From Japan to the World

The Internal Exposure of the Thyroid to Radioiodine from the Fukushima Nuclear Accident

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On 11th March 2011, a 9.0 magnitude earthquake and subsequent tsunami led to major problems in the stabilization of nuclear power reactors in the Fukushima Daiichi Nuclear Power Plant (F1-NPP). Following plural hydrogen explosions and fire damage to the facilities, a large amount of radioactive material was released to the environment. A primary health concern among residents and evacuees in affected areas immediately after the nuclear accident is the internal exposure of the thyroid to radioiodine, which is known to accumulate in the thyroid, giving the gland relatively high dose. This increases the risk of thyroid cancer, in particular among those exposed as young children. Since ^{131}I has the half-life of 8 days, it is necessary to perform the measurements as early as possible.

WHO reported a preliminary estimate of radiation doses to the public resulting from the F1-NPP accident.¹⁾ The thyroid equivalent dose in this report is the sum of external dose to the thyroid in the first year and the committed equivalent doses to the thyroid from intakes by ingestion and inhalation over the first year following the start of the release. In the most affected areas of Fukushima prefecture, the characteristic thyroid doses from the radionuclides containing ^{131}I were estimated to be within a dose band of 10 to 100 mSv. In one particular location, the dose assessment indicated that the characteristic thyroid dose to one-year-old infants would be within the dose band between 100 and 200 mSv, with the inhalation pathway being the main contributor to the dose (50% of the total). The dose assessment in this report is intended to be realistic, but contains a number of assumptions (e.g. radioactive cloud composition and dispersion, time spent indoors/outdoors, and consumption levels) due to the limited information. In particular, some assumptions regarding the implementation of protective measures are conservative (e.g. the assumption that people in the most affected areas outside the 20-kilometre radius continued to live there for four months after the accident), and consequently, some possible dose overestimation may have occurred.

On 23th March 2011, based on the estimated thyroid doses among one-year-old infants obtained from the System for Prediction of Environmental Emergency Dose Information (SPEEDI), an advisory panel for the Nuclear Safety Commission (NSC) of Japan recommended evaluation of the internal thyroid equivalent dose to ^{131}I for children in high-radiation dose areas (**Fig. 1**). In response to the

Fig. 1 An example of thyroid equivalent dose contour map.⁴⁾ The thyroid equivalent doses for one-year-old infants spending time outdoors during the period between 6:00 on 12th March 2011 to 0:00 on 6th April 2011 in the areas surrounding the F1-NPP reactor were estimated by SPEEDI.

recommendation, local health authorities measured the activity in the thyroid glands of 1,080 children aged from 0 to 15 years in Iwaki City, Kawamata Town and Iitate Village in Fukushima prefecture from 24th to 30th March 2011.²⁾ For this measurement a 1-in. $\times$ 1-in. NaI(Tl) scintillation survey meter was placed on the neck of examinees. The survey meters indicated that 1% of children exceeded 0.04 mSv h^{-1} . The maximum dose rate from these measurements was 0.07 mSv h^{-1} , which was considered to be equivalent to a thyroid dose of 35 mSv .³⁾ It should be noted that the starting date of internal exposure, which is necessary for estimating cumulative thyroid dose, is not entirely clear. Since this thyroid monitoring could only be regarded as a screening test, more detailed measurements were needed. Although the NSC pointed out the need for further investigation, no further examinations were carried out by the local authorities at the time.

TOKONAMI et al.⁴⁾ conducted the first extensive measurement of ^{131}I activity in the thyroid for 62 people of residents and evacuees in the middle of April 2011, placing a 3-in. $\times$ 3-in. NaI(Tl) scintillation spectrometer at the neck of examinees. The result indicated detectable ^{131}I activities in 39 of the 45 people evacuated from the coastal areas, and in 7 of the 17 residents in Namie Town in Fukushima prefecture. The median thyroid equivalent dose was estimated to be 4.2 mSv for children and 3.5 mSv for adults (**Fig. 2 (A)**), much smaller than the population-weighted average thyroid dose in the Chernobyl accident (490 mSv in evacuees).⁵⁾ The thyroid doses assessed assuming an ingestion pathway (**Fig. 2 (B)**) were similar to those found for inhalation (**Fig. 2 (A)**). Even when

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Fig. 2 Distribution of measured persons by thyroid equivalent doses from inhalation (A) and ingestion (B) of ^{131}I .⁴⁾ The equivalent doses from inhalation and ingestion were estimated using the thyroid equivalent dose coefficients by inhalation⁶⁾ and by ingestion,⁷⁾ respectively, for their comparison.

either of the two intake pathways or their combination was assumed, no dose exceeded 50 mSv. As the most conservative scenario, the thyroid dose to children was also estimated using the atmospheric ^{131}I concentration estimated from the maximum dose for adults (33 mSv). The dose estimates for 1-, 5- and 10-year-old children could exceed 50 mSv, with an uncertainty affected by the factors such as residential history,

and information on house occupancy and outdoor activities. Thus it is necessary to identify children who were outdoors during the period when the highly radioactive plume arrived, and to periodically examine them. From both radiological and risk-assessment aspects, it is important to conduct these investigations to better understand the initial exposure conditions following the Fukushima accident.

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