rate to Residents and Patients?

Figure 4 shows the dose rates in Fukushima Prefecture after the accident. When, for example, these data were released, it was reported on the news that residents of Fukushima Prefecture were exposed to a higher level of radiation than usual. However, if physicians do not know the health effects of radiation that residents received, it becomes a big problem because they cannot give a correct explanation to them.

Further, the dose rate in Fukushima City,

which is almost 60 km away from the NPP whereas Tokyo is about 230 km away, was higher than usual around March 15. I think that how to explain the present dose rate in Tokyo to residents is important.

Radiation Cannot Be Correctly Feared

There were many misunderstandings about this accident. Residents and patients even in Hokkaido and Osaka were very anxious on March 15 notwithstanding the fact that there was hardly any effect on the dose rates of radiation in those areas.

That is, the present situation is such that people cannot correctly fear radiation to such an extent that they develop the idea that they do not want to take medical tests involving radiation exposure, such as chest X-rays and CT scans at hospital.

Looking at the flow of the radiation plume (the condition of gaseous radioactive material flowing together with air like a cloud) for March 15 released by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, we see that it flowed in two directions from the Fukushima Daiichi NPP. One flowed to the northern Kanto region and the other went out to the ocean and flowed in through Chiba and Ibaraki Prefectures.

Table 1 Case I

- A man was injured and contaminated at the hydrogen explosion on March 14 2011
- He was decontaminated at a local hospital and then transferred to NIRS by a Japan Self-Defense Forces (JSDF) helicopter
- The level of surface contamination was under 100 kcpm, whereas almost whole body was contaminated
- The wound showed 2,500cpm on the right thigh
- Contamination of the abdominal part was the most prominent (31 kcpm)
- I-131, Te-132, and I-132 were detected from the right nasal swab

Contamination and Decontamination of Fukushima Residents

A major problem we faced in Fukushima was the decontamination of residents. Before the accident, Fukushima Prefecture had their cut-off criterion for screening of the public of 40 Bq/cm² for beta/gamma contamination. The level of this contamination corresponds to 10,000 to 130,000 counts per minute (cpm) when measured by a Geiger-Müller survey meter as ¹³¹I, depending on the type of detector. On March 12, 2011, however, the levels of body surface contamination of some evacuees in shelters exceeded the criterion. At a level higher than this, decontamination would be performed; at a lower level, decontamination would not be performed. When contamination is found on residents, they should change their clothing and/or remove the contamination with wet towels as soon as possible. But tap water was shut down in most shelters so decontamination was not possible. Only drinking water was available. The outside temperature was low, and heating was insufficient, so many residents could not stay in the shelters for long periods without warmer clothes and overcoats. Thus, the pre-accident criteria had to be revised. Fukushima Prefecture changed the screening level required for decontamination from 13,000 to 100,000 cpm, with decontamination by wiping being performed for over 13,000 cpm.

The concern regarding the revision of the screening level is whether or not this screening level fits the intervention exemption from the viewpoint of radiation protection. According to the Manual for First Responders to a Radio-

logical Emergency of the International Atomic Energy Agency, a dose rate of 1 μ Sv/h at a distance of 10 cm is a standard for decontamination in the case of surface contamination of the body for the general public (IAEA 2006). We calculated the dose rate at a distance of 10 cm from a surface contaminated area with 100,000 cpm of ¹³¹I, assuming that the surface of the head/face is approximately 2,300 cm² and is uniformly contaminated. The contamination with 100,000 cpm was almost 1 μ Sv/h at 10 cm. Thus, a screening level of 100,000 cpm could be applied for decontamination of the surface of the human body.

Patients Accepted at the National Institute of Radiological Sciences

The National Institute of Radiological Sciences (NIRS) accepted 4 workers who had been involved in emergency tasks at the Fukushima NPP. In **Table 1**, I would like to introduce a worker accepted by the NIRS. This patient was injured by the hydrogen explosion and transported to the NIRS. There was contamination over the entire body, as high as about 31,000 cpm. Most of the contamination was iodine-based.

If a patient is physically injured, the injury must be treated first regardless contamination or not. The NIRS has many staff members who can measure radiation and experts who can manage radiation contamination; so these kinds of patients can be accepted smoothly without any problems.

On March 24, workers being involved in a cable work plunged their feet into contaminated water and it was reported on the news that these workers were diagnosed with possible β ray burns on their skin before they were even transported to the NIRS. However, since we knew that cases with β -ray burns are very few, we wondered whether β burns could occur in the Fukushima accident. They certainly had a lot of contamination on their feet from contaminated water. However, we found a number of problems. One thing that became clear was that even though workers were given personal dosimeters set to alarm when a certain dose was reached, they ignored or did not realize the alarming sound and continued working, suggesting that they were working under quite chaotic circumstances.

On the other hand, looking at the level of contamination on their feet, there was contami-

nation exceeding $10 \mu\text{Sv}$ per hour at 10 cm. However, if you have enough knowledge, you can judge right away whether it is dangerous or not for the medical staff. We accepted these patients, but no physicians or nurses—no one—hesitated to approach them. We had judged straight away that there was no problem. In other words, correct knowledge is extremely important.

Skin doses of these feet were about 500 mSv in these workers. It is thought that erythema appears with about 3,000 mSv. Compared to that, there is no way erythema was going to appear. However, we had a very unfortunate experience, since this incident became worldwide news.

We are cognizant that it would be unacceptable to not deal with these patients if they had had serious injuries or a heart attack or hemorrhage. Thus, we think that it is essential for physicians to have correct knowledge and to correctly fear radiation.

Guidelines for Medical Education Core Curriculum

Lastly, I would like to talk about the core curriculum in the education of medical students. In March 2001, the Model Core Curriculum for Medical Education—Guideline for Medical Education was published by the MEXT of Japan (MEXT 2011). The guideline presents what should be taught in medical schools and is a reference for medical school curricula. At the time when students move from basic medical courses into clinical education, they have to pass a standardized test based on the guideline that is conducted voluntarily in medical schools. Those guidelines were revised on March 31, 2011, just after the earthquake. The rationale for this revision was that physicians need

- to know that humans are constantly being exposed to natural radiation in nature;
- to understand the impact of the use of ionizing radiation for medical purposes; and
- to understand that radioactive materials are ubiquitous, thus increasing chances for radiation exposure.

In this latest revision, the guidelines recommended that the following be included in medical school curricula:

1. Radiation, radioactivity, their characteristics, radiation measurement, and units of measurement

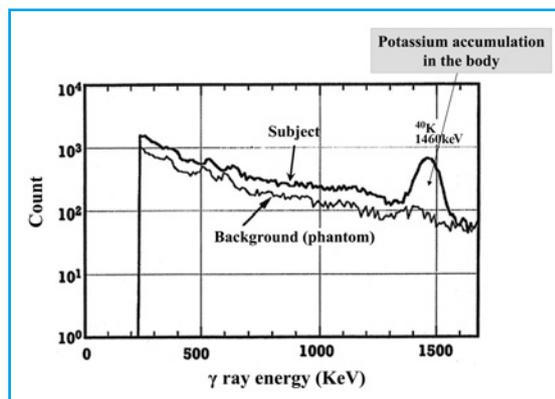


Fig. 5 No radioactive material has been incorporated into the body

2. Effects of radiation on genes
3. Interactions of radiation with cells
4. Mechanisms for cell death from radiation
5. Radiation sensitivity in various tissues
6. Local and whole-body injuries
7. Effects of radiation on humans, including the fetus (acute and late effects)

We physicians use radiation on a daily basis, and of course accidental exposure to radiation is different from medical exposure. However, from the viewpoint of the radiation effects on the body, they are exactly the same. Accordingly, I think it is an extremely important point for physicians to have correct knowledge about radiation and to use radiation correctly.

Additionally, the curriculum also includes the ability to explain injuries caused by radiation, and the ability to accurately describe side effects of diagnosis and treatment as well as the ability to explain radiation protection for medical professions and patients. I think these are matters that we physicians are expected to know.

Whole Body Counter

What should be performed when radioactive material has been incorporated into the body? There is a machine that detects radioactive material in the body—called a whole body counter (WBC). However, basically it can detect only γ rays, suggesting that WBC is used for internal contamination with γ -emitters. When there is no radioactive materials incorporated into the body accidentally or medically, a spectrum for potassium 40 (^{40}K , naturally occurring radionuclide),

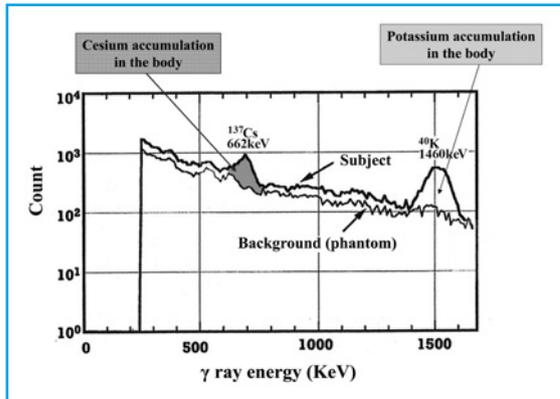


Fig. 6 Radioactive material has been incorporated into the body

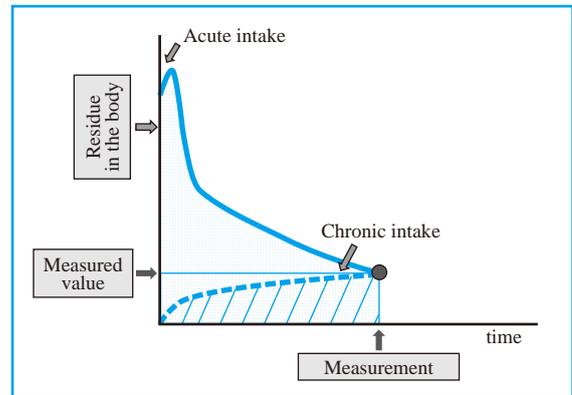


Fig. 7 Mechanism for dose calculation from WBC

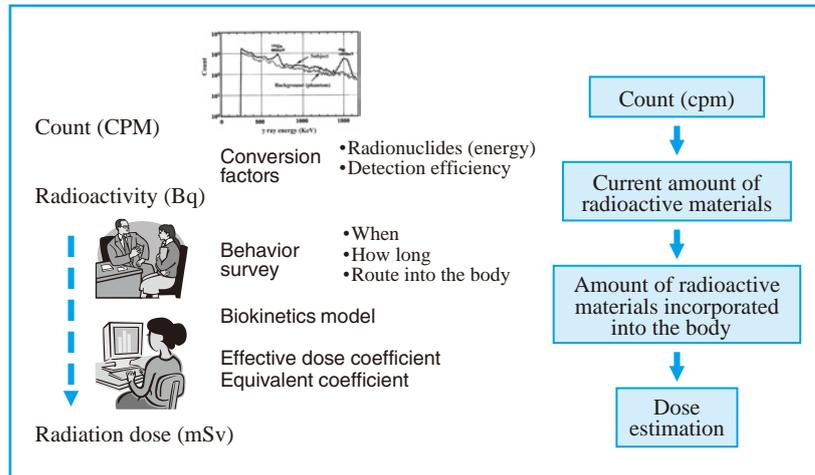


Fig. 8 From measurement to internal exposure dose

which everyone has, will show up as marked by the arrow in Fig. 5. This means accumulation of ⁴⁰K in the body.

If the body has been internally contaminated with cesium Cs, Cs accumulation in the body will show up as shown by the arrow in Fig. 6.

Whole Body Count Is Not Omnipotent

The problem is that what WBC can measure is how much radioactive material is accumulated in the body when the measurement has been taken; the separate calculation is required for dose assessment as Sv. The dose will be changed even if the amount of accumulated radionuclide is the same but if how or when the radionuclide

has been incorporated is different. For example, the exposure dose is completely different in the case where a large amount of radioactive material entered the body all at once on March 12, 2011 and then gradually fell to the measured value versus the case in which radioactive material slowly entered the body from food and the environment contamination up to the same measured value. That is, if the radionuclide was inhaled only on March 12 and then the level was decreased to the measured value, the amount of radionuclide that would have gone through the body would be the integrated value shown by the bold line (Fig. 7).

On the other hand, if one eats and inhales radioactive material every day, it would be the

integrated value shown by the dotted line. The radioactive material that had entered the body would only be the amount shown by the diagonal lines. Thus, dose assessment of internal exposure depends on the scenario used. Therefore, the radiation dose could be 10 times or even 20 times different depending on the scenario. Understanding WBC correctly will lead to a scientifically right dose assessment. If you think that the internal radiation dose will all be shown by measuring with WBC—like having someone step on a scale and showing his weight immediately—it is wrong. A whole body counter is not that kind of machine.

I would like you to have this kind of knowl-

edge as well. I think that a big role given to our medical professions is to be able, when consulted, to carefully explain correct knowledge and scientifically right dose assessment in clear and simple words.

Conclusion

What a WBC tells us is only the current amount of radioactive material in the body (**Fig. 8**). From these results, we calculate the internal exposure dose based on the assumption or scenario. If you can see that there are a number of steps and assumptions to go through until the dose calculation can be made, then I am very much pleased.