Thyroid Monitoring for Residents of Disaster-affected and Neighboring Areas

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The devastating environmental contamination caused by the nuclear disaster at the Fukushima Daiichi Nuclear Power Station of The Tokyo Electric Power Company is exposing the residents of the disaster-affected areas to health risks attributable to radiation exposure, and fear of the development of 131I-induced thyroid cancer, which is a stochastic effect of radiation and is particularly high. As part of the response to nuclear disasters by the government of the municipality where the nuclear power station is located and in operation and by the governments of neighboring municipalities, it is necessary to conduct thyroid monitoring for the purpose of alleviating the fears of residents of the disaster-affected areas as well as those living in the contaminated, even if only slightly, neighboring areas (local residents). This health monitoring needs to be implemented without delay in the case of a disaster along with dissemination of a portable type thyroid monitoring system available at evacuation centers, etc. for assessing thyroid exposure doses. The establishment of a system for developing personnel ready to perform monitoring is also essential.

Assessing thyroid exposure doses is indispensable as a means of assuring local residents not only of safety but also of security from the risks of radiation.

To date, contamination has not been detected in people, except for residents contaminated by a large amount of iodine, by employing the mobile type of thyroid monitoring system. However, when local residents seeking security desire thyroid monitoring, it is preferable that a portable type simplified thyroid monitoring system be used as a means of ensuring security against radiation.

Key words: 131I, Thyroid monitoring, Fukushima nuclear accident, Internal exposure assessment, portable simplified system

1. Introduction

The catastrophic environmental contamination caused by the radioactive materials released at the time of the nuclear disaster at the Fukushima Daiichi Nuclear Power Station of The Tokyo Electric Power Company, which occurred concomitantly with the Great East Japan Earthquake and the resultant tsunami that struck East Japan on March 11, 2011, is multiplying the health risks of the residents of disaster-affected areas as well as those of neighboring areas (local residents), particularly their fear of developing thyroid cancer, which is a stochastic effect of radiation. This fear of radiation exposure has already given rise to a serious social issue. Some people have developed a syndrome called Post Traumatic Stress Disorder (PTSD) out of fear of radiation exposure. An assessment of thyroid exposure induced by radioactive iodine 131 (131I) is indispensable for internal exposure assessment and exposure control of local residents.

After the disaster, the Disaster Provision Main Office of Fukushima Prefecture, the Disaster Medical Assistance Team (DMAT), and related cooperative institutions jointly performed emergency exposure screening on some of local residents. We would like to express my heartfelt respect for those who bravely participated in the screening regardless of the risks of their own exposure, but we are hesitant to say that the activities com-
pletely achieved the intended purpose despite their dedicated efforts with a spirit of sacrifice. For example, only simplified thyroid monitoring using survey meters was conducted on a small number of children living in Fukushima Prefecture from the end of March to April 2011 as part of the measurement and assessment of internal exposure, which is one of the particularly important roles of screening activities.

While screening, though imperfect, was conducted, no public institutions planned organized exposure assessments, assessments and control of internal exposure above all other issues, for all victims until mid-June. Behind this issue is a discrepancy between safety and security against exposure. Besides, there is the fact that both special thyroid monitoring systems necessary for assessing thyroid internal exposure and personnel capable of performing it are scarce from a technical standpoint. Thus, it is presently impossible to perform thyroid monitoring on many local residents in a short period of time.

As of July 2011, $^{131}$I with a short half-life has already decreased, and there is little likelihood that another internal exposure will occur unless further $^{131}$I is released. In addition, iodine cannot be detected in people at present, except for those exposed to several Sv of iodine, even if high-sensitivity measuring instruments (whole body counter, etc.) are used. According to an announcement from the government, medical treatment must have been provided for residents who might have received large doses of $^{131}$I. Thus, at this point in time, thyroid monitoring using high-sensitivity measuring instruments, from the aspect of exposure control, is entirely meaningless scientifically.

Thyroid monitoring of local residents is important at present in that it is performed on those who desire thyroid monitoring for security. Probably, many residents will want to receive monitoring for their own sense of security. This means that it is necessary to perform thyroid monitoring on a large number of local residents in a short period of time. It should be noted, however, that the personnel responsible for monitoring need to explain to those who will undergo monitoring prior to the actual monitoring that it will only show that the exposure dose is below several Sv. In addition, the government of the municipality where the nuclear power station is located and in operation, and the governments of the neighboring municipalities should review their thyroid exposure control actions for local residents in anticipation of future nuclear disasters with the current state of thyroid monitoring taken into account.

These situations signify the necessity of making efforts to establish a system capable of conducting thyroid monitoring on a large number of local residents in a short period of time.

The purpose of this report is to propose a method for assessing thyroid exposure doses based on measured values and a feasible approach to developing a versatile thyroid monitoring system and personnel ready for thyroid monitoring in order to assess and control the internal exposure of local residents by radioactive iodine and thereby resolve the aforementioned issues.

2. Importance of thyroid exposure dose assessment of local residents

2.1 System for controlling the exposure of local residents

The nuclear disaster at the Fukushima Daiichi Nuclear Power Station of The Tokyo Electric Power Company triggered anxiety about health risks resulting from environmental contamination, medical care systems, etc. both in Japan and overseas. The timetable for calming this situation and resolving the nuclear disaster was announced, but there is apprehension that the disaster will take a longer time to reach a resolution. Under these circumstances, establishing a medical care system, an exposure control system in particular, for nuclear power station operators and local residents is an urgent necessity.

2.2 Necessity of forming and maintaining an exposure dose assessment system for local residents

The formation and maintenance of an exposure dose assessment system is indispensable for the establishment of an exposure control system for all local residents, which, in turn, requires two databases.

The sources of exposure were radioactive iodine $^{131}$I ($^{131}$I) soon after the nuclear disaster, and radioactive cesium $^{134}$ and $^{137}$ (Cs and Cs) after the decrease in $^{131}$I. Data on the released amount of $^{131}$I is important for assessing both internal exposure and external exposure at the initial stage, whereas data on the released amounts of $^{134}$Cs and $^{137}$Cs is required to assess external exposure after the decrease in $^{131}$I.

The first database relates to behavioral records of individuals. It is absolutely necessary to verify where each individual stayed and traveled and how many days or how long he/she stayed in each place after the disaster. Keeping track of and recording the behaviors of individuals by conducting hearings and questionnaire surveys while they retain clear memories of their behaviors is crucial. These behavioral records of individuals must then be compiled into a database.
The second database covers the air dose distribution and radiation concentration distribution in the air of contaminated areas (hereinafter called the dose distribution, etc.). Assessments of exposure doses require the dose distribution, etc. to be determined based on measured values and estimated values using data obtained by SPEEDI, etc., such as the types and amounts of radioactive materials in contaminated areas and periods of contamination. A database on the air dose distribution and the radiation concentration distribution as basic data for calculating the external and internal exposure doses of residents must be created.

By linking these two databases, a system can be built up, which makes it possible to keep track of and assess exposure doses over time. This system also enables users to trace the cause-effect relationship between individual exposure doses and the occurrence of radiation hazards over an extended period of time by accumulating not only past but also new data.

The contamination caused by the disaster spread widely from Fukushima Prefecture, which was directly damaged, to neighboring municipalities. All prefectures in which a nuclear power station is located and in operation, as well as neighboring municipalities, should, therefore, establish and maintain an exposure control system in preparation for future nuclear disasters.

2.3 Screening and triage

At the disaster site, triage is conducted to determine treatment priority for the injured. It is also necessary to perform screening intended to determine whether radiation medicine should be provided to the injured. According to a report, the following were performed in the screening inspection in the Fukushima nuclear disaster: (1) survey meters were used to measure surface contamination to determine whether decontamination was required with the counting rate or dose rate used as an index; and (2) thyroid contamination monitoring was conducted, and stable iodine was distributed as a measure against internal exposure if higher contamination than the standard level was detected.

Information conveyed from the site, however, indicates that thyroid monitoring was not always performed in actual screening. This implies that even higher exposure than the specified thyroid screening level is occasionally overlooked. On the other hand, lower exposure than the thyroid screening level is considered to represent an uncontaminated state, but this is not actually correct. Since the screening level is set for triage, lower contamination than the screening level must not be neglected. The exposure doses of all residents should be assessed even if contamination is lower than the screening level.

2.4 Fear about radiation and radiation PTSD

It is widely known that victims of earthquakes or other disasters suffer Post Traumatic Stress Disorder (PTSD), and news that many experts visited the areas damaged by the Great East Japan Earthquake to deal with personnel suffering from PTSD were broadcast. In addition, organizations involved in PTSD deliver information about psychological care through their websites, etc.

The residents of the areas contaminated by the Fukushima nuclear disaster were exposed to variable amounts of radiation. Medical treatment is given to the residents with higher contamination than the screening level, but their fears about the development of cancer in the future persist. On the other hand, those who are below the screening level and are not considered contaminated also express fears. For these residents, there is an underlying fear about cancer, which is a stochastic effect. Mothers with infants, as well as children who already understand the meaning of exposure to radiation, in particular, must live with this fear for many years to come. The possibility that they will become unstable mentally and develop PTSD (radiation PTSD) under these circumstances cannot be denied.

In assessments of radiation exposure and contamination, comparisons between the measured values of exposure doses, dose rates, contamination concentration, etc. and legal regulation values are indispensable. Objective numerical data will become necessary for dealing with fears about radiation. Obtaining objective information, or exposure doses, is expected to dispel the fears of many residents. Those in a position to use such numerical data, however, must not say that victims are safe even if their contamination is below the legal regulation levels because safety and security are not realities for these individuals due to past dubious disclosures of information about radiation contamination and radiation exposure.

There may be also residents who will not be able to eliminate their fears and will become unstable mentally, even if they have access to objective data on exposure doses. In this case, there will be no choice but to determine that they have sustained radiation PTSD. Nonetheless, assessing the exposure dose of each individual is still indispensable for mental care.

At present, there are no experts on radiation PTSD. Thus, PTSD experts and radiation experts must collaborate with one
another to establish specific care approaches for those suffering from radiation PTSD in the future.

2.5 Importance of thyroid equivalent dose assessment

The most important aspect of the internal exposure caused by a nuclear disaster is thyroid exposure by radioactive iodine. Since the Chernobyl nuclear disaster, a large number of children have developed thyroid cancer, and the Ukrainian government has kept track of the health conditions of children who were under 15 years of age at the disaster. Judging from the fact that the released amount of radioactive iodine was overwhelmingly higher than those of the other nuclides in the Fukushima nuclear disaster, the development of thyroid cancer in children living in the disaster-affected areas is a risk which absolutely must be dealt with.

Adults age 40 or older are less affected by thyroid exposure. This indicates that thyroid monitoring should be performed on residents younger than 40 years of age and internal exposure doses should be assessed based on the monitoring results for the purpose of following up the health of local residents over a long period of time as well.

Many of local residents feel anxiety about their future health in different ways; some may be affected by a stochastic effect, and even some of those who were not exposed to radiation express their uneasiness about their health. Counseling for these people about fears of radiation and radiation PTSD based on scientific grounds will become extremely important. It is important to eliminate fears about future health and keep track of the health of local residents for a long period of time through assessments of internal exposure doses.

2.6 Necessity of portable type monitoring system

Thyroid monitoring, which aims to estimate the internal exposure doses of the thyroid glands caused by radioactive iodine, is generally conducted using a special, high-sensitivity instrument, such as a whole body counter (WBC) or thyroid monitor. The purpose of using these instruments is different from that of survey monitors with low measurement accuracy employed for screening. If wide areas are affected by a disaster, like the Fukushima nuclear disaster, it is impossible to monitor local residents with these instruments in a short period of time, taking into account the number of residents to undergo measurement and the number of instruments available.

To perform thyroid monitoring on a large number of local residents in a short period of time, many of the portable type simplified monitoring systems and many measurement technologists familiarized with monitoring skills are needed. It is easy to establish a scheme for making these systems available and training technologists.

3. Portable type simplified thyroid monitoring system

A portable type simplified thyroid monitoring system consists of the same units as those making up a thyroid uptake measuring instrument for nuclear medicine. As a collimator for a detector and a support, those of the uptake measuring instrument can be used (Fig. 1a). This monitoring system can be clamped using a supporting pole for intravenous drips if it is not equipped with a support or another suitable component (Fig. 1b). In this case, no cylindrical tube made of lead for the detector is provided, but it is necessary to set a cylindrical tube made of lead on the NaI (Tl) detector. Connect the NaI (Tl) detector to a high-voltage power supply unit (HV), a multi-channel pulse height analyzer (MCA), and a PC (Fig. 1c). Although these units are independent (Fig. 1c), their performance is equal to that of the components of the thyroid uptake measuring instrument for nuclear medicine. In this configuration, the thyroid monitoring system is capable of measuring thyroid exposure with an error level equivalent to that of the uptake measuring instrument. Another type is also available, which can be directly connected to a detector with HV and a PC containing MCA and other components (Fig. 1d).

The lower detection limit of the simplified thyroid monitoring system is 600 Bq for 10-minute measurement, and the thyroid equivalent dose in this measurement is 0.17 mSv in the case of an adult or 1.45 mSv in the case of a 1-year-old child. Although the thyroid monitoring system can ensure a satisfactory level of accuracy for adults in 10-minute measurement, it may not be sufficiently capable of providing a high level of accuracy in measurement of 1-year-old children (Fig. 2, Table 1). With this thyroid monitoring system, users can select a proper measurement time for each age by making reference to Fig. 2 and Table 1.

4. Progress toward implementation of thyroid monitoring

This monitoring system is easy to carry, install, and operate, and it is probably possible to prepare a sufficient number of systems at relatively low cost.

In addition, the accuracy of these monitoring systems can be
Ito maintained by standardizing the measurement method. The most suitable candidates for personnel responsible for measurement are those qualified as radiological technologists, physicists in medicine, class I supervisors of radiation protection, or class I working environment measurement experts (radioactive substances). To make effective use of these qualified personnel, it is important to cooperate with the Japanese Society of Radiation Safety Management, the Japanese Society of Radiological Technology, the Japan Association of Radiological Technologists, the Supervisors of Radiation Protection Work Group of Japan Radioisotope Association, and other related associations to train and procure competent personnel.

Exposure-related health investigations are indispensable. It is important to hold hearings and questionnaire surveys to fully ascertain where the residents affected by disasters have stayed and how long they have stayed in these places, while they retain clear memories of their behaviors. Dose distributions in contaminated areas must also be formulated. The health of local resi-
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Residents can be kept track of for an extended period of time by creating a database on the exposure doses of residents to external radiation based on the data, making it possible to trace the doses of residents, and adding thyroid monitoring data.

Governmental organizations and the governments of local municipalities are requested to immediately establish an emergency exposure medical treatment system for victims, a medical treatment system and a security system against radiation hazards, as well as a system focusing on mental care for long-term health follow-up.

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![Fig. 2. Lower detection limits of portable type simplified thyroid monitoring system](image-url)

Table 1: Lower detection limits of portable type simplified thyroid monitoring system and thyroid equivalent doses

| Time (min) | Lower detection limit (3σ) (Bq) | Thyroid dose* (mSv) Adult | Thyroid dose* (mSv) Child 1 year |
|-----------|--------------------------------|---------------------------|----------------------------------|
| 1         | 1836                           | 0.53                      | 4.59                             |
| 5         | 812                            | 0.24                      | 2.03                             |
| 10        | 578                            | 0.17                      | 1.45                             |
| 20        | 400                            | 0.12                      | 1.00                             |
| 30        | 329                            | 0.10                      | 0.82                             |
| 40        | 292                            | 0.08                      | 0.73                             |
| 50        | 256                            | 0.07                      | 0.64                             |
| 60        | 234                            | 0.07                      | 0.58                             |

* The thyroid dose is the value when the internal residual rate of $^{131}$I is regarded as 1.

Measuring instruments: NaI (Tl) scintillation detector for γ-rays
Aloka Model ND-51 Series
Multi-channel analyzer

Measurement conditions
Distance: 20 cm from the detector.
Energy window: 364 keV ± 10%
Detection efficiency: 0.02%

Measurement environment
Air dose rate: 0.11 μSv/h
(Measuring instrument: Aloka γ-Survey Meter Model TCS-171)
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