ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Case Studies in Environmental Medicine

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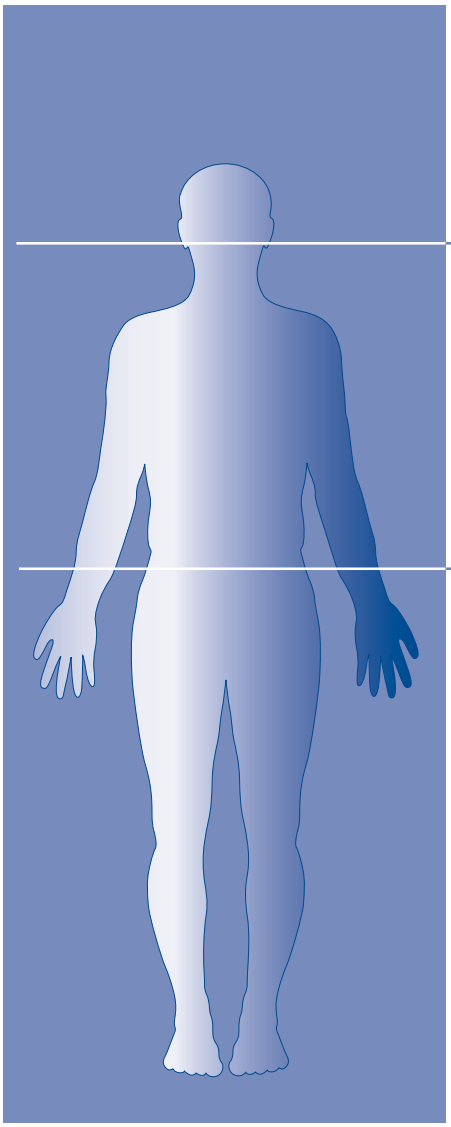

RADIATION EXPOSURE FROM IODINE 131

Environmental Alert

- During 1945 through 1962, many people in the United States were exposed to radiation fallout from iodine 131 (I-131) from multiple sources. Many of those exposed were children younger than 10 years of age, the population most vulnerable to radiation exposure. This exposure put those children at risk for thyroid and parathyroid disease and cancer of the thyroid.
- The health care community should be able to medically evaluate the health effects resulting from past exposure to releases of I-131.
- The health care community should be prepared to handle their patients' health effects from acute unintentional or intentional releases of I-131.

This monograph is one in a series of self-instructional publications designed to increase the primary care provider's knowledge of hazardous substances in the environment and to aid in the evaluation of potentially exposed patients. This course is also available on the ATSDR Web site, www.atsdr.cdc.gov/HEC/CSEM/. See page 3 for more information about continuing medical education credits, continuing nursing education units, continuing education units, and continuing health education specialist credits.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmetnal Medicine

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Disclaimer

The state of knowledge regarding the treatment of patients potentially exposed to hazardous substances in the environment is constantly evolving and is often uncertain. In this monograph, ATSDR has made diligent effort to ensure the accuracy and currency of the information presented, but makes no claim that the document comprehensively addresses all possible situations related to this substance. This monograph is intended as an additional resource for physicians and other health professionals in assessing the condition and managing the treatment of patients potentially exposed to hazardous substances. It is not, however, a substitute for the professional judgment of a health care provider. The document must be interpreted in light of specific information regarding the patient and in conjunction with other sources of authority.

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Figures and Tables

We would like to extend a special thank you to the members of the Hanford community and others who provided input and comments on this document. Their comments have contributed greatly to this case study.

This case study was prepared with the assistance of those who share a common concern for health professional education, public health, and the environment, including the American College of Medical Toxicology (ACMT) and the American College of Preventive Medicine (ACPM). Final responsibility for the contents and views expressed in this case study resides with ATSDR.

Each content expert for this case study indicated no conflict of interest to disclose with the case study subject matter.

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Case Studies in Environmental Medicine: Radiation Exposure From Iodine 131

Goals and Objectives

The goal of the ATSDR series of Case Studies in Environmental Medicine (CSEM) is to increase the health professional's knowledge of hazardous substances in the environment and to aid in the evaluation of potentially exposed patients.

After completion of this educational activity, the reader should be able to describe the major sources of I-131 in the environment, identify the major routes of human exposure, describe the population group most at risk for health effects from past exposure to I-131 and why, describe the four factors contributing to the internal dose of I-131 contamination, assess a patient's environmental or occupational exposure to I-131, describe the diagnostic evaluation of a thyroid nodule in an individual exposed to I-131, list two important actions to take if an environmental release of I-131 occurs, discuss indications for prophylactic use of potassium iodine (KI) after an I-131 exposure, and list three sources of information one could access if there is a release of I-131.

Accreditation

Continuing Medical Education (CME)

The Centers for Disease Control and Prevention (CDC) is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians. CDC designates this educational activity for a maximum of 2.25 hours in category 1 credit toward the American Medical Association (AMA) Physician's Recognition Award. Each physician should claim only those hours of credit that he/she actually spent in the educational activity.

Continuing Nursing Education (CNE)

This activity for 2.5 contact hours is provided by CDC, which is accredited as a provider of continuing education in nursing by the American Nurses Credentialing Center's Commission on Accreditation.

Continuing Education Units (CEU)

CDC has been approved as an Authorized Provider of continuing education and training programs by the International Association for Continuing Education and Training and awards 0.2 continuing education units (CEUs).

Continuing Health Education Specialist (CHES)

CDC is a designated provider of continuing education contact hours (CECH) in health education by the National Commission for Health Education Credentialing, Inc. This program is a designated event for the CHES to receive 2.0 category 1 contact hours in health education.

Instructions

See page 4

The questionnaire and posttest must be completed and returned electronically, by fax, or by mail for eligibility to receive continuing education credit.

Instructions for Completing CSEM Online

1. Read this CSEM, *Radiation Exposure From Iodine 131*; all answers are in the text.
2. Link to the MMWR/ATSDR Continuing Education General Information page (www.cdc.gov/atsdr/index.html).
3. Once you access this page, select the Continuing Education Opportunities link.
4. Once you access the MMWR/ATSDR site online system, select the electronic file and/or register and test for a particular ATSDR course.
   a. Under the heading "Register and Take Exam," click on the test type desired.
   b. If you have registered in this system before, please use the same login and password. This will ensure an accurate transcript.
   c. If you have not previously registered in this system, please provide the registration information requested. This allows accurate tracking for credit purposes. Please review the CDC Privacy Notice (www.cdc.gov/privacy.htm).
   d. Once you have logged in/registered, select the test and take the posttest.
5. Answer the questions presented. To receive continuing education credit, you must answer all of the questions. Some questions have more than one answer. Questions with more than one answer will instruct you to "indicate all that are true."
6. Complete the course evaluation and posttest no later than **November 23, 2005**.
7. You will be able to immediately print your continuing education certificate from your personal transcript.

Instructions for Completing CSEM on Paper

1. Read this CSEM, *Radiation Exposure From Iodine 131*; all answers are in the text.
2. Complete the evaluation questionnaire and posttest, including your name, mailing address, phone number, and e-mail address, if available.
3. Circle your answers to the questions. To receive your continuing education credit, you must answer all of the questions.
4. Sign and date the posttest.
5. Return the evaluation questionnaire and posttest, no later than **October 24, 2005**, to CDC by mail or fax:

Mail
Continuing Education Coordinator
Division of Toxicology and
Environmental Medicine, ATSDR
1600 Clifton Road, NE (MS F-32)
Atlanta, GA 30333

or

Fax
770-488-4178
ATTN: Continuing Education Coordinator

. You will receive an award certificate within 90 days of submitting your credit forms. No fees are charged for participating in this continuing education activity.

Case Study

A 55-year-old female child care worker comes to your office concerned about a nontender thyroid mass that has slowly grown over the last 2 years. She is worried that this condition could be passed on to her daughter, who is pregnant.

A 55-year-old female presents with a nontender thyroid mass that has slowly grown over the last 2 years.

Your patient was born in 1945 in Washington State. She grew up on a farm near the Hanford Nuclear Reservation, where her father worked as a machinist during World War II. The family history reveals that the woman lives with her husband of 41 years; her daughter, born in 1963, who is 6 months pregnant; and her daughter's husband. They have lived in your community for the last 12 years, in a single home in a low income area of town.

The patient's past medical history is noncontributory, and her family history is unremarkable. Her father died at age 84 of a myocardial infarction, and her mother died of colon cancer at age 77. The patient has no family history of thyroid disease or of other endocrine disease. She has two brothers and a sister; all are reportedly in good health.

Your patient does not have symptoms consistent with hyperthyroidism or hypothyroidism; does not smoke and has not smoked in the past, but she occasionally drinks alcohol. She does not have any past workplace or hobby chemical exposures, and she has not received any therapeutic radiation exposures.

Challenge Question

(1) What have been the main sources of I-131 in the environment?

Pretest

(a) Which organ system is considered the critical organ for exposure to I-131?

(b) What are the main routes of human internal exposure for I-131?

(c) What are the most significant health effects from exposure to I-131?

(d) Which group is most at risk for health effects from exposure to I-131, and why?

Exposure Pathways

"If the levels of environmental I-131 ... were released now instead of in the late 1940s–1960s, contaminated food quarantine, and emergency evacuation of many parts of the country would occur. The population would be outraged. A national health emergency would be declared. Congress would pour monies into health care and other help for those exposed. Ours may be exposures of the past, but those of us exposed as children, when we were most vulnerable to radioactive harm, are still alive and some of us have developed exposure health outcomes. We must not be discounted...."

> Testimony of a Hanford community member exposed to I-131 (Hanford, Washington).

- I-131 is radioactive, has an 8.03 day half-life, and emits beta and gamma radiation.
- I-131 is normally present at low levels in hospital nuclear medicine departments, in patients administered radioactive iodine in the last 3 months, and in releases from nuclear power plants.
- I-131 is produced during nuclear fission, which occurs during the operation of nuclear reactors or detonation of a nuclear bomb. When uranium or plutonium atoms undergo fission, about 1.5%–2.0% of the fission products become I-131.

During the Cold War, national security policies prevented government authorities from disclosing the risks and health hazards associated with living near or working at weapon production facilities. These facilities released harmful levels of radiation into the environment.

Many people in the United States, especially those living near or working at weapon production facilities, such as the Hanford Nuclear Reservation, were unknowingly exposed to multiple sources of I-131, including fallout. The Nevada Test Site (NTS), which was used to test nuclear weapons, produced considerable amounts of fallout, which exposed most of the American population. The existing national security policies kept that information from reaching the American public.

This case study focuses on iodine 131 (I-131) because large amounts of this isotope were released during the production and testing of nuclear weapons. Iodine 127 (I-127) is the only naturally occurring iodine isotope, and it is the only nonradioactive (stable) iodine isotope. All other iodine isotopes (I-123, I-125, I-129, I-131, and I-135) are radioactive. Only I-131 and I-135 are associated with medical administration.

The Legacy of I-131 in the Environment

In the United States, past releases of I-131 have occurred at fuel reprocessing plants and some weapon production facilities of the Department of Energy (DOE). Since 1944, when the first production atomic reactor came into service, large amounts of I-131 have been periodically released into the atmosphere. I-131 was released to the atmosphere as a gas during nuclear weapons production (1945–1980s), aboveground nuclear tests (1951–1962), medical isotope production, medical administrations to patients, and unintentional releases. Multiple releases over time could have maintained constant or repetitive high levels of radioactivity, particularly around weapon production facilities. The highest levels of combined I-131 releases occurred from the early 1940s through the mid-1960s.

- The main sources of I-131 in the environment have come from nuclear power plant releases and from the production and testing of nuclear weapons.
- The highest levels of combined I-131 releases occurred between the early 1940s and mid-1960s.

The annual dose of background radiation received by an average person in the United States comes from the following sources: radon gas, 55%; internal radiation, 11%; cosmic rays, 8%; terrestrial radiation, 8%; and manmade products, 18%. Less than 1% of the radiation from manmade products comes from nuclear power plant releases and fallout. Typically, little of this dose is from I-131 because of the short half-life of the element: it decays (loses its level of radioactivity) rapidly and rarely exists at any meaningful level in the environment. However, this changes if a major nuclear release occurs. When a nuclear bomb detonates or nuclear power plant fuel melts and causes an explosion, the volatile I-131 produced is forced up to various elevations (potentially exceeding 10 kilometers

[6.2 miles]) by the intense heat, and is subsequently swept by the winds. I-131 can be deposited on the ground as dry deposition (I-131 adsorbs to particulates in the air and drops to the ground) or as wet deposition (I-131 dissolves in atmosphere moisture, some of which becomes rainwater and falls to the ground). The initial quantity released determines the significance of the fallout. Persons living in the direction in which the wind blows are referred to as "downwinders." Many of the persons living downwind from the Hanford Nuclear Reactor could have received multiple exposures over time.

Total releases of I-131 worldwide equal 24,000,000,000 curies. The curie, or Ci, is the measurement for the rate of radioactive decay. If you would like more information on general ionizing radiation principles, please see ATSDR's Case Studies in Environmental Medicine: Ionizing Radiation (ATSDR 1993a).

Worlwide, major significant I-131 releases ocurred at the following locations.

Total Estimated Amount of I-131 Released From the Site (in curies)	Site	Time Period
150,000,000 Ci	Nevada Test Site, Nevada	1952–1970
50,000,000 Ci	Chernobyl (former Soviet Union)	1986
740,000 Ci	Hanford Reservation, Washington	1944–1972
60,000 Ci	Savannah River Site, South Carolina	1955–1990
8,000–42,000 Ci	Oak Ridge National Laboratory, Tennessee	1944–1956
20,000 Ci	Windscale, United Kingdom	1957
15–21 Ci	Three Mile Island, Pennsylvania	1979

The peak years for the releases at the Hanford Nuclear Reservation were 1944–1947 (92%), with minimal releases after 1947, except for two peaks in December 1949 (the Green Run) and May 1951 (filters removed). The largest I-131 releases from the Oak Ridge National Laboratory occurred between 1952 and 1956. An April 29, 1954, accident released 105 to 500 Ci over 2½ hours, accounting for about 6.5% of the total release for 1954. The Nevada Test Site had 90 nuclear tests that released almost 99% of the total I-131 released into the atmosphere from 1952 through 1957. The Windscale release in the United Kingdom in 1957 was caused by a fire in the graphite moderator of an air-cooled plutonium production reactor. The Three Mile Island release in Harrisburg, Pennsylvania, in 1979,

released 15–21 Ci of I-131 into the atmosphere. During and after the explosion and fire at the Chernobyl nuclear plant, large amounts of radioactive materials were released over a 10-day period, with 25% of the total amount released in the first day. These materials were subsequently spread over parts of Europe and the rest of the world by wind.

Challenge Question

(2) Why is dietary intake information important for assessing the patient's exposure to I-131?

Exposure Route

The amount of I-131 available to expose a person after a release depends on the

- amount released
- distance between the populated area and the place of the release
- height of the release, and
- meteorologic conditions at and after the time of the release.

The exposure pathway of greatest public health significance is the deposition of I-131 on pasture grasses, followed by the ingestion by cows or goats and the subsequent consumption of contaminated milk and fresh dairy products by humans.

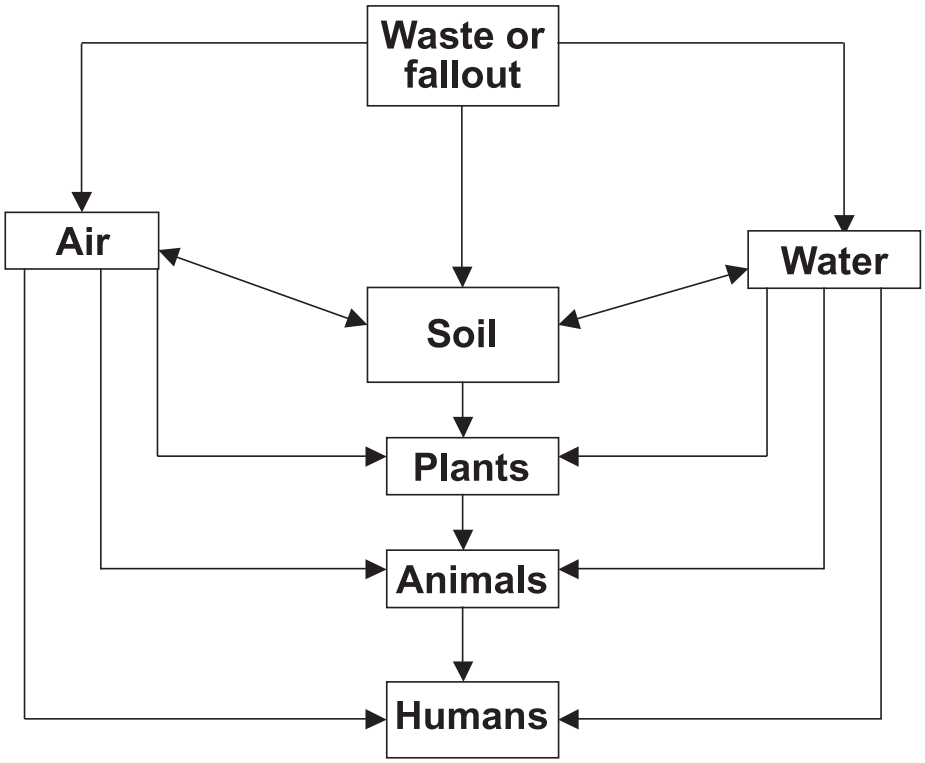
- The activity of I-131 (quantity of radioactive material present), the exposure route, and the individual's age are factors that determine the exposure dose from radiation.
- Infants' and children's increased rate of growth and development make them more vulnerable to radiation exposures.
- Ingestion of contaminated milk has been the major I-131 exposure pathway for humans.
- The concentration of I-131 in milk from goats and sheep is 10 times higher than the concentration in cow's milk.

Exposure begins immediately for persons in the immediate vicinity of a nuclear release who are in the plume (the visible or invisible cloud of contamination). Internal exposure by inhalation occurs for persons inside the plume. External exposure occurs while the person is in the plume or on land left contaminated by fallout from the plume. Internal exposure by ingestion occurs when persons eat food that is contaminated with the fallout. The oral pathway is the main route of internal I-131 exposure for people. Milk is the major source of internal exposure.

Dietary intake of iodine before exposure is important because a relative iodine deficiency increases the thyroid uptake of I-131. After exposure, the most critical dietary information needed is the amount and type of milk and milk products consumed, their I-131 concentrations, and the time they were consumed relative to the time of the release.

Goat's milk and sheep's milk contain approximately 10 times the concentration of radioiodine found in cow's milk. Inhalation, especially near releases of I-131 in the absence of rain, is another route of internal exposure. However, doses to humans from inhalation and from ingestion of plants, animals, or water are usually small in comparison. Figure 1 shows the exposure pathways of I-131 from the environment to humans.

Figure 1. Exposure Pathways of I-131 From Environment to Humans



Acute exposure to I-131

- Acute exposure to I-131 today could occur from unintentional or intentional releases.
- Public exposure to I-131 or contamination of soil, food, or water by I-131 engenders intense fear. The emotional and psychologic stresses resulting from exposure should be recognized and addressed early in a radiation incident.

Explosion of a nuclear bomb produces a small amount of local I-131 fallout; the remainder distributes over large distances, with only 10% making its way to the surface before transforming to stable xenon 131 (UNSCEAE 2000a, 2000b). The less intense heat from a nuclear reactor release allows higher local I-131 fallout.

The current main sources of I-131 exposure would be a localized hospital accident, a major nuclear power plant release involving melted fuel, or an aboveground atomic bomb detonation. The resulting iodine levels along the plume path would vanish over a period of a few days to months depending on dilution and radioactive decay.

Doses of I-131 that result from medical procedures, including therapeutic thyroid ablations, release low levels of radiation in hospital nuclear medicine departments. Therapeutic thyroid ablations have a mean thyroid dose of 10–100 Gray (Gy) to the patient, which is equivalent to a radiation absorbed dose (rad) of 1,000–10,000. These ablations significantly exceed an entire year's worth of background radiation. Patients undergoing this procedure release low levels of radiation for about 3 months.

Challenge Question

(3) Which age groups are the most sensitive to I-131 exposure?

Who's At Risk

- Incidence of thyroid cancer depends on many factors, including thyroid dose and age at the time of exposure.

During 1945–1962, when they were young children (and more vulnerable than adults to radiation exposure), many persons in the United States were exposed to radiation fallout from I-131 from multiple sources. Those exposures put those persons at risk for thyroid and parathyroid disease and cancer of the thyroid.

Any person who was a child under the age of 10 between 1945 and 1962 in the United States and who drank milk should be considered potentially exposed to I-131. People who lived near or around weapons production facilities, especially downwinders, are at risk for having received higher levels of exposure to I-131.

National Cancer Institute materials on I-131

- Web site: http://www.cancer.gov/i131
- Phone: 1-800-4-CANCER (1-800-422-6237)

More detailed information on how Americans were exposed to I-131 is available from the National Cancer Institute (NCI). The institute provides free print materials and maintains a Web site on I-131.

Epidemiologic studies on thyroid cancer and I-131 at Chernobyl confirmed that the risk for thyroid cancer is dependent on the absorbed dose, the age and location of persons at time of exposure, and the absence of immediate iodine prophylaxes for I-131 exposure. A strong relationship exists between the incidences of thyroid neoplasia, hypothyroidism, and autoimmune thyroiditis and the received dose. In the most contaminated area after the nuclear release at Chernobyl, thyroid cancer incidence was significantly higher compared with other regions. There are no earlier studies comparable to those for Chernobyl because no studies were conducted around U.S. weapon production facilities when I-131 was released.

Age is a factor for exposure to I-131 because of the differences between thyroid doses for children and adults. The dose to children is much higher than that to adults because the thyroid mass in children is smaller, and because milk, as the main route of contamination, is consumed in higher quantities during childhood. For an equivalent uptake of I-131, a child's thyroid receives a higher radiation dose because the same amount of energy is deposited in a smaller tissue mass (more energy per gram = higher dose). For newborns, the thyroid dose is about 16 times higher than that for adults for the same ingested radioactivity; similarly, the absorbed dose is about 8 times higher for children under 1 year old and 4 times higher for children 5 years old.

- Children are the most sensitive group for exposure to I-131.

Most of the immigrants from the former Soviet Union who came to the United States during the 1990s came from the Ukraine. Many of them came from areas that had been contaminated with I-131 during and after the Chernobyl explosion. Therefore, many of them—some of whom were children at the time—have been exposed to I-131.

During pregnancy, the maternal thyroid has an increased rate of I-131 uptake, especially during the first trimester. I-131 crosses the placental barrier. During the second and third trimesters, the fetal thyroid takes up and stores iodine in increasing amounts. During the first postpartum week, thyroid activity increases up to fourfold. This critical period lasts for a couple of days. Infants and children are at high risk from radioiodine exposure because their thyroids are small. This risk decreases as children age, although it continues until they are about 20 years old. About one-quarter of the iodine ingested by the mother is secreted in breast milk, which adds an additional risk factor for the breast-feeding infant.

- Special considerations exist for pregnant women and nursing mothers.

The geographic distribution of persons exposed to I-131 is important for three reasons. First, the risk is higher for those in rural areas because fresh milk is often consumed. This is important when the milk is produced from a contaminated pasture. The delay between the production and consumption of milk contributes to decreasing radioactivity for urban populations. Second, the risk is higher for populations with endemic deficiency of iodine. I-131 absorption is higher for these populations. Third, different types of milk and dairy products are consumed in some rural areas. In goat's milk and sheep's milk, I-131 concentrations are up to 10 times higher than in cow's milk for the same concentration of I-131 in the pasture.

- Drinking fresh versus pasteurized milk leads to a higher dose of I-131.

Challenge Question

(4) Which organ is the critical target organ for exposure to I-131?

Biologic Fate

Radiation dose and health risk must be calculated from continued exposures. The radiation dose from internalized I-131 is estimated on the basis of the following:

- activity deposited in the lungs and ingested (quantity of radioactive material measured in units of Becquerels or Curies);
- I-131's chemical form and physical properties;
- the types, energies, and intensities of the emitted radiation;
- physical and biologic half-lives;
- the thyroid mass (which is age dependent); and
- the thyroid uptake fraction (based on diet and metabolism).

With chronic exposure, the half-life of the radionuclides released becomes less relevant because new releases occur continuously. Many of the earlier off-site radiation exposures from nuclear weapon production facilities were chronic. In this case study, the term "dose" is used to refer to the radiation dose (the amount of energy deposited in tissue). The exposure dose depends on an individual's risk factors (for example, age at time of exposure and the consumption of milk and milk products).

- The critical target organ for I-131 is the thyroid gland.

The thyroid gland uses iodine to produce thyroid hormones which help regulate growth and metabolism. Iodine has a strong affinity for the thyroid gland, which is the critical target organ for exposure. Iodine is readily absorbed from the gastrointestinal tract and lungs into the bloodstream. Most of the iodine that enters the body quickly becomes systemic (EPA 1988), with approximately 30% depositing in the thyroid. Exposure to I-131, especially in childhood, increases the risk for hypothyroidism, thyroid nodules, and cancer.

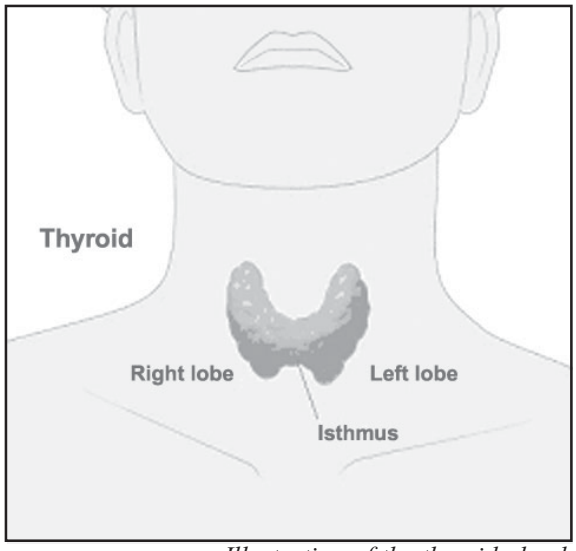


Illustration of the thyroid gland. Source: National Cancer Institute.

The metabolism of iodine is linked closely with the functional activity of the thyroid. The portion of systemic iodine that redistributes to the thyroid ranges from 20% (for hypothyroidism or iodine-rich diets) to 75% (for hyperthyroidism or iodine-deficient diets), with an average of 30%–50% for normal diets. The rest is excreted via urine. The moderate to severe iodine deficiency in the area near Chernobyl was a predisposing factor that caused thyroid doses to be higher than doses in regions where iodine uptake was normal.

- Hyperthyroidism or iodine deficiency results in increased uptake of I-131.

Thyroid Dose Due to Internal Radiation

Estimating the radiation dose delivered by I-131 radiation to either the thyroid or the whole body involves multiplying the activity inhaled or ingested by an age-specific dose factor. Activity inhaled is the product of the mean air concentration of I-131, respiratory rate, and exposure time. Activity ingested is the product of the mean concentrations of I-131 in both food and water and the amounts of each consumed. These concentrations are functions of time delays between production and consumption as well as the geographic pattern of air concentration and fallout distribution. If the I-131 exposure was chronic, daily totals must be calculated and added using appropriate formulas and methods.

- Thyroid dose from ingestion of I-131 can be 10 times higher for newborns than for adults.
- Thyroid dose from inhalation of I-131 can be two times higher for infants than for adults.
- Thyroid dose can be 15–20 times higher than the overall dose to the rest of the body.

A child's thyroid dose from ingestion can be up to 20 times that of an adult because the same amount of energy is deposited in a smaller tissue mass. A child's thyroid dose from inhalation can be twice that of an adult, and is 15–20 times higher than the overall dose to the rest of the body. Children living in the maximum exposure area of the Hanford Nuclear Reservation were estimated to have received doses that were 10 times the estimated dose of adults over the same period.

Factors Affecting the Internal Thyroid Dose Produced by Milk Consumption

Four factors can affect the internal contamination dose of persons who ingested milk containing the same I-131 concentrations.

1. Time between production and consumption. Because of the short half-life of I-131, even a short delay caused by the processing and transport of milk can decrease the radioactivity of ingested milk. This factor played an important role in past releases, depending on whether a population was urban or rural; in general, urban populations consumed processed milk transported from farms, whereas rural populations consumed unprocessed fresh milk. Most populations today consume processed milk.
2. Rate of consumption of fresh milk or of dairy products such as cheese. It is important to take into account that milk from cows,

goats, and sheep contain different levels of I-131, and that goat's and sheep's milk have the highest concentrations.

3. Age and sex of exposed groups. Children and older people consume more milk than other groups do. Age at time of exposure is an important factor that influences individual thyroid dose. Because the infant's thyroid is small, the dose conversion factor for milk consumption is strongly dependent on age. After age 50, the thyroid mass and the capacity for uptake of iodine is gradually reduced. During pregnancy, the uptake of iodine is slightly increased because of the relative iodine deficiency of the body.
4. Geographic distribution of population related to the factors affecting thyroid dose (residence in relation to release or wind pattern).

Physiologic Effects

- Thyroid nodules, neoplasia, hypothyroidism, and autoimmune thyroiditis with or without hypothyroidism are the main effects of internal exposure to I-131.
- Benign neoplasms are more common than malignant neoplasms.

Persons exposed to releases of I-131 involving melted fuel at nuclear power plants, from production of nuclear weapons, and from fallout from aboveground detonation of atomic bombs have a higher risk for developing thyroid cancer or thyroid disease, or both, than do unexposed populations. In particular, persons exposed during childhood received higher doses, which in many cases were repetitive over time. These persons were more vulnerable than were those exposed as adults.

Radiation causes health effects when either enough cells are killed quickly enough to disrupt tissue function (acute health effects) or damaged cells are incompletely repaired but still viable (carcinogenic, tumorigenic). I-131 radiation might affect cells in the thyroid gland, leading to hypothyroidism or thyroiditis, or might cause benign or malignant thyroid tumors and nodules. The thyroid gland has one of the lowest cell-proliferation rates of body tissues, and its regenerating ability is also low.

Thyroid Tumors

Even in the absence of exposure to I-131, thyroid tumors are the most common endocrine neoplasms. Thyroid tumors are usually nodules localized to the thyroid gland, and are often palpable on examination of the anterior neck. I-131 exposure increases the risk of thyroid nodules and cancer. Thyroid cancer is rare. The mean rate of spontaneous thyroid cancer is one in 1 million for children (10 in 1 million for adults), with a female-to-male ratio of 3 to 2. The increased risk for thyroid cancer is especially important for exposures to I-131 during childhood. The incidence of thyroid nodules increases with age. However, thyroid cancer in children often presents at a more advanced stage than in adults: more distant metastases, more lymph node involvement. The risk of recurrence

is higher in children, but the death rate (at least over 20 years) is much lower in children than in adults.

When identifying those nodules that are likely to be malignant, a careful history is crucial. The history should include past medical history, occupational history, environmental (exposure) history, family history including dietary exposure, and social history. Of particular importance is a history of external radiation exposure to the head, neck, or upper mediastinum in infancy or childhood.

- 5%–10% of palpable nodules are thyroid cancer; the remainder are benign thyroid nodules.

Exposure of the thyroid gland to moderate to high doses (from 6.5 to 2,000 centigray) of I-131 linearly increases the risk for thyroid cancer. Nodular disease occurs in about 20% of these patients, but it might not be apparent until 30 or more years after the initial exposure. The risk for thyroid neoplasm has been correlated directly with younger age at radiation exposure, radiation dose, and sex. (A male patient with a nodule should be regarded with greater suspicion because more women have thyroid cancer—by a ratio of 2:1—and women have more thyroid disease—by a ratio of about 8:1.) Thyroid nodules in children and elderly patients are more likely to be malignant.

More information on ionizing radiation, taking exposure histories, pediatric environmental health, and reproductive and developmental hazards is readily available in other ATSDR case studies (ATSDR 1993a, 1993b, 2001, 2002).

Excesses of thyroid nodules and cancer (including 1,800 cases of thyroid cancer) reportedly occurred from the Chernobyl nuclear power plant release. These results might have reached higher levels than expected due to low dietary intake of iodine in the region and high endemic rates of goiter.

"Further research related to iodine-131 would be useful in several areas including the risk posed by low levels of exposure, possible differences in radiation-related and naturally occurring thyroid cancers...." (Committee on Thyroid Screening 1999). The Hanford Thyroid Disease Study found no dose-response relationship. An individual's increased risk, however, cannot be ruled out. The Hanford thyroid dose estimates were based on a dose reconstruction model using historical records and assumptions that result in uncertainty of doses.

Thyroid Cancer After X-Ray Exposure

Several cohorts of pediatric patients irradiated in head and neck area for thymus hypertrophy, tinea capitis, and chronic tonsillitis have been studied. These studies suggested three findings. First, the thyroid of children is more sensitive to carcinogenesis than is the thyroid of adults. Second, the delay between the external irradiation and the appearance of the cancer is at least 10 years (average delay 20 years). Third, the dose-response curve is linear for persons exposed before 15 years of age (even down to 0.1 Gy [10 rad]). The excess relative risk per unit of

exposure (ERR/Gy) for childhood exposure is 7.7 (95% confidence interval, 2.1–28.7).

Reproductive and Developmental Effects From Therapeutic Uses of I-131

I-131 has become a standard treatment for thyroid ablation in persons with hyperthyroidism or thyroid cancer. At least seven case reports and small case series on adverse reproductive outcomes of medical I-131 use have been published; however, sufficient information was not provided to determine whether the fetus was exposed to I-131 radiation and, if so, to what extent. The authors concluded that although the abnormalities found could not be directly attributed to the therapy, it is prudent to avoid pregnancy for 1 year after radiation treatment.

Other Effects

Thyroid exposure to either internal or external radiation might trigger an immune response. Changes in thyroid autoimmunity after I-131 therapy have been attributed to the production and release of autoantigens as a result of radiation damage.

- Increased risk for thyroid neoplasm remains elevated for at least 40 years after exposure.

Acute/Recent Exposure

Acute radiation thyroiditis occurs within 2 weeks after high exposure to I-131 and is characterized by local pain and tenderness over the gland. Occasionally, significant systemic symptoms have been associated with a massive release of stored thyroid hormone. This syndrome can require treatment with anti-inflammatory agents and beta-adrenergic antagonist agents. Clinically significant acute radiation thyroiditis is unlikely to occur at thyroid I-131 doses below 20,000 rad. Radioactive iodine can accumulate during pregnancy in the fetal thyroid and cause its permanent ablation. Because of the risk for fetal exposure to I-131, women of childbearing age must take a pregnancy test before undergoing medical radioiodine treatment.

Psychosocial Effects

A nuclear release or known past exposure from any type of radiation can lead to increased psychologic stress because of the invisible nature of the event and concern for serious health-related effects from a radiologic contaminant. Results from studies in communities affected by previous nuclear releases, such as Three Mile Island (TMI), showed that area residents experienced long-term elevations of stress with increases in community rates of subclinical depression, anxiety, demoralization, and a heightened perception of risk. Indeed, the high levels of psychosocial stress in communities affected by the TMI release remained elevated for

- Elevated levels of psychologic stress, which can lead to increased risk of depression, anxiety, and posttraumatic stress disorders in some people, can occur after incidents involving nuclear releases.

6 years after the release and did not return to normal until 10 years after the incident (Baum et al. 1983).

Health care providers may hear concerns from people who might have been exposed to radioactive releases from nuclear tests or facilities. It is common for these people to talk about uncertainties about their health concerning previous or present exposure and the effect on their health. Patients' health concerns may center around whether they will get ill and—if so—when, what caused the illness, whether the illness can be diagnosed properly, and what its prognosis, treatment, and financial impact will be. Because of fear of cancer and the uncertainty of when or whether it might occur, patients can have emotional stress, risk for developing anxiety, and depression (Vyner 1988).

Social consequences to exposure to radiation can also occur. Many of the men and women exposed in Nagasaki and Hiroshima during World War II were perceived as "damaged" and shunned for marriage because of the potential for "damaged genes."

Challenge Questions

(5) What would you include in your patient's exposure history?

(6) What is the procedure of choice to study a palpable nodule of the thyroid gland?

- Most people want to receive information as quickly as possible after notification of a nuclear or chemical release. They want public health officials or their primary care providers to give them advice about potential health risks and what actions to take to prevent serious consequences of their exposure. Timely and correct information is key to preventing stress and relieving its psychosocial effects.

- Mothers are especially susceptible to psychological effects because of their concern about the effects of radiation on their children's health. Pregnant women have added worry about risks to their unborn children.

Clinical Evaluation

Because I-131 concentrates in the thyroid gland, evaluation of a patient exposed to I-131 centers on diseases of the thyroid. Exposure to I-131 can cause thyroiditis, hypothyroidism, and thyroid neoplasms. The patient might have a variety of symptoms related to exposure or might have health-related concerns about past exposure. The occurrence of thyroid diseases caused by exposure is indistinguishable from those that occur spontaneously. The patient might not have specific knowledge of the nature of the exposure, which might have occurred years earlier.

A history and appropriate physical examination supplemented with laboratory investigation, imaging studies, and fine-needle aspiration biopsy (FNAB) of the nodules in question should provide the clinician with sufficient information to assess the likelihood of malignancy and to advise his or her patients of appropriate treatment options.

Ultrasound can find many nodules not palpable during the physical examination. Ultrasound is being used for thyroid monitoring programs in other countries where some of the population has been exposed to I-131 releases. However, the use of thyroid ultrasound in mass

"Early detection of a change in health status is the most effective way to lessen the burden of more advanced disease and enhance survival."

Dr. Barry L. Johnson, assistant surgeon general and ATSDR assistant administrator, congressional testimony on the National Cancer Institute's Management of Radiation Studies (Congressional testimony 1998).

screenings for thyroid nodules is controversial because of its high sensitivity and low specificity.

If a nodule is identified, fine-needle aspiration biopsy (FNAB) performed by an experienced physician with appropriate training and experience is the procedure of choice. If the cytology of the nodule is malignant or nondiagnostic, the patient should be referred to a specialist for surgical resection.

Patient History

The medical history should include prior endocrine, thyroid, or parathyroid problems; prior thyroid diagnostic tests and treatments; and history of thyroid or neck surgery. Information about changes in the size of the nodule or nodules can assist in determining the etiology. Nodules that are unchanged for years are probably benign, but nodules that grow rapidly demand careful evaluation and are more likely to be associated with parathyroid disorders.

- History and physical exam should focus specifically on signs and symptoms related to the thyroid gland.

A family history of Hashimoto thyroiditis, benign thyroid nodule, or goiter favors a diagnosis of benign disease. Other history that suggests benign disease includes symptoms of hypothyroidism or hyperthyroidism, and pain or tenderness of the nodule. Risk factors for malignant disease can include a family history of thyroid carcinoma or multiple endocrine neoplasia type II; the patient's age (<20 years or >70 years); the patient's gender (male); recent changes in voice, breathing, or ability to swallow; and a childhood history of head, neck, or upper mediastinum radiation exposure.

Exposure History

An exposure history includes previous childhood head, neck, and upper mediastinum radiation exposure; previous residences (downwind from or proximity to nuclear testing or release sites); dietary habits since childhood; source of drinking water; occupational history; and hobbies. Milk consumption and source are important risk factors (for example, fresh versus processed milk; milk from a cow, sheep, or goat). The patient should be asked about symptoms consistent with hypothyroidism, hyperthyroidism, and disorders of calcium metabolism.

Exposure to I-131 could be indicated by the patient's answers to questions in the exposure history relating to the following:

- previous childhood head, neck, and upper mediastinum radiation exposure
- previous residences
- dietary habits since childhood
- milk consumption and source.

Populations exposed to I-131 can have a higher prevalence rate for thyroid nodules than populations that have not been exposed. Patients, especially infants and children who have been exposed to significant doses of I-131, are more susceptible to the associated negative health effects. The major clinical concerns after significant I-131 exposure include hypothyroidism and thyroid cancer.

Physical Examination

Physical examination of the neck and thyroid should evaluate the gland's size, presence of nodules, and the cervical lymph nodes. The thyroid gland should be inspected for shape, consistency, and areas of tenderness. Local examination of the neck is best accomplished with the patient seated in good light with the neck moderately extended. To facilitate the examination, the patient should be given a glass of water to assist swallowing. Auscultation of the neck provides some indication of the vascularity of the gland. A systolic or continuous bruit is usually associated with hyperthyroidism. The parathyroid glands are also susceptible to the effects of I-131 exposure. The presence of cervical lymphadenopathy, especially in children, might be the first sign of thyroid cancer. In general, a nodule 1 centimeter (cm) or greater should be palpable on physical examination.

Signs and symptoms that should prompt concern include rapid enlargement of a previous or new thyroid nodule, unilateral vocal cord paralysis, dysphagia, and dyspnea. A solitary nodule in an otherwise normal gland should raise the suspicion of thyroid carcinoma. A lesion is probably malignant if it is adherent to the surrounding structures (trachea or strap muscles). Palpable cervical lymphadenopathy adjacent to a thyroid nodule is suspicious for a carcinoma, or it might be the only indication of metastatic thyroid cancer when no thyroid nodule is palpable.

It would be appropriate to consult an internist, endocrinologist, a surgeon specializing in thyroid surgery, or an interventional radiologist when

assessing a patient with a suspicious thyroid nodule and an abnormal screening evaluation. These specialists can either assist with the interpretation of the screening results or formulate a management plan for the patient. (Information about specialists is available from the American Board of Medical Specialties, which has a Web site at URL: http://www.abms.org/).

Case Study (continued)

The woman is a well-developed, mildly overweight, well-nourished female who looks her stated age of 55 years. Palpation of her neck reveals an ill-defined thyroid that is slightly tender diffusely with a homogenous, rubbery texture. A 1-cm nodule is just palpable in the left lobe. Auscultation of the neck reveals no bruits, either over the carotids or over the thyroid. No cervical nodes are palpable. Chvostek and Trousseau signs are negative. Hair and skin appear unremarkable, with perhaps the exception of some puffiness of the face. No evidence of mental dullness is seen. Deep tendon reflexes are normal without prolongation of relaxation phase. The rest of the examination is unremarkable.

When requestioned about specific symptoms of hypothyroidism, your patient admits that she has felt a bit more tired lately. She has been constipated occasionally and intolerant of cold. She has gained weight despite eating less. She attributed these symptoms to aging and had not thought much about them.

Challenge Questions

(7) Which diagnostic tests are recommended for routine initial screening of thyroid function?

(8) What additional tests could be obtained for the evaluation of a thyroid nodule?

Laboratory Analysis

No evaluation of the thyroid gland is complete without a structural assessment (physical exam) and a functional assessment (blood analysis to determine the TSH level). Thyroid function tests are mandatory for evaluation of a thyroid nodule; however, these tests do not differentiate between benign and malignant nodules.

- Initial laboratory evaluation should include a serum thyroid stimulating hormone (TSH) level.

In screening programs, it is important to test for the noncancerous effects of I-131. The serum TSH level should be obtained to identify those patients with thyroid gland dysfunction. If TSH is abnormal, serum free thyroxine (FT4) and levothyroxine (T3) levels should be measured. Most patients with thyroid cancer are euthyroid (their thyroid glands function normally), and it is rare for a patient with thyroid cancer to have an abnormal TSH level.

- Screening patients for thyroid effects of I-131 is different from evaluating a known thyroid nodule.

Chronic autoimmune thyroiditis can be found with an increased TSH level and a thyroid nodule or bilateral nodules. Serum antithyroid peroxidase antibody and antithyroglobulin antibody levels can assist in the diagnosis of chronic autoimmune thyroiditis. However, the diagnosis of chronic autoimmune thyroiditis does not exclude the presence of cancer within the thyroid gland. Serum calcium levels should be assessed because of the risk for hyperparathyroidism after I-131 exposure. If the calcium level is abnormal, measure parathyroid hormone and phosphorus.

Ultrasound is useful to determine the size and physical characteristics of a nodule once it has been identified. However, ultrasound cannot differentiate benign from malignant nodules and therefore is not required in the evaluation of a palpable thyroid nodule.

Case Study (continued)

Your patient's lab results were as follows:

A thyroid ultrasound showed a heterogeneous gland with multiple small cysts and one 1-cm x 1-cm cyst in the left lobe.

Parameter	Result	Normal Range
TSH	7.0 nanograms per milliliter (ng/mL)	0.36–4.7 ng/mL
FT4	0.83	0.83–1.44
T3 resin uptake	1.2 micrograms per deciliter (µg/dL)	0.8–1.2 µg/dL
Calcitonin	15 picograms per milliliter (pg/mL)	< 20 pg/mL
Calcium	9.1 milligrams per deciliter (mg/dL)	8.5–10.4 mg/dL
Ionized calcium	1.30 millimoles per liter (mmol/L)	1.16–1.32 mmol/L
Phosphorus	2.9 mg/dL	2.8–4.6 mg/dL
Parathyroid hormone	50 pg/mL	10–65 pg/m

Challenge Question

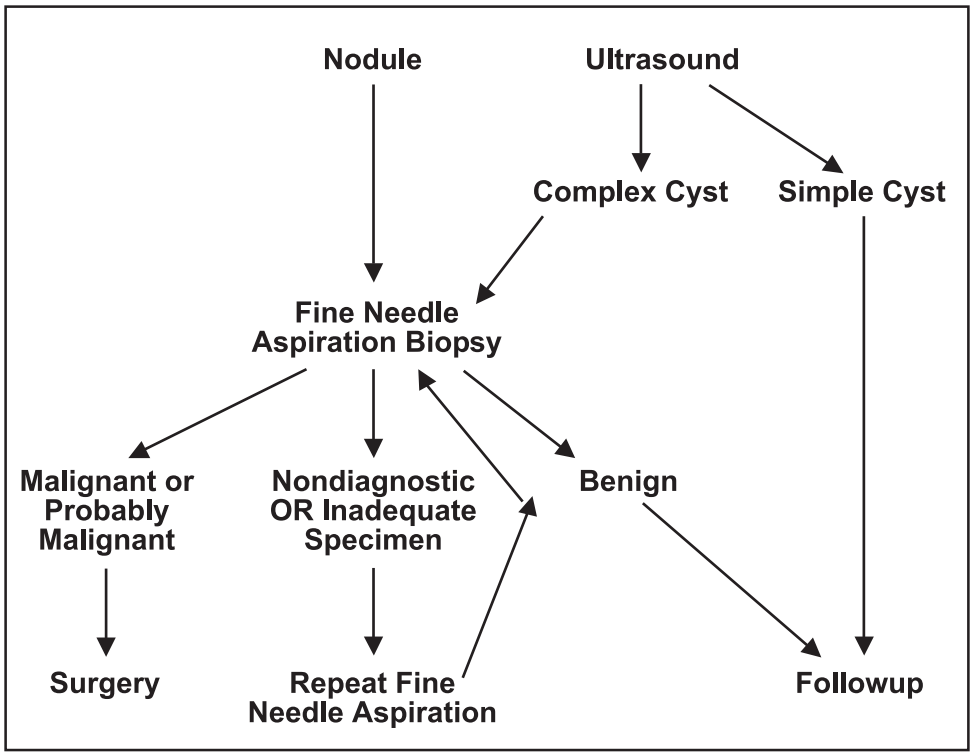
(9) What are the recommendations for managing a thyroid nodule found to be benign by FNAB in a patient with a history of exposure to I-131?

Fine Needle Aspiration Biopsy

- Fine needle aspiration biopsy is the procedure of choice for evaluating whether or not a thyroid nodule is malignant.

The challenge to clinicians is to distinguish benign nodules from malignant tumors. The prevalence of clinical thyroid cancer in the general population is significantly less than 1%, and the majority of nodules are benign. Fine needle aspiration biopsy (FNAB) is the procedure of choice for evaluating a palpable nodule. The technique is simple and generally free of complications when performed by an experienced physician with appropriate training. If a nodule is found with ultrasound, the physician must differentiate between a simple cyst and a complex cyst. A simple cyst will require followup. A complex cyst must undergo an FNAB. If the results of the cytologic examination indicate the nodule is benign, no further testing is required but followup should be on an annual basis. Nondiagnostic results call for a repeat of the FNAB. Diagnosis of a malignancy or a probable malignancy requires surgery. (Figure 2 illustrates the process of nodule evaluation.)

Figure 2. Evaluation of a Euthyroid Nodule



FNAB is reportedly superior to all other techniques for diagnosing thyroid cancer. The use of FNAB can reduce the number of unnecessary surgical operations for suspicious nodules that prove to be benign. It is also the procedure of choice for evaluating a complex cyst after it has been identified on ultrasound imaging of the thyroid gland. Very few palpable thyroid nodules are actually simple cysts (defined as a cystic structure with no internal echoes and no evidence of thickening of the cyst wall). Most palpable thyroid nodules are solid nodules with cystic components. A simple cyst is almost always benign. Occasionally, cancer is found in the wall of the cyst. For this reason, recurrent cysts should be imaged by ultrasound. Surgical evaluation is indicated if evidence exists for a separate lesion or growth in the wall of the cyst.

FNAB for cytology with ultrasound guidance is often a diagnostic procedure; when the nodule is cystic, FNAB might also be curative. A satisfactory aspirate specimen combined with an accurate cytology evaluation by a cytopathologist provides a reliable means of differentiating between a benign and malignant nodule in all but highly cellular or follicular lesions. FNAB does not allow for differentiating Hashimoto disease from lymphoma of the thyroid. This can be done using a combination of FNAB cytology and clinical evaluation. A "nondiagnostic" specimen should be followed up with a repeat FNAB. A nodule that gives persistently nondiagnostic FNAB results should be surgically removed.

In general, 20% to 30% of patients are referred for surgical evaluation on the basis of FNAB cytologic features.

Cytologic Assessment

Diagnosis and classification of thyroid cancers are performed by cytology. The most efficient way of screening for thyroid malignancy in a patient is to elicit a thorough history and perform a careful physical examination, followed by an FNAB and interpretation of the specimen by an experienced cytopathologist. Neck ultrasound is an ideal technique for establishing whether a palpable cervical mass is within or adjacent to the thyroid, and for differentiating thyroid nodules from other neck masses such as cystic hygromas, thyroglossal duct cysts, and enlarged lymph nodes. Papillary thyroid cancer is the most common type of cancer found among the population exposed to I-131 releases in Chernobyl.

Case Study (continued)

The patient in the case study was diagnosed with mild hypothyroidism and prescribed levothyroxine (50 µg/day). She was seen 1 month later; test results revealed TSH of 3.1 ng/mL (normal 0.36–4.7 ng/mL). She had lost 3 pounds and felt less tired.

Challenge Question

(10) Are the patient and the rest of her family at increased risk for cancer? Is there increased risk for any other disease? Were there any risks to her daughter's unborn child because of the patient's (and potentially the daughter's) past exposure to I-131?

Treatment and Management

Initial and Follow-Up Visits for Patients Identified as Exposed to I-131

The major clinical concerns after significant I-131 exposure, especially in infants and children who are more susceptible than adults, include developing hypothyroidism and thyroid cancer. Currently, children who are born in the United States are screened at birth for thyroid function; therefore, no thyroid tests are necessary for children growing normally without other medical problems, unless they are exposed to significant doses of I-131.

If a nodule is benign, the patient could be treated with T4 in a dose sufficient to suppress serum TSH, which will limit glandular growth. If the nodule decreases in size, the patient should be maintained on T4 indefinitely and the nodule monitored with palpation and ultrasound. If the nodule persists while the patient is on T4 therapy, a repeat FNAB is necessary. If the nodule grows during T4 therapy, surgical resection is indicated.

Distant metastasis is uncommon, but lung and bone are the most common sites. In the case of thyroid cancer that has metastasized to other organs, it is helpful to have additional pathology analysis to determine whether the cancer is a thyroid cancer or whether it originated from another organ. This is particularly important in the case of former nuclear workers who might be eligible for compensation only for cancer originating from certain organs, or for nonworkers who are seeking compensation through the legal system for exposure health outcomes.

Approach to the Patient and Family

To work effectively with patients, physicians need to understand that people who have been exposed to radiation are having normal, typical emotional responses that are to be expected under the circumstances. After any exposure, it is important that the psychologic support for the patient be combined with a risk communication plan to provide accurate information about the acute and delayed health effects of I-131. This will

Table 1. Summary of Initial and Follow-Up Visits for Patients Identified as Exposed to I–131 in Previous Years

Exam	Test	Results	Actions
Initial patient visit	Medical history	History of exposure only with normal examination and screening tests	Educate patient on early warning signs of thyroid and parathyroid diseases.
	Physical exam with thyroid gland palpation	Thyroid nodule found (1 cm or larger)	Begin screening workup. Schedule next visit.
	Serum thyroid stimulating hormone (TSH) level	TSH or serum free thyroxine (FT4) abnormalities	Obtain levels of serum calcium, parathyroid hormone (PTH), FT4, and antithyroid peroxidase antibodies. Refer patient to an endocrinologist, as appropriate.
		Abnormal serum calcium level	Redraw blood; if abnormal, test for PTH and refer to endocrinologist as appropriate.
		Abnormal antithyroid peroxidase antibody level	Schedule repeat exam in 1 year with palpation and thyroid function tests. Refer patient to an endocrinologist, as appropriate.
		Normal antithyroid peroxidase antibody level	
Follow-up visit for a patient with a palpable thyroid nodule	Follow medical protocol for ultrasound and FNAB	Normal or benign	Schedule next visit. See Figure 2.
		Abnormal or nondiagnostic	Schedule for evaluation by surgeon.
During future physical examinations	Medical history update		
	Serum TSH and calcium levels	Normal examination and tests	Educate patient on early warning signs of thyroid and parathyroid diseases.
		Abnormal examination or tests	Schedule for evaluation by surgeon.
	Physical exam with thyroid palpation	Thyroid nodule found (1 cm or larger)	Begin screening workup. Schedule next visit.

The frequency of examinations will depend on the presence of any thyroid abnormalities. For patients who have no abnormalities identified initially, no periodic visits are necessary but TSH should be tested when a physical is performed. For patients with abnormalities, the provider should schedule examinations at yearly intervals.

- Most people affected by I-131 exposure are psychologically healthy, functioning adults who are experiencing high levels of stress.
- Accurate information on the possible health effects of I-131 is needed after exposures due to nuclear releases.

give exposed persons some of the information they need to understand the event. To ensure that information is accurately and completely understood, it may need to be repeated over a period of days or weeks. Distribution of clearly written information, with references to the scientific literature, might also be useful. Provision of timely and correct information is one key to preventing stress and relieving psychosocial effects after notification of the potential health risks of I-131 exposure.

Persons exposed to I-131, as well as family members of those exposed, need an opportunity to ask questions of health experts about the potential risk for present or future effects. Psychologic support should be continued after the immediate event because fear of possible future health effects can persist and might contribute to psychologic illness.

Distress Versus Disease

Most people will suffer normal emotional distress; only a few will develop psychologic illnesses depending on the circumstances of their exposure. Specific psychotherapeutic or psychopharmacologic treatments might also be useful to treat posttraumatic stress disorders, anxiety disorders, or depression that might occur in some patients in the aftermath of exposure. However, if depression occurs in a patient exposed to I-131, it is important to differentiate organically based mood changes possibly related to hypothyroidism from psychologically based depression related to stress about the exposure. Depression is a disorder, but can be a symptom. Symptoms similar to depression, such as a sad mood, lethargy, and lack of appetite, can be caused by an underlying hypothyroid condition, which must be diagnosed and treated correctly and not mistaken for depression. Consultations between endocrinologists and psychiatrists are recommended for these complex situations.

Challenge Question

(11) How can you find out if potassium iodide (KI) is available to your community in case of an emergency?

Acute Exposure

To reduce internal exposure to I-131 by inhalation, residents of communities near a release could stay indoors with the doors and windows closed to keep contaminated air out of their homes. Moist towels can be laid on window sills and at the bottom of doors to reduce air infiltration. The exposure scenario determines the relative significance of the different pathways (Whicker and Pinder 2002).

Prophylactic Administration of Stable Iodine (Potassium Iodide)

Potassium iodide (KI) is the preferred form of stable iodine. Thyroid uptake of I-131 can be reduced by more than 90% through an immediate oral dose of KI. Failure to administer KI within 2–4 hours after exposure to I-131 eliminates protection against the risk for adverse health outcomes.

Taking KI just before or within 1 to 2 hours after exposure to I-131 can block more than 90% of the radioactive iodine uptake by the thyroid. This means that public health officials must notify the public and the health professional community of I-131 releases immediately. If KI is taken 3 hours after acute exposure, approximately 50% of the thyroid uptake of I-131 is blocked. When KI is taken 4 hours after acute exposure, only 10% of the I-131 thyroid uptake is blocked. Taking KI more than 4 hours after exposure provides little protection unless the exposure to I-131 continues. Contraindications include allergies to iodine and must be considered before administering KI. Potassium iodate (KIO_3) can also be used, although it might be associated with slightly more gastrointestinal irritation. Information on age-specific dosage recommendations is given in Table 2. Precautions and contraindications applicable to KI are found in Food and Drug Administration (FDA) guidelines (FDA 2001). To continue treatment, doses of KI should be administered once each day for 7 to 14 days to prevent recycling of the I-131 into the thyroid.

- Administration of potassium iodide (KI) can significantly reduce thyroid I-131 uptake.

Table 2. Recommended Single Doses of Potassium Iodide (KI) as a Blocking Agent, by Age Group

Age Group	Fraction of Tablet	
	130 milligram	65 milligram
Neonates (birth to 1 month)	1/8	1/4
Infants (1 month–3 years)	1/4	1/2
Children (3–12 years)	1/2	1
Adolescents and adults (12–40 years)	1	2
Adults over 40 years	0	0

For persons older than 40 years of age, the risk for radiation-induced thyroid cancer is extremely low, while the potential side effects of prophylaxis due to preexisting thyroid disease tend to increase. Adults over 40 therefore do not need to take potassium iodide as prophylaxis for exposure to I-131. In the United States, the FDA has recommended prophylaxis with stable iodine when the committed dose equivalent to the adult thyroid is expected to exceed 250 milliSieverts (mSv), the equivalent of 25 rem (Roentgen equivalent in man or mammal) (FDA

2001). Sale or use of KI for this purpose does not require a physician's prescription.

Current Nuclear Regulatory Commission (NRC) policy acknowledges that the use of KI is a protective measure for specific local conditions for populations exposed to I-131. It also states that KI is an inexpensive and reasonable supplement to sheltering and evacuation in case of a nuclear release. NRC policy requires that consideration be given to the use of KI in developing site-specific emergency plans.

If you live within 50 miles of a nuclear facility (Emergency Planning Zones or EPZ) that produces or is capable of releasing I-131, you should work with your medical association, local or state public health department, emergency response organizations, and elected representatives to ensure that a stockpile of KI is available and a distribution plan is in place. Predistribution of sealed packets of KI tablets to residents within the EPZ, combined with educational materials, instructions, and engagement in exercises would enable a significant percentage of the at-risk population to efficiently undergo prophylaxis when so advised by public health officials. However, because predistribution is unlikely to completely reach the target or vulnerable population, supplemental stocks of KI tablets should be stored at strategic locations such as schools, hospitals, pharmacies, fire departments, and police stations. Individually sealed tablets of KI incorporated into a cardlike dose pack will be stable for 5–10 years, or possibly longer.

The easiest way to reduce or eliminate internal exposure to I-131 during a release is to find an alternate food source of items produced outside the contamination zone. Contaminated milk can be made into cheese, yogurt, or ice cream; it can also be converted to powdered milk that can be used after the I-131 decays away.

- The conversion of contaminated milk to powdered milk, cheese, yogurt, or ice cream allows I-131 to decay to lower levels, thus reducing radiation exposure.

Challenge Questions

(12) What are some of the factors that can affect the way an individual (or a community) perceives the risk of exposure to I-131?

(13) How can you communicate information about the risks associated with exposure to I-131 to your patients and your community?

Communicating About Risks

During the Three Mile Island release in 1979, the population in the area perceived a high risk associated with the release. Poor management of the situation and poor communication with the population in the affected area led to mistrust and increased levels of psychosocial stress that remained elevated for many years.

The field of health risk communication has developed science-based approaches for communicating effectively in high-concern, low-trust, sensitive, or controversial situations. Good risk communication involves a dialogue among all persons and groups concerned to communicate the nature and level of risk and the steps to take to change that level. The goal of risk communication is to increase knowledge and understanding, to enhance trust and credibility, and to resolve conflict.

Risk communication is of critical importance in the evaluation and management of persons with concerns about past exposure to I-131. It involves the characterization of information with the involvement of individuals and communities who might have been exposed. These individuals and communities are stakeholders in the risk communication process. In this process the risks are effectively communicated, relieving tension and anxiety, improving subsequent communications, and increasing the effectiveness of risk management decisions.

The perception of risk by individuals or communities can be affected by several factors other than how the risk is communicated. This includes cultural, social and economic level, geographic location, previous experience, and other variables inherent to the individual, such as personality. In matters of high concern and low trust, perception equals reality. Peter Sandman (1993) developed a framework for dealing with risk. Risks that are

- natural are more readily accepted than those that are man-made
- visible and avoidable are more readily accepted than those that are unseen and imposed by others
- voluntarily assumed are more acceptable than those that are involuntarily imposed
- familiar are more acceptable than risks that are exotic or unfamiliar.

The public might be distrustful and upset because a real threat to their health has occurred. They expect to receive information about the incident, about who is exposed and what dose was received, and about how the exposure will affect their health. The level of trust a source has developed with a community will determine how credible the community will perceive the message to be.

Empathy and caring, dedication and commitment, competence and expertise, and honesty and openness are important trust and credibility factors. Health care providers are among the top third in surveys on trust and credibility on health and environmental issues.

Key issues within communities are health, safety, environment, quality of life, fairness, legality, and economics. The media has an important role in

- Effective risk communication allows the populations affected to improve decision making; it also can relieve tension.
- Perception of risk is affected by many factors and can be unrelated to actual risk.
- Good communicators establish trust by getting factual, timely information to the community and including all stakeholders early in the process.

communicating risks to the general public and should be included as partners in a risk communication plan. Government officials and health care and public health professionals often seek out the media, or are sought out by the media, to explain risk resulting from catastrophic events. A communications plan must be in place before such an event to maximize the opportunity to promptly and accurately inform the public.

In communicating information about health risks, it is important for messages to be consistent. Coordinate with your local medical association, local or state public health department, emergency response organizations, and elected representatives to ensure that all segments of the community receive clear and consistent messages.

Persons with concerns about exposure to I-131 might have fear and anger that need to be addressed in a timely manner by health care providers. The health care provider can encourage trust and credibility by getting the facts of the exposure straight, being forthcoming with information that meets the needs of the individuals, coordinating efforts with public health agencies, and avoiding giving mixed messages.

In persons with concerns about I-131 exposure, great uncertainty exists about the risk. Uncertainty exists with respect to previous and present exposures, the dose received by individuals, the clinical significance of exposure and dose, and who might be legally and morally responsible for the financial costs of the exposure. The health care provider needs to anticipate this uncertainty to effectively help the patient recognize the risks. It is important to deal with the uncertainty; listen to and deal with specific concerns; convey the same information to all segments of your audience; and explain risk in language people understand, simplifying language and presentation, but not content.

Standards and Regulations

Environmental Protection Standards

The United States (FDA and EPA) and the World Health Organization (WHO) have issued standards that limit the amount of contamination in food, water, and air.

Table 3 provides a summary of standards for environmental and occupational exposures to I-131. The FDA food concentration guidelines both (a) restrict the flow of contaminated food out of an affected area into the regional or global food supply and (b) set limits on local consumption of affected food and water. If limits are exceeded for the local population, uncontaminated food should be provided from outside the affected area. This also applies to drinking water with I-131 levels above EPA limits.

Occupational limits for radionuclide exposure address ingestion, inhalation, and external exposure and are set by the Nuclear Regulatory Commission (NRC) for NRC licensees and by the Department of Energy for DOE facilities. The NRC limits for I-131 are as follows:

- 2×10^{-8} µCi/mL (for occupational air exposure)
- 2×10^{-10} µCi/mL (for effluent air to which the public could be exposed)
- 1×10^{-6} µCi/mL (in effluent water), and
- 1×10^{-5} µCi/mL (for monthly average releases to sewers from medical facilities).

These NRC limits are intended to ensure that no worker exceeds 50 mSv (5 rem) of I-131 to the whole body or 500 mSv (50 rem) to the thyroid, and that no member of the public exceeds 1 mSv (0.1 rem) to the whole body.

- Standards and regulations have been established to limit the use of I-131 for medical purposes and the concentration of I-131 released into the environment.

Table 3. Summary of Recommended Maximum Concentrations of I-131 in Specific Media and for Occupational Exposure

Agency	Media	Standard
U.S. Environmental Protection Agency	Drinking water	4 Becquerels per liter (108 pCi/L)
	Air	100 pCi/m3
Food and Drug Administration	Food in commerce (derived intervention level)*	170 Becquerels per kilogram (4,600 pCi/kg)
NRC, DOE, OSHA, National Council on Radiation Protection and Measurement (NCRP), and International Commission on Radiological Protection (ICRP)	Annual occupational exposure limits†	50 mSv (5 rem) (whole body) 500 mSv (50 rem) (thyroid)

* Foods destined for general consumption and also for infant milk and drinking water.
† Additional limits of 100 mSv (10 rem) over 5 years or a cumulative dose limit of 10 mSv (1rem) times age in years (ICRP).

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Answers to Pretest and Challenge Questions

Pretest

(a) The thyroid gland is the critical organ for I-131 exposure. Essentially all of the iodine entering the body quickly becomes systemic (EPA 1988), with approximately 30% depositing in the thyroid.

(b) The main route of human internal I-131 exposure of humans is ingestion of contaminated fresh dairy products, eggs, and leafy vegetables, depending on downwind distance from the release; the major source of internal exposure is milk consumption. Goat's and sheep's milk contain approximately 10 times the concentration of radioiodine found in cow's milk.

(c) I-131 in large amounts can produce thyroiditis. Hypothyroidism and thyroid cancer can result from smaller exposures of I-131 and its accumulation in the thyroid gland.

(d) Infants and children are the groups most sensitive to I-131 exposure. The dose to children is much higher than for adults because the thyroid mass in children is smaller than that for adults; the first week of life is an especially vulnerable period. Populations in the former Soviet Union exposed to much larger radiation doses (especially those affected by the Chernobyl nuclear release) showed an increased incidence of thyroid cancer for children younger than 15 years old at the time of the release.

Challenge

(1) The main sources of I-131 in the environment have been from nuclear power plant releases and nuclear weapons production and testing. The main sources in the United States have been the Nevada test site and the Hanford Nuclear Reservation.

(2) Dietary intake of iodine before exposure is important because a relative iodine deficiency increases the thyroid uptake of I-131. After exposure, the most critical dietary information needed is the amount and type of milk and milk products consumed, their I-131 concentrations, and the time they were consumed relative to the time of the release. The concentration of I-131 in goat's and sheep's milk is 10 times that of cow's milk. Fresh milk drunk directly on the farm has higher amounts of I-131 than the amount in milk that has been sent from the farm to the processing plant and then to a store. This variation in amount of I-131 is related to the short half-life of I-131 and the decay that occurs in the time the milk is

processed. Although cheese and other aged-milk products tend to have lower amounts of I-131, it is also important to determine how much of these products have been consumed and what their I-131 concentrations were when they were consumed.

(3) Infants and children are the groups most sensitive to I-131 exposure. The dose to children is much higher than the dose to adults because the thyroid mass in children is smaller than that of adults. The first week of life is an especially vulnerable period. Populations in the former Soviet Union exposed to much larger radiation doses (especially those affected by the Chernobyl nuclear release) showed an increased incidence of thyroid cancer for children younger than 15 years old at the time of the release.

(4) I-131 has a strong affinity for the thyroid gland, which is the critical target organ for exposure. Essentially all of the iodine entering the body quickly becomes systemic (EPA 1988), with approximately 30% distributing to the thyroid.

(5) This patient's exposure history should include previous childhood head, neck, and upper mediastinum radiation exposure; previous residences (proximity to nuclear testing or release sites); dietary habits since childhood, including milk consumption and source (fresh vs. processed milk; whether milk was from a cow, sheep, or goat); source of drinking water; occupational history; and hobbies. Patients who consumed goat's milk contaminated with I-131 have a higher radiation dose of exposure than if they drank contaminated cow's milk from the same pasture. The patient also should be asked about symptoms consistent with hypothyroidism, hyperthyroidism, and disorders of calcium metabolism.

(6) Fine needle aspiration biopsy (FNAB) is the procedure of choice for evaluating a palpable nodule and determining whether or not it is malignant.

(7) Serum TSH level is a useful initial screening assay because it can identify patients with either thyrotoxicosis or hypothyroidism. Chronic autoimmune thyroiditis can present with an increased TSH level and a thyroid nodule.

(8) Serum FT4 and T3 should be measured if TSH is abnormal. A serum calcitonin level should be obtained if either a medullary thyroid carcinoma or a multiple endocrine neoplasia type II is suspected. Also, because of the risk of hyperparathyroidism after exposure to I-131, serum calcium, phosphorus, and parathyroid hormone should be assessed.

(9) If the nodule is found to be benign by FNAB, the patient could be treated with T4 in a dose sufficient to suppress serum TSH, which will limit glandular growth. If the nodule decreases in size, the

patient should be maintained on T4 indefinitely and the nodule monitored with ultrasound. If the nodule persists while on T4 therapy, the patient will need a repeat FNAB. If the nodule grows during T4 therapy, a surgical resection is indicated.

(10) The patient and her husband are at higher risk for developing thyroid disease or thyroid cancer because they received higher levels of exposure to I-131 than persons who did not live near the Hanford Reservation during the time of the highest I-131 emissions. The daughter is not at higher risk because she was born in 1963, and emissions decreased after 1962. No higher risk for any other disease is known. Children in the United States are screened at birth for thyroid function; no further thyroid tests are needed if the child is growing normally without other medical problems. Good prenatal care would be highly advised for your patient's daughter. However, you could reasonably reassure your patient that an abnormal pregnancy outcome as a result of exposure to I-131 is unlikely because all of the potential exposures for the patient and her daughter were in the past.

(11) If you live within 50 miles of a nuclear facility that produces or is capable of releasing I-131, you should work with your medical association, local or state public health department, emergency response organizations, and elected representatives to ensure that a stockpile of KI is available and a distribution plan is in place to distribute it if required.

(12) The perception of risk by individuals or communities can be affected by several factors other than how the risk is communicated. This includes culture, social and economic level, geographic location, previous experiences, and other variables inherent to the individual. In matters of high concern and low trust, perception equals reality. Peter Sandman (1993) developed the following framework for dealing with risk:
"Risks that are

- natural are more readily accepted than those that are man-made
- visible and avoidable are more readily accepted than those that are unseen and imposed by others
- voluntarily assumed are more acceptable than those that are involuntarily imposed
- familiar are more acceptable than risks that are exotic or unfamiliar."

(13) The health care provider can encourage trust and credibility by getting the facts of the exposure straight, being forthcoming with

information that meets the needs of the individuals, coordinating efforts with public health agencies, and avoiding giving mixed messages. It is important to deal with the uncertainty; listen to and deal with specific concerns; convey the same information to all segments of the audience; and explain risk in language people understand, simplifying language and presentation, but not content.

Additional Sources of Information

Hanford Community Health Project (HCHP)

HCHP is an education and outreach program for persons exposed as young children to past releases (between the years 1945 and 1951) of I-131 from the Hanford Nuclear Reservation. HCHP is sponsored by ATSDR and makes a variety of health information material related to I-131 exposure available to citizens. For more information about HCHP, contact

Hanford Community Health Project
1-800-207-3996
hanford@norcmail.uchicago.edu
www.atsdr.cdc.gov

or

ATSDR Information Center
1-888-42ATSDR (1-888-422-8737)
atsdric@cdc.gov
www.atsdr.cdc.gov

National Cancer Institute

The National Cancer Institute (NCI) has developed new educational materials that will help people understand their potential thyroid cancer risk from iodine 131 (I-131) radiation fallout from nuclear testing in the 1950s and early 1960s. Materials include brochures, a thyroid screening decision aid, public service announcements, and a new interactive Web site that incorporates a dose calculator for assessing individual exposure.

The NCI I-131 Web site, which includes fact sheets, PowerPoint presentations, a dose calculator, and many additional resources, is available at URL: http://www.cancer.gov/i131. You may also call NCI's Cancer Information Service at 1-800-4-CANCER (1-800-422-6237) to receive free copies of print publications.

Additional Sources of Information

More information on the adverse effects of I-131 and the treatment and management of persons exposed to it can be obtained from ATSDR, your

state and local health departments, and university medical centers. For clinical consultation and assistance, physicians and other health care providers are urged to contact the following:

Radiation Emergency Assistance Center/Training Site (REAC/TS)
c/o Oak Ridge Institute for Science and Education
P.O. Box 117
Oak Ridge, TN 37831-0117
Telephone: 865-576-3131 - ask for REACTS staff on call (M-F 8am-5pm EST); nights, weekends and holidays call 865-576-1005
Web site: www.orau.gov/reacts

Nuclear Regulatory Commission (NRC)
Telephone: 301-816-5100
Web site: www.nrc.gov/what-we-do/regulatory/allegations/safety-concern.html

Chemical Transportation Emergency Center (CHEMTREC)
Telephone: 1-800-424-9300 (24-hour hotline)
Web site: www.chemtrec.org (provides a reference to available resources).

U.S. Department of Energy (DOE)
Telephone: 1-800-dial-DOE (1-800-342-5363)
Web site: www.energy.gov

DOE regional coordinating offices should be notified for radiologic assistance. At the request of a patient or the attending physician, a DOE radiologic assistance team physician can give advice about hospitalization and further definitive treatment. The physician can also make available special DOE medical facilities for the diagnosis and treatment of radiation injury. DOE's geographic areas of responsibility are listed below. The resources of 13 federal agencies are available through DOE.

Department of Energy Regional Offices

Region 1
(Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont)

Brookhaven Area Office; Upton, Long Island, New York, NY 11973
Telephone: 516-345-2200.

Region 2
(Arkansas, Kentucky, Louisiana, Mississippi, Missouri, Puerto Rico, Tennessee, Virgin Islands, Virginia, and West Virginia)
Oak Ridge Operations Office; P.O. Box E; Oak Ridge, TN 37831
Telephone: 865-525-7885.

Region 3
(Alabama, Canal Zone, Florida, Georgia, North Carolina, and South Carolina)
Savannah River Operations Office; P.O. Box A; Aiken, SC 29802
Telephone: 803-824-6331, extension 3333.

Region 4
(Arizona, Kansas, New Mexico, Oklahoma, and Texas)
Albuquerque Operations Office; P.O. Box 5400; Albuquerque, NM 87115
Telephone: 505-844-4667.

Region 5
(Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin)
Chicago Operations Office; 9800 S Cass Avenue; Argonne, IL 60439
Telephone: 312-972-5731 or 312-972-4800.

Region 6
(Colorado, Idaho, Montana, Utah, and Wyoming)
Idaho Operations Office; P.O. Box 2108; Idaho Falls, ID 83401
Telephone: 208-526 1515.

Region 7
(California, Hawaii, and Nevada)
San Francisco Operations Office; 333 Broadway; Oakland, CA 94612
Telephone: 510-273-4237.

Region 8
(Alaska, Oregon, and Washington)
Richland Operations Office; P.O. Box 550; Richland, WA 99352
Telephone: 509-842-7381.

Case Studies in Environmental Medicine:

Radiation Exposure From Iodine 131

Evaluation Questionnaire and Posttest, Course Number SS3059

Course Goal:

To increase the primary care provider's knowledge of hazardous substances in the environment and to aid the evaluation of potentially exposed patients.

Objectives:

- Describe the major sources of I-131 in the environment.
- Identify the major routes of human exposure.
- Describe the population group most at risk for health effects from past exposure to I-131 and why.
- Describe the four factors contributing to the internal dose of I-131 contamination.
- Assess a patient's environmental or occupational exposure to I-131.
- Describe the diagnostic evaluation of a thyroid nodule in an individual exposed to I-131.
- List two important actions to take if an environmental release of I-131 occurs.
- Discuss indications for prophylactic use of potassium iodine (KI) after an I-131 exposure.
- List three sources of information one could access if there is a release of I-131.

Tell Us About Yourself

Please read the questions carefully. Provide answers on the answer sheet (page 55). Your credit will be awarded based on the type of credit you select.

1. What type of continuing education credit do you wish to receive?
****Nurses should request CNE, not CEU. See note on page 53.**

A. CME (for physicians)
B. CME (for nonphysicians)
C. CNE (continuing nursing education)
D. CEU (continuing education units)
E. [Not used]
F. [Not used]
G. [Not used]
H. CHES (certified health education specialist)
I. None of the above

2. Are you a...

A. Nurse
B. Pharmacist
C. Physician
D. Veterinarian
E. None of the above

3. What is your highest level of education?

A. High school or equivalent
B. Associate, 2-year degree
C. Bachelor's degree
D. Master's degree
E. Doctorate
F. Other

4. Each year, approximately how many patients with iodine 131 exposure do you see?

A. None
B. 1–5
C. 6–10
D. 11–15
E. More than 15

5. Which of the following best describes your current occupation?

A. Environmental health professional
B. Epidemiologist
C. Health educator
D. Laboratorian
E. Physician assistant
F. Industrial hygienist
G. Sanitarian
H. Toxicologist
I. Other patient care provider
J. Student
K. None of the above

6. Which of the following best describes your current work setting?

A. Academic (public and private)
B. Private health care organization
C. Public health organization
D. Environmental health organization
E. Nonprofit organization
F. Other work setting

7. Which of the following best describes the organization in which you work?

A. Federal government
B. State government
C. County government
D. Local government
E. Nongovernmental agency
F. Other type of organization

Tell Us About the Course

8. How did you obtain this course?

A. Downloaded or printed from Web site
B. Shared materials with colleagues
C. By mail from ATSDR
D. Not applicable

9. How did you first learn about this course?

A. State publication (or other state-sponsored communication)
B. MMWR
C. ATSDR Internet site or homepage
D. PHTN source (PHTN Web site, e-mail announcement)
E. Colleague
F. Other

10. What was the most important factor in your decision to obtain this course?

A. Content
B. Continuing education credit
C. Supervisor recommended
D. Previous participation in ATSDR training
E. Previous participation in CDC and PHTN training
F. Ability to take the course at my convenience
G. Other

11. How much time did you spend completing the course, and the evaluation and posttest?

A. 1 to 1.5 hours
B. More than 1.5 hours but less than 2 hours
C. 2 to 2.5 hours
D. More than 2.5 hours but less than 3 hours
E. 3 hours or more

12. Please rate your level of knowledge before completing this course.

A. Great deal of knowledge about the content
B. Fair amount of knowledge about the content
C. Limited knowledge about the content
D. No prior knowledge about the content
E. No opinion

13. Please estimate your knowledge gain after completing this course.

A. Gained a great deal of knowledge about the content
B. Gained a fair amount of knowledge about the content
C. Gained a limited amount of knowledge about the content
D. Did not gain any knowledge about the content
E. No opinion

Please use the scale below to rate your level of agreement with the following statements (questions 14–28) about this course.

A. Agree
B. No opinion
C. Disagree
D. Not applicable

14. The objectives are relevant to the goal.

15. The tables and figures are an effective learning resource.

16. The content in this course was appropriate for my training needs.

17. Participation in this course enhanced my professional effectiveness.

18. I will recommend this course to my colleagues.

19. Overall, this course enhanced my ability to understand the content.

20. I am confident that I can describe the major sources of I-131 in the environment.

21. I am confident I can identify the major routes of human exposure to I-131.

22. I am confident I can describe the population group most at risk for health effects from past exposure to I-131 and tell why.

23. I am confident I can describe the four factors contributing to the internal dose of I-131 contamination.

24. I am confident I can assess a patient's environmental or occupational exposure to I-131.

25. I am confident I can describe the diagnostic evaluation of a thyroid nodule in an individual exposed to I-131.

26. I am confident I can list two important actions to take if an environmental release of I-131 occurs.

27. I am confident that I can discuss indications for prophylactic use of potassium iodine (KI) after an I-131 exposure.

28. I am confident I can list three sources of information one could access if there is a release of I-131.

Posttest

If you wish to receive continuing education credit for this program, you must complete this posttest. Each question below contains five suggested answers, of which one or more is correct. Choose all correct answers for each question.

29. The main source of internal contamination with I-131 near a nuclear release is

(A) air.
(B) water.
(C) vegetables.
(D) milk.
(E) dietary products.

30. What age or functional group is most sensitive to thyroid disease after I-131 exposure?

(A) Pregnant women between 25 and 40 years old.
(B) Elderly persons (older than 65 years old).
(C) Children younger than 5 years old.
(D) School-aged athletes who practice outdoors.
(E) Women between 14 and 44 years old.

31. The thyroid dose of I-131 due to milk consumption is elevated

(A) when people drink fresh cow's milk.
(B) when people drink fresh goat's and sheep's milk.
(C) in an area with an iodine-deficient diet.
(D) when people eat dairy products.
(E) when people are inhaling the contaminated air.

32. What is the initial test for screening a patient for the noncancerous effects of I-131?

(A) Ultrasound imaging.
(B) Serum TSH level.
(C) Serum antithyroglobulin antibody level.
(D) Serum antithyroid peroxidase antibody level.
(E) FNAB.

33. Once a nodule has been identified, how can we determine whether it is solid, cystic, or both?

(A) Ultrasound imaging.
(B) Radionuclide scan.
(C) Surgical resection.
(D) Repeat ultrasound imaging.
(E) FNAB.

34. After careful examination, a thyroid nodule is found. Ultrasound imaging shows that the nodule is solid. What should be the next diagnostic test?

(A) T4 suppression challenge.
(B) FNAB.
(C) Surgical resection.
(D) Radionuclide scan.
(E) Repeat ultrasound imaging.

35. Ultrasound imaging reveals that a thyroid nodule is a complex cyst. What diagnostic test should be performed next?

(A) Radionuclide scan.
(B) FNAB.
(C) Surgical resection.
(D) Serum TSH level.
(E) Repeat ultrasound imaging.

36. A patient who was exposed to a significant dose of I-131 years ago has a thyroid nodule and undergoes FNAB. The cytology report is "nondiagnostic." What should be recommended next to this patient?

(A) T4 suppression challenge.
(B) Repeat FNAB.
(C) Surgical resection.
(D) Radionuclide scan.
(E) Follow-up ultrasound imaging.

37. The results of repeated FNAB of a thyroid nodule is reported by an experienced pathologist to be "nondiagnostic." What should be recommended next to this patient?

(A) T4 suppression challenge.
(B) FNAB.
(C) Surgical resection.
(D) Radionuclide scan.
(E) Repeat ultrasound imaging.

38. Ultrasound imaging reveals that a thyroid nodule is a simple cyst. What should be the next diagnostic test performed?

(A) T4 suppression challenge.
(B) FNAB.
(C) Surgical resection.
(D) Radionuclide scan.
(E) Repeat ultrasound imaging.

39. What is the most efficient way of evaluating whether a thyroid nodule is malignant?

(A) Thorough physical examination, radionuclide scan, FNAB, and surgical resection.
(B) Brief history, physical examination, ultrasound imaging, and radionuclide scan.
(C) Thorough history, careful physical examination, FNAB, and cytologic interpretation by experienced pathologist.
(D) Serum TSH level, serum antithyroglobulin antibody level, and serum antithyroid peroxidase antibody level.
(E) Serum TSH level, ultrasound imaging, and FNAB.

40. The following measures are needed immediately after a nuclear release occurs:

(A) Informing the population about the risks from exposure to I-131.
(B) Treatment with KI.
(C) Shutting doors and windows.
(D) Forbidding fresh milk consumption.
(E) Thyroid screening.

Note to Nurses

CDC is accredited by the American Nurses Credentialing Center's (ANCC) Commission on Accreditation. ANCC credit is accepted by most State Boards of Nursing.

California nurses should write in "ANCC - Self-Study" for this course when applying for relicensure. A provider number is **not** needed.

Iowa nurses must be granted special approval from the Iowa Board of Nursing. Call 515-281-4823 or e-mail marmago@bon.state.ia.us to obtain the necessary application.

Case Studies in Environmental Medicine:

Radiation Exposure From Iodine 131

Answer Sheet, Course Number SS3117

Instructions for submitting hard-copy answer sheet: Circle your answers. To receive your certificate, you must answer **all** questions. Mail or fax your completed answer sheet to

Fax:770-488-4178, ATTN: Continuing Education Coordinator

Mail:
Agency for Toxic Substances and Disease Registry
ATTN: Continuing Education Coordinator
Division of Toxicology and Environmental Medicine
1600 Clifton Road, NE (MS F-32)
Atlanta, GA 30333

Be sure to fill in your name and address on the back of this form.

Remember, you can access the case studies online at www.atsdr.cdc.gov/HEC/CSEM/ and complete the evaluation questionnaire and posttest online at www2.cdc.gov/atsdrce.

Online access allows you to receive your certificate as soon as you complete the

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Name: E-mail (not required):

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Access the case studies online at ~~www.atsdr.cdc.gov/HEC/CSEM/~~ and complete the evaluation questionnaire and posttest online at ~~www2a.cdc.gov/atsdrce~~.

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DEPARTMENT OF HEALTH
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