INFLUENCE OF AGE AND MODE OF RADIOIODINE EXPOSURE ON THYROIDAL RADIOLOGIC DOSE*

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Isotopes of iodine released to the environment from nuclear power-related operations may easily enter the human body, either by inhalation of contaminated air or by ingestion of contaminated foods, and ultimately deposit in the thyroid gland. Inhalation is an important route of exposure for all radioiodines, in particular those with physical half-lives (Tp's) of less than one day, such as ^{130}I, ^{132}I, ^{133}I, and ^{135}I. Ingestion is a more significant route for those radioiodines with longer Tp's. Iodine-131 (Tp = 8 days) passes from atmosphere to man by the vegetation → cow → milk pathway. The longest-lived radioiodine, ^{129}I (Tp = 16 million years), assumes an essentially permanent residence in the environment upon its release, and may reach man by several dietary pathways (2,8).

The radioiodines are readily transported across biological membranes. Hence, the thyroid glands of fetuses and children may be exposed to radioactivity as a result of the ease with which these radionuclides cross the placenta and mammary gland, respectively.

The thyroid is intimately involved in growth and development, and actively concentrates iodine as required for its hormonogenic processes. Since metabolism changes with age, so, too, will the pattern of thyroidal radioiodine uptake and retention. Similarly, respiration rates vary with age, and dietary requirements and habits change, thus altering the potential for radioiodine assimilation from these routes.

As a result of age-related differences in both intake and metabolism of radioiodine, radiologic doses to the thyroid glands of young and mature individuals from the same environmental exposures will differ. This paper assesses the relationship of age and thyroidal irradiation as a result of acute radioiodine exposures, with the intent to identify the potentially more susceptible members of the population.

METHODS

Data on iodine metabolism for humans or derived from animal studies have been utilized to estimate thyroidal doses following acute exposure to ^{131}I, ^{132}I, and ^{133}I. Data on milk consumption and respiration (6) were utilized to provide appropriate input values for ingested or inhaled radioiodine, respectively. Age groups considered include fetuses in the 13th, 20th, and 32nd week of gestation, infants, 5-, 10-, and 15-year-old children, and adults. Some of the parameters used in this paper are presented in Table 1.

Thyroidal uptakes for ^{131}I for adults and children 2-months-old and older were assumed to be 30% (4,9). Fetuses were assumed to concentrate 0.7, 6.4, and 9 times the maternal concentration in the 13th, 20th and 32nd week of gestation, respectively, based upon maximal values from animal and human data (3). Uptakes for ^{132}I (Tp = 2.3 hours) and ^{133}I (Tp = 20.8 hours) were calculated to reflect their increased rate of decay. Uptakes used were 6% for ^{132}I and 11% for ^{133}I, with values for fetuses altered by the same proportions as for ^{131}I. Uptake of inhaled radioiodine was 77% of that from ingestion (4).

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Biological half-lives (T_b's) of 100 days for adults (5), 50 days for 10- and 15-year-olds, and 20 days in younger children (8) were assumed. Fetuses were assumed to have T_b's of one day at 13 weeks and 4 days at 20 weeks based upon human data (1). Those in the 32nd week of gestation were assumed to have a longer T_b than younger fetuses based upon unpublished studies in guinea pigs and were assigned a T_b of 13 days.

RESULTS AND DISCUSSION

The results of dosimetric calculations are presented in Table 2. Calculated doses, relative to those of adults, are presented in Fig. 1. One day's ingestion of milk containing ^{131}I was calculated to result in differing radiologic doses to thyroid glands of various members of the population, reflecting both differences in iodine metabolism and variations in milk consumption. Under the assumed conditions, fetal thyroid glands were calculated to receive approximately 0.1, 2.5 and 6 times the dose of the thyroid of the adult male in the 13th, 20th and 32nd weeks of gestation, respectively. Thyroids of infants were calculated to receive the highest relative dose, approximately 30 times the adult dose for the 6-month-old. The higher dose arises from increased milk consumption to a maximum of 1 liter/day at 6 months of age. Thyroidal doses to 5-, 10- and 15-year-old children were determined to be about 5, 3 and 2 times the adult dose, respectively.

Inhalation of radioiodine would also lead to age-related variations in thyroidal dose. From inhaled ^{131}I, ^{132}I and ^{133}I, the thyroid of the 13-week-old fetus would receive less than the adult dose but up to 7 and 10 times that value at 20 and 32 weeks of age, respectively. Relative doses were higher for ^{132}I and ^{133}I than for ^{131}I, since effective half-lives were similar for young and old alike with ^{132}I and ^{133}I but shorter for ^{131}I in the young. Doses to the infant were up to 4 times the adult value; thyroidal doses declined with age to about 10% above the adult value at 15 years of age.

These calculations show that, from exposure to environmental radioiodines, there may be considerable differences in the thyroidal dose among various members of the population. Young infants appear to be the cohort which would receive the greatest potential radiologic dose to the thyroid gland from ingested ^{131}I. Their dose was calculated to be $\sim$30 times the adult dose, or more than 5 times that of near-term fetuses. The near-term fetus on the other hand, receives the highest relative thyroidal dose from inhaled radioiodines, up to 10 times the adult value. The calculated dose to the fetal thyroid was also several times that of the infant.

These estimates of an increased relative radiologic dose to the thyroid glands of developing young following assimilation of radioactive iodine do not address, however, the possibility of a greater radiosensitivity of the immature thyroid (10). Hence, the relative risk of biologic damage to the thyroid of the young might be several-fold higher than the relative dose presented here, reflecting more biologic effectiveness per rem in the young. Therefore, the 10-fold increase in dose for the fetal gland for inhaled radioiodines and the 30-fold increase in dose for the thyroid of the infant from those which are ingested, relative to that calculated for adults, would appear to be appropriate lower limits.

In conclusion, dosimetric calculations for population exposures to the radioiodines from nuclear fuel cycle activities should address both ingestion and inhalation as routes of potential exposure. Such information would enable the potentially more sensitive members of the population to be defined and the variety of radioiodines to be considered.

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Table 1. Dose Estimation Parameters

Age	Thyroid Wt (g)	T_b (days)	Milk Consumption/Day (liters)	Inhalation Rate (m^3/min)
Adult (male)	20	100	0.3	0.02
(female)*	17	100	0.3	0.019
Infant (6 mo)	1.5	20	1.0	0.004
(1 yr)	2	20	0.58	0.0042
Child (5 yr)	5	50	0.49	0.0065
(10 yr)	10	50	0.48	0.013
(15 yr)	15	100	0.44	0.0165

*Utilized for the calculation of fetal thyroidal doses.

Table 2. Doses to thyroid glands from one day's ingestion of milk containing 1 μCi of ^{131}I/liter and from one minute's exposure to air containing 1 μCi of ^{131}I, ^{132}I or ^{133}I per m^3.

	Ingestion (rem/day)	Inhalation (mrem/min)		
	^{131}I	^{131}I	^{132}I	^{133}I
Adult	0.48	25	0.17	2.3
Fetus (13 wk)	0.04	2	0.1	1.0
(20 wk)	1.2	60	1.2	13.4
(32 wk)	3.3	160	1.8	22
Infant (6 mo)	15.7	50	0.6	6.1
(1 yr)	6.8	40	0.4	4.7
Child (5 yr)	2.4	20	0.2	1.9
(10 yr)	1.4	30	0.2	3.0
(15 yr)	0.9	25	0.2	2.5

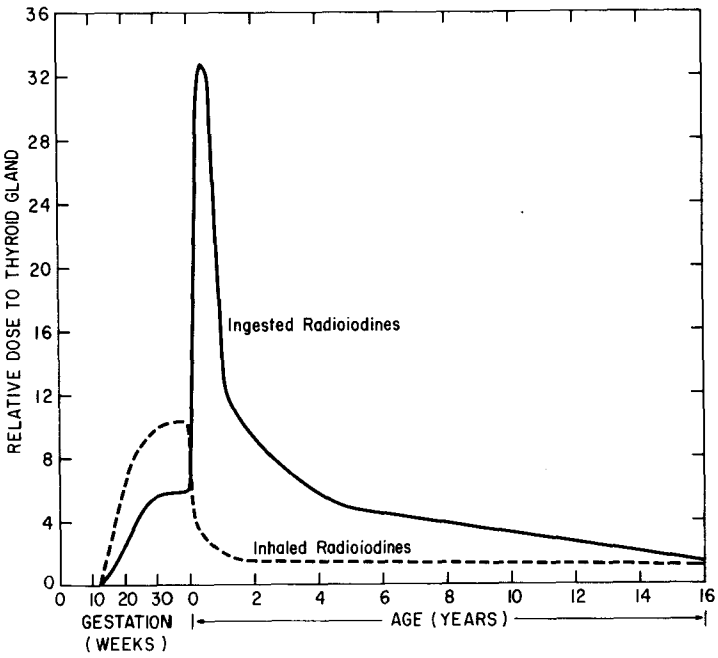

Fig. 1. Doses to thyroids of fetuses and children, relative to those of adults, from ingested or inhaled radioiodine.