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Review

Risk of thyroid cancer after the Fukushima nuclear power plant accident

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ABSTRACT

The appropriateness of the initial response and countermeasures taken following the Fukushima nuclear power plant accident after the Great East Japan Earthquake on March 11, 2011 should be further examined. Implementation of a prospective epidemiological study on human health risks from low-dose radiation exposure and comprehensive health protection from radiation should be emphasized on a basis of the lessons learnt from the Chernobyl nuclear power plant accident. In contrast, the doses to a vast majority of the population in Fukushima were not high enough to expect to see any increase in incidence of cancer and health effects in the future, however, public concerns about the long-term health effects of radioactive environmental contamination have increased in Japan. Since May 2011, the Fukushima Prefecture started the Fukushima Health Management Survey Project with the purpose of long-term health care administration and early medical diagnosis/treatment for prefectural residents. In this report, risk and countermeasures of thyroid cancer occurrence after nuclear accidents, especially due to early exposure of radioactive iodine, will be focused upon to understand the current situation of risk of thyroid cancer in Fukushima, and the difficult challenges surrounding accurate estimations of low-dose and low-dose rate radiation exposures will be discussed.

Contents

1. Introduction 129
2. Chernobyl accident and thyroid cancer risk 129
3. Radiation dose estimation after the Fukushima nuclear power plant accident 130

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3.1. Thyroid ultrasound examination in Fukushima . . . 131
4. Summary . . . 131
Conflicts of interest . . . 132
References . . . 132

1. Introduction

The worst nuclear power plant accident in Japan occurred just after the Great East Japan Earthquake on March 11, 2011. The scientific understanding about the relationship between radiation exposure dose and health risks continues to be indispensable for proper emergency correspondence immediately after nuclear power plant accidents. According to accumulated data from survivors of the atomic bomb analyzed by the Radiation Effects Research Foundation [1], risks of leukemia and solid cancers occur in a dose-response manner [2,3]. Among human cancer occurrences associated with radiation, thyroid cancer risk increases not only after external exposure, but also after internal exposure to radioactive iodine, as epidemiologically clarified just after the Chernobyl accident [4–6]. Both factors are especially important to understand the health effects of radiation exposure, and a standardized measure of radiation dosage known as the Sievert unit (Sv) should be utilized. Measurements using the Sv unit have indicated that health effects between external and internal exposure are theoretically the same from the standpoint of biological effects.

Although by International Standard, the Fukushima nuclear power plant accident was estimated as a level 7 accident that caused massive environmental radioactive contamination equivalent to the Chernobyl accident, the actual condition and damage scales differ greatly. Thyroid blocking with suitable medication like a stable iodine tablet should be prepared for the reduction and prevention of any internal exposure to radioactive iodine immediately after an accident [7]. Moreover, the safety of food should be strictly controlled by discarding polluted milk and other food items after large-scale accidents. Although the side effects and effectiveness of iodine tablet dosage needs to be verified [8], ample room remains for the development and practical improvement of campaigns toward iodine thyroid blocking in Japan. More specifically, evaluation of the dose of radioactivity is of utmost importance, and longitudinal epidemiologic surveys, such as improvement to the regional cancer registration system and mortality surveys, would be indispensable to our precise understanding of radiation-associated cancer risk. Since thyroid cancer risk principally occurs due to a stochastic effect, and simultaneous comprehensive health risk management and risk communication are necessary for the public. In addition, an understanding of the basics of the molecular mechanisms underlying thyroid biology and carcinogenesis is also required [9].

This report outlines the nuclear accident at Fukushima and summarizes thyroid cancer risk, assuming the possibility of initial exposure to radioactive iodine and drawing lessons from the Chernobyl nuclear accident.

2. Chernobyl accident and thyroid cancer risk

On the early morning of April 26, 1986, an explosion occurred in the Chernobyl Nuclear Power Unit No. 4 High Power Channel-type Reactor, a water-cooled, graphite-moderated nuclear power reactor designed in the former Soviet Union (existing Ukraine). The nuclear reactor and the building that housed the reactor were destroyed by the accident. Subsequently, a fire broke out and spread rapidly due to scattering of hot black lead. Large-scale radioactive material was released into the environment until May 6, 1986. The main radioactive materials emitted were iodine-131, cesium-134, cesium-137, niobium-95, cerium-144, ruthenium-103, ruthenium-106, strontium-90, plutonium-239, and plutonium-240, which reached a total amount of 14 exabecquerel. An exabecquerel is a unit representing 1000 quadrillion times (10^{18}). Although large particles of strontium and plutonium descended in an area less than 100 km from the nuclear plant, other radioactive materials were widely diffused in the Northern Hemisphere around Europe [10].

Immediately after the accident, external exposure became a problem for workers inside the nuclear power plant or in nearby high-dose areas, whereas internal exposure became a problem for nearby residents exposed indirectly to radioactive fallout.

In particular, iodine-131 contamination was found in milk derived from pastured cows that fed on iodine-131-contaminated grass from the surrounding Chernobyl area; this was a critical problem for the local residents. Due to insufficient restriction of the distribution and ingestion of the iodine-131-contaminated milk by the government, people continued to consume the contaminated milk, particularly children from Belarus, Russia, and the Ukraine of the former USSR during the Cold War era. Chernobyl is an inland area that previously lacked iodine contamination. When ingested, the thyroid gland selectively takes in iodine, including iodine-131. Therefore, milk contaminated with iodine-131 was the contributing factor that exacerbated internal exposure to the thyroid glands of children who ingested the contaminated milk. These children were exposed to an estimated dozen to several thousand millisievert dose of radiation to their thyroid gland. As a result, it has been reported that infant thyroid cancer (papillary adenocarcinoma) increased rapidly in children, especially those aged 0–5 years at the time of the accident [11]. The case-control study supports a positive relationship between childhood thyroid cancer occurrence and thyroidal iodine-131 exposure [12]. The dose threshold of radiation-associated thyroid cancer in childhood has not been scientifically clarified, and no consensus exists on the threshold according to the hypothesis of the linear non-threshold (LNT) model [13]. However, some reports using theoretical models from Chernobyl, such as the LNT model, suggest that the critical internal thyroid exposure doses are conservatively more than 50–200 mSv in children [4–6]. Thyroid dose re-evaluation poses many difficulties; however, a comparative study on children who were born before and after the Chernobyl accident supports the etiological role of short half-life radioactive iodine on childhood thyroid cancer, despite a lack of direct measurements of the dose of thyroid exposure [14].

The number of thyroid cancers cases continues to increase, even 25 years after the accident [15], and has amounted to