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Review

Thyroid side effects prophylaxis in front of nuclear power plant accidents

Prophylaxie des conséquences thyroïdiennes des accidents des centrales nucléaires

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Abstract

The better knowledge of the mechanisms of nuclear incidents and lessons learned from accidents in the recent past to improve the effectiveness of measures taken following a nuclear accident exposure to fallout of radioactive iodine isotopes. Thus, immediate, passive measures, such as containment, and stopping consumption of contaminated products are paramount. The earliest possible administration of stable iodine as potassium iodide (KI) reduces significantly (up to 90% if taken at the same time of the accident) thyroid radioactive contamination. These tablets should be given in priority to children and pregnant women. The side effects are minor. KI is not recommended for persons aged over 60 years, or for adults suffering from cardiovascular disorders.

Keywords: Thyroid; Cancer; Iodine; Nuclear power plant accident

Résumé

La meilleure connaissance des mécanismes des incidents nucléaires et les leçons tirées des accidents survenus dans le passé récent améliorent l'efficacité des mesures prises suite à un accident nucléaire exposant à des retombées d'isotopes radioactifs de l'iode. Ainsi, des mesures immédiates, passives telles que le confinement, tout comme l'arrêt de la consommation de produits contaminés sont primordiales. L'administration la plus précoce possible d'iode stable sous la forme d'iodure de potassium (KI) permet de réduire de façon significative (jusqu'à 90 % en cas de prise au moment même de l'accident) la contamination thyroïdienne radioactive. Cette mesure s'adresse en priorité aux enfants et aux femmes enceintes. Elle s'accompagne de très peu d'effets secondaires, surtout si l'on respecte les rares contre-indications. Elle pourrait être inutile chez l'adulte, voire déconseillée après soixante ans et chez l'adulte aux antécédents de pathologie cardiovasculaire.

Mots clés : Thyroïde ; Cancer ; Iode ; Accident nucléaire

1. Introduction

Several serious accidents involving nuclear power stations have occurred in recent decades, most of which remain etched in people's minds years later (Table 1) [1–6]. First one, a level 5 accident on the 7-point International Nuclear Event Scale (INES) took place in the TMI-2 unit of the Three Mile Island nuclear power plant, USA, on March 28th 1979, less than 3 months after it had started normal service. Partial fusion of

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Table 1
The seven levels of the International Nuclear Event Scale (INES).

Level 1	Simple functional anomalies at a nuclear installation, with no radioactive consequences
Level 2	Technical incidents significantly affecting the safety provisions or causing a breach of annual radiation standards for a worker
Level 3	Incidents seriously affecting the safety of the facility and/or leading to radioactive releases into the environment above the authorized limits and/or serious radiation exposure for one or more workers
Level 4	Accidents meeting one or more of the following criteria: releases not involving significant risks off-site, damage to the nuclear heart, radiation or contamination of one or more workers that can lead to death
Level 5	Accidents creating risk for the environment leading to implementation of the emergency plan and external protection provisions of the site due to risk of significant radioactive release. Severe damage causing release of large quantities of radiation within the installation
Level 6	Serious accidents involving very large radioactive releases to the outside (a significant portion of the radioactivity contained in a reactor heart)
Level 7	Major accidents leading to the release into the environment of a large part of the radioactive elements in the heart of a reactor. Discharges leading to serious damage to the environment and people's health within a wide radius of the plant

the reactor core caused a large quantity of radioactive material to be released. Estimates suggest that 43,000 curies (1.59 PBq) of Krypton 85, a radioactive gas, entered the environment, along with up to 20 curies (740 GBq) of iodine 131. The second event was the Chernobyl disaster on April 26th 1986, when a dozen human errors and multiple design faults in the power station led to overheating of the fuel in reactor n° 4 following a poorly conducted experiment and a drop in power. Within a few hours, the temperature at the bottom of the reactor reached 2500 °C, and it exploded. Uranium, which melts at 1130 °C, turned into a sticky magma that destroyed the concrete and mixed with other components of the reactor. One second later, the hydrogen caught on fire and caused a second explosion, which lifted the reactor shield weighing 14,000 tonnes, exposing the reactor core to the air. It released dozens of tonnes of burning, high pressure, radioactive vapour into the atmosphere. The third accident was the result of the tsunami that hit the pacific coast of Tōhoku in Japan on March 11th 2011. According to estimates published by the Japanese Nuclear Safety Agency, the event released the equivalent of 10% of the radioactive material recorded following Chernobyl; i.e., between 1.3 and 1.5×10^{17} Bq of iodine 131 (compared to 1.8×10^{18} for Chernobyl), and between 6.1 and 12×10^{15} Bq of caesium 137 (compared to 8.5×10^{16}) making it the worst nuclear accident since Chernobyl. However, levels in the thyroid glands of Japanese children were substantially lower than those observed after the Chernobyl disaster (< 50 mGy). As a result, few of the iodine doses distributed to more than a million people were actually used [7]. The 360,000 people aged 18 or less who were living in the Fukushima area at the time of the accident have been monitored since October 2011 using ultrasound of the thyroid gland.

On July 1 2013, a total of 427 nuclear reactors an average of 28 years old were functioning in 31 different countries, roughly one hundred of them in the US and 58 in France. Of the total output of 364 gigawatts hours, 63 gigawatts hours were generated in France. In 2012, roughly 10% of all global energy production was nuclear in origin [8]. At the time of writing in 2014, 58 nuclear reactors are operational in France, spreading over 19 sites. Nuclear energy accounts for 3/4 of French electricity production. France owns 44% of all European nuclear reactors and produces 14% of the world's nuclear electricity, making it the world's second largest producer of nuclear power [9]. These installations carry various nuclear risks, such as those linked to aging and corrosion, natural events, mechanical failure and technical issues and terrorist attacks [10].

Protection against the health risks associated with a nuclear event falls to the government, under the direction of the prime minister, to manage major crises (ministerial note n° 5567/SG, January 2nd 2012) [11]. In the case of a serious incident in a nuclear power plant, the prime minister gives operational authority to the interior minister, who then runs the interministerial crisis cell (CIC). The initial organisation is based on the activation of two networks: the representatives of local authorities (prefects for zones and regions), and nuclear bodies (safety, operators, IRSN) so as to guarantee a first level of response before activating the CIC. The zone prefect, once alerted, coordinates the necessary logistics for the local authority prefect via the zone operation centre (COZ). The population is warned by sirens that emit three long blasts of roughly 1 minute with a 3-second pause between each. Populations are asked to listen to the media, especially the radio, to receive real time information from the prefect and from outside [11].

2. Risk for the thyroid

2.1. Physiology of the absorption of iodine

Iodine plays a central role in thyroid physiology, as a constituent of the thyroid hormones and the thyroid metabolism regulator [12]. Iodine is first absorbed by the intestine in the form of iodides. The uptake of iodide by the thyreocytes is done through an active transport by the symporter Na/I (NIS), ATP-dependent. Iodine is then oxidized by thyroperoxydase. It then binds to tyrosyl residues of thyroglobulin, giving rise to the precursor of thyroid hormones: monoiodotyrosine (MIT) and diiodotyrosine (DIT). Deiodinases devices allow the recycling of the iodine flowing to its reuptake by the gland.

In 1948, Wolff and Chaikoff showed that the uptake of iodide in the thyroid is decreased when the plasma levels of iodide are high, and that this adjustment can be done quickly in the presence of high permanent plasma concentrations of iodide [13]. The iodide administration decreases the expression of NIS mRNA and protein, decreasing uptake iodides in the thyroid. The concomitant decrease in the expression of TPO in this context could lead to iatrogen hypothyroidism [14].