Minimizing thyroid damage from nuclear fallout: KI prophylaxis and the importance of population iodine sufficiency


The fission of uranium, which takes place in the course of a nuclear accident, produces large amounts of radioactive iodine-131 ($^{131}$I) that may be released into the atmosphere. Depending on the atmospheric conditions, the radioactive plume may travel as far as 300 miles. Iodine-131 can then enter the human body by inhalation, or by ingestion of contaminated food. Exposure to ionizing radiation is known to precipitate the development of benign and malignant thyroid nodules. The Chernobyl nuclear accident in 1986 resulted in 5,000 cases of thyroid cancer in children, with a nearly 100-fold increase in its incidence.

**Effects of radioiodine on the thyroid**

Iodine is readily absorbed from the intestinal tract and the lungs. It is transported in the bloodstream to the thyroid, where it is concentrated and used to make the thyroid hormones T4 and T3. The body of an average euthyroid person contains 15–20 mg of iodine, with ca. 75% aggregating in the thyroid. The maximum amount the gland can hold is upwards of 50 mg. Only about 1% of the stored iodine is secreted daily. Iodine-131 is chemically identical to stable iodine, and it follows the same pathway.

Iodine-131 atoms are unstable due to an excess of energy in the nucleus. This excess is emitted in a process called radioactive decay. When $^{131}$I decays, electrons are ejected from the nucleus as beta particles and transfer all of their energy to the surrounding tissue within 1–2 mm, causing cellular damage. Because of its relatively short physical half-life (8 days) and prolonged retention, $^{131}$I delivers almost all of its radiation to the thyroid. The radiation dose is proportional to iodine uptake, and so if enough is concentrated in the thyroid, the absorbed radiation may be high enough to kill thyroid cells. This can be beneficial in patients with overactive thyroid glands and thyroid cancer, and $^{131}$I is used extensively in cancer treatment. At lower radiation doses (such as those encountered during nuclear accidents), the cells may remain viable, and radiation-induced mutations may result in malignant transformations.

**Uptake of radioactive iodine in iodine deficiency**

Iodine deficiency disorder is the world’s leading cause of preventable brain damage, inducing average reductions in IQ of 10 to 15 points. Worldwide, around 240 million school-age children are estimated to have insufficient iodine intake, inducing a myriad of learning disabilities. Thyroidal uptake of iodine is higher in people with iodine deficiency than in people with iodine sufficiency. For this reason, iodine-deficient individuals have a higher risk of developing radiation-induced thyroid cancer when exposed to radioactive iodine. Similarly, individuals with thyroids of lesser volume (e.g., infants and children) and higher activity will experience increased thyroid clearance and subsequently will be more vulnerable to radioiodine exposure.
Studies in the Bryansk region of Russia after the Chernobyl accident showed that the excess relative risk (ERR) of thyroid cancer associated with $^{131}$I exposure was twice as high in areas with severe iodine deficiency as in areas with adequate iodine status. An inverse relationship was discovered between the levels of urinary iodine and the ERR of thyroid cancer in these individuals, suggesting that iodine sufficiency provides protection against radioiodine exposure and helps to mitigate the thyroid cancer risk. Chronic iodine deficiency itself may be associated with an increased risk of goiter and another form of thyroid cancer (follicular cancer). Consequently, by ensuring adequate intake of iodine, we can prepare for a possible nuclear event as well as improve public health.

**Prophylaxis with potassium iodide**

Timely potassium iodide (KI) prophylaxis can significantly reduce the $^{131}$I radiation dose to the thyroid and prevent the development of thyroid cancer. KI prophylaxis floods the body with an excess of stable iodine that competes with $^{131}$I for transport into the thyroid and can effectively block radioiodine uptake. The ingested or inhaled $^{131}$I that is not concentrated in the thyroid is rapidly excreted in the urine with a smaller amount excreted in the feces, perspiration, and in breast milk.

A number of governments recommend KI prophylaxis. In addition, the WHO stresses the importance of thyroid blocking in children and pregnant/nursing women. Taken just prior to radioiodine exposure by a euthyroid adult, 100 mg of KI is at least 95% effective in blocking radioiodine uptake. If risk of exposure persists over 24 h, 15 mg of KI taken on subsequent days will reduce radioiodine uptake by 90%. However, it is critical that KI be taken within a few hours of exposure.

After as little as 3–4 hours, its effectiveness decreases by 50%.

Thyroidal iodine turnover rate is 1% in adults and 17% in iodine-replete neonates, but it can be as high as 62% and 125% in cases of moderate and severe iodine deficiency. It has been suggested that increased clearance may necessitate larger dosages of KI or more frequent dosing at lower KI dosages. An accelerated iodine turnover rate may also necessitate continued prophylaxis for children and iodine deficient individuals in instances where the risk of exposure is persisting. The neonate is hypersensitive to iodine loading, therefore, prolonged prophylaxis in neonates requires additional investigation. KI prophylaxis used in Poland after the Chernobyl accident in 1986 was overall well tolerated. Reported side effects included gastrointestinal distress and rash. Importantly, newborns receiving single 15 mg doses of KI showed transient hypothyroidism.

**Using food for iodine prophylaxis**

Informational agencies should emphasize the potential for alimentary sources of iodine to be used in the absence of KI tablets. Seaweed, especially kelp is the best natural source of iodine, and it may be the only possible dietary substitute for KI in prophylaxis. When the supply of alimentary iodine is increased, $^{131}$I uptake appears to be reduced. This effect has been observed and confirmed in several studies. Importantly, there is high variability in the iodine content of alimentary sources, dependent on where and when the foodstuff is produced. In addition, the fast food and pre-prepared food industries could utilize iodized salt to help combat iodine deficiency and, by doing so, mitigate the potential risks associated with radioiodine exposure. Iodization of salt is an effective and inexpensive means of eliminating iodine deficiency and helping to protect the population against nuclear fallout.