Thyroid Uptake of Iodine-131 and Iodine-133 from Chernobyl in the Population of Southern Sweden

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The accident at the nuclear power plant of Chernobyl on April 26, 1986 led to radioactive contamination of many countries including Sweden. The population was exposed to released radionuclides, both by inhalation and from contaminated food. We have studied the content of gamma-emitting radioisotopes in the thyroid glands of a normal population from southern Sweden using measurements of samples taken at autopsy. The first samples are from a person who died on April 27, 1986. This report contains results for ^{131}I and ^{133}I. The time-activity curve for ^{131}I shows an immediate uptake with a maximum 18–26 days after the accident. No measurable levels were observed after 93 days. We have found that the increase in dose equivalent to the thyroid for the population of southern Sweden due to the released ^{131}I and ^{133}I will be < 0.1 mSv. This may lead to an increase in the incidence of thyroid cancer of 0.1% during a period of 25 yr.

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After a nuclear reactor accident, the population in a contaminated area will have a rapid uptake of released radioactivity by inhalation of airborne radionuclides, as well as a prolonged uptake from the food. This makes it difficult to predict the time course of activity uptake so as to estimate the absorbed dose. The Chernobyl accident on April 26, 1986 offered a unique opportunity to study the uptake and retention in a normal population. Due to close cooperation between the Departments of Radiation Physics and of Forensic Medicine in Lund, Sweden, the first observation of radioactive uptake in man in the western countries after the accident was reported from our department (*1*).

In order to ascertain the cause of death for persons who have died outside hospitals, autopsy is often performed at a Department of Forensic Medicine. Although the accident in Chernobyl did not become known to the public until late on Monday, April 28, 1986 an opportunity to obtain measurements on a person who died Sunday, April 27 was available as a result of the time lag between death and autopsy. Since then we have monitored the distribution of released gamma-emitting radionuclides in different body tissues as a function of time. Uptake, retention, and dosimetry for ^{131}I and ^{133}I are reported here.

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MATERIALS AND METHODS

Population / Geographic Area

The area studied is the southern part of Sweden, including the two provinces of Skåne and Blekinge (~1,200 km from Chernobyl). The geographic location is presented in Figure 1. The 1,025,000 inhabitants of Skåne, and the 152,000 of Blekinge together comprise 14% of the Swedish population (*2*).

Spread of Activity over Skåne and Blekinge

On April 26, 1986 at 1:23 a.m. (Swedish time), the worst accident in the history of nuclear power occured in the nuclear power plant of Chernobyl in the Soviet Union. From the damaged reactor, a large part [~5% (*3*)] of the radionuclide inventory was released into the atmosphere including $670 \cdot 10^{15}$ Bq of ^{131}I (*3*). The radioactivity was carried at an altitude of 500 to 1,500 m by southeastern winds at a speed of 10 m/s towards the Nordic countries (*4*). The cloud reached the south of Sweden late on Sunday, April 27, 1986. On April 30th the wind direction changed, but between May 5th and May 9th the winds from Chernobyl were once again directed towards Scandinavia. These two periods with winds directed from Chernobyl to Sweden happened to coincide with the two peaks in the radionuclide emission from the reactor, as can be seen in Figure 2C (*3*). Figure 1 illustrates the approximate

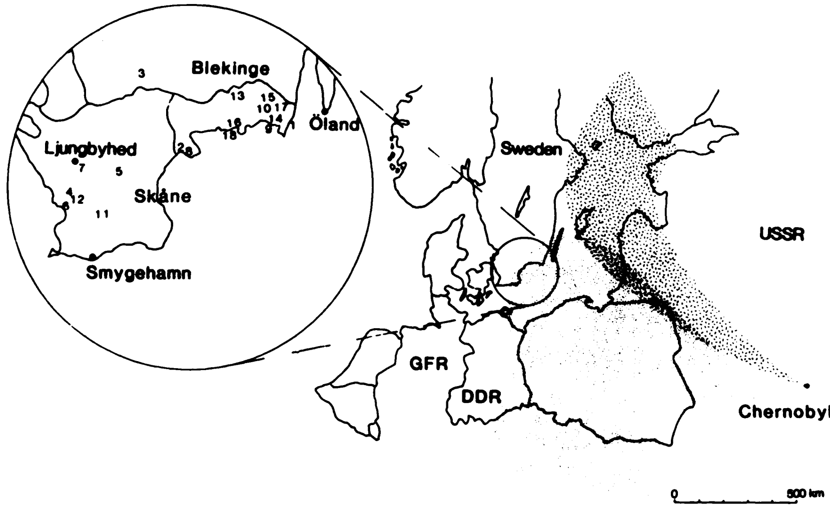

FIGURE 1
Map of northern Europe showing the dispersion of the radionuclides emitted from the Chernobyl reactor on April 26, 1986 at noon (northern plume), and at midnight (5). The blowup shows Skåne and Blekinge in the southern part of Sweden and the place of death of the persons included in the study.

progress of the plumes of radionuclides emitted on April 26th and 27th (*5*).

At different locations in Sweden, the airborne particulate activity is continuously measured by the Swedish Defence Institute and the exposure rate is measured by the Swedish Radiation Protection Institute. Some of these measurements for the area studied from the time of the accident until August, 1986 are shown in Figure 2. Figure 2D shows the air concentration of particulate ^{131}I in the northern part of the investigated area (Ljungbyhed). The exposure rate in the eastern and southern parts (Öland and Smygehamn) are shown in Figure 2E and F (*6,7*)).

Method

Whole thyroid glands were collected at autopsy in the Department of Forensic Medicine in Lund from persons from Skåne and Blekinge. These persons are considered to be representative of the population for the purpose of this study (natural deaths outside hospital, suicides or accidents). The data are summarized in Table 1.

The samples (4-55 g) were weighed placed in identical receptacles (90 ml) with formalin. Measurements were made for 24 h with a 92 cm^3 Ge(Li) detector, placed in a 4-cm thick lead case in a special low background room, and connected to a multichannel analyzer and a computer. Calibrations were made for different sample volumes. The background was measured once a week for 24 hr, and subsequently subtracted. The lowest detectable activity of ^{131}I was 10 mBq. Figure 3 shows a typical pulse height distribution from one thyroid sample (No. 9).

RESULTS

The activity content of ^{131}I and ^{133}I in the different thyroid glands have been summarized in Table 1 and plotted in Figure 2A and B, respectively, as a function of time after April 25, 1986. For the purpose of estimating the maximal and minimal activity uptake in the population, the data points were divided into two subsets, representing maximal (Samples 1–4, 7, 10–11, 14–18) and minimal (Samples 5–6, 8–9, 12–13, 17–18) values, respectively. In Figure 2A, two curves have been fitted to the different subsets. The curve fitting was made by polynomial regression with polynomials of the 5th degree using the computer program package BMDP (*8*). The highest value of the maximal-activity curve lies in a region with few data points. To estimate the error in the determination of the time for highest activity value, the calculations were repeated several times, removing different data points. The maximal-activity curve reached its highest value after 26 ± 5 days and zero after 75 days. The highest value of the minimal-activity curve occurred after 18 ± 1 days and it reached zero after 65 days.

ABSORBED DOSE CALCULATION

Iodine-131 activity

The highest and lowest cumulated activity ($\tilde{A}$) of ^{131}I, obtained by integration of the two curves in Figure 2A, were 13.7 kBq·h and 3.3 kBq·h, respectively. The absorbed/dose (D) to the thyroid gland was calculated using the MIRD formalism [Eq. (1)] with an S-value of 5.95 mGy/MBq·h (*9*).

$$D = \tilde{A} \cdot S \tag{1}$$

$$H = D \cdot Q \cdot N. \tag{2}$$

The dose equivalent (H) is given by Eq. (2). For photons and electrons, the quality factor Q equals 1. The modifying factor N is also equal to 1. The following values were obtained for the maximal and minimal dose equivalents from ^{131}I to the thyroid gland:

$H_{max}(^{131}I) = 0.08$ mSv and
$H_{min}(^{131}I) = 0.02$ mSv, respectively.

Using the relative number of data points related to each curve as a weight factor (12/20 and 8/20, respectively),

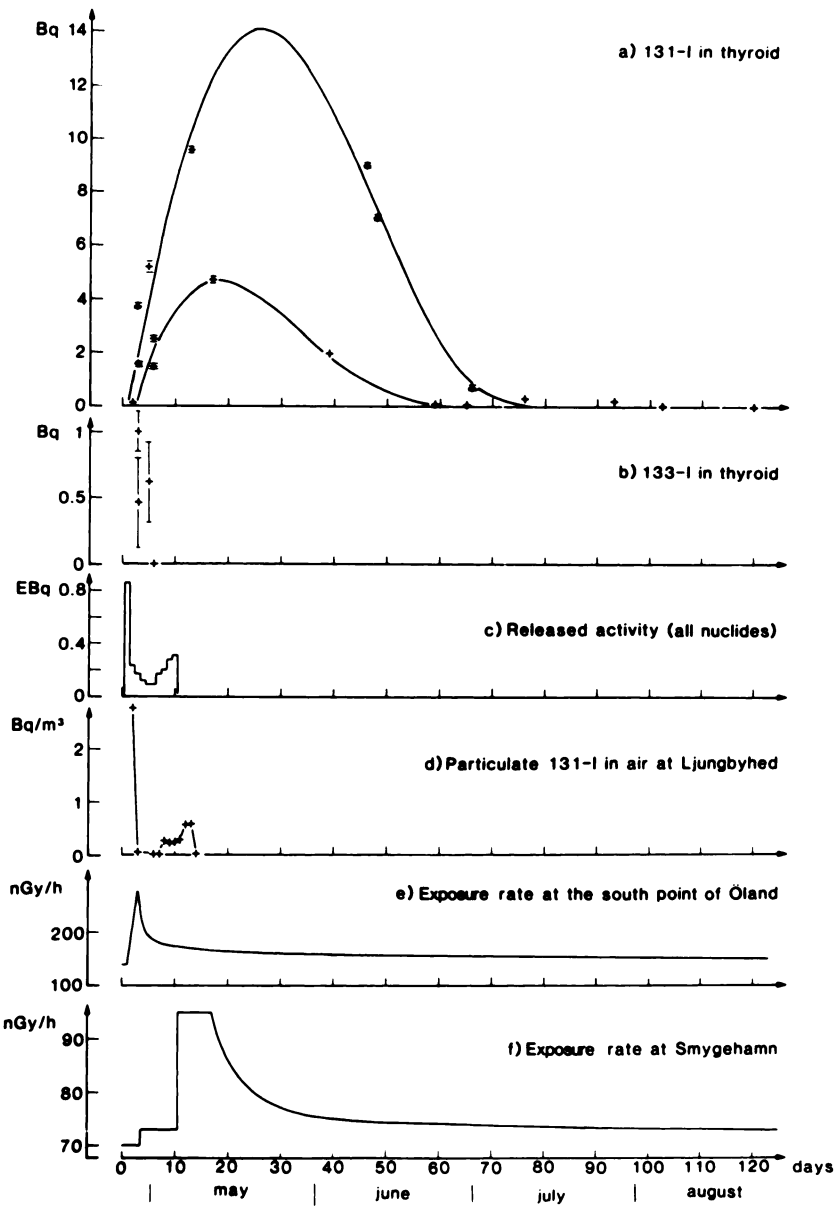

FIGURE 2
Biokinetic and environmental measurements as function of time after April 25, 1986. A: ^{131}I activity in the thyroid gland; B: ^{133}I activity in the thyroid gland; C: Released activity of all radionuclides from the Chernobyl reactor (*3*); D: Activity concentration of particulate ^{131}I in air at Ljungbyhed; E: Exposure rate at the southern point of Öland (*6,7*); F: Exposure rate at Smyghamn (*6,7*).

the weighted mean of the dose equivalent is:

$$H_{mean}(^{131}I) = 0.06 \text{ mSv}.$$

Iodine-133 Activity

The calculations for ^{133}I were made in a similar manner. By integration of the data in Figure 2B, the cumulated activity was found to be ~50 Bq·h. Multiplication of this value with an S-value of 12 mGy/MBq·h (*9*), a Q-value of 1, and a N-value of 1. yields a dose equivalent to the thyroid gland of:

$$H_{mean}(^{133}I) = 0.6\ \mu\text{Sv}.$$

RISK ESTIMATIONS

Assuming that the whole population in the two provinces studied (1,177,000 persons) has on an average received the same dose equivalent to their thyroid glands (0.06 mSv), a total of 70 man·Sv has been added to the population. With a risk factor of 50–150 cases per 10^4 man·Sv for radiation induced thyroid cancer during a period of 25 years (*10*), an increase in incidence of 0.3–1.0 thyroid cancers was calculated. No correction for the age distribution of the population was attempted. Normally a total of 45.5 cases of thyroid cancer per year can be expected in Skåne and Blekinge (*2*). Thus an increase in incidence of < 0.1% during the 25 yr following the accident can be estimated due to the release of ^{131}I and ^{133}I from the Chernobyl reactor.

DISCUSSION

In a similar study from the north of Italy, a dose equivalent of 0.2 mSv has been reported (*11*). In that

TABLE 1
Date and Cause of Death, Thyroid Weight, and Activity Content of ^{131}I and ^{133}I for the 18 Subjects Studied

Patient no.	Age (yr)	Sex	Death date 1986	Cause of death	Thyroid weight/g	Activity content/Bq ^{131}I	^{133}I
1	91	F	Apr. 27	CHD*	20.5	0.08 ± 0.06	<0.01
2	36	M	Apr. 28	CHD	9.0	3.72 ± 0.09	1.00 ± 0.15
3	38	M	Apr. 28	suicide	5.0	1.54 ± 0.08	0.46 ± 0.34
4	78	M	Apr. 30	CHD	9.2	5.16 ± 0.22	0.62 ± 0.31
5	78	M	May 1	trauma	20.4	2.47 ± 0.10	0.02 ± 0.00
6	79	F	May 1	CHD	45.2	1.45 ± 0.09	<0.01
7	77	F	May 8	CHD	15.8	9.58 ± 0.12	<0.01
8	69	M	May 12	CHD	13.4	4.69 ± 0.12	<0.01
9	55	F	Jun. 3	trauma	7.5	1.93 ± 0.10	<0.01
10	75	M	Jun. 10	CHD	55.5	9.00 ± 0.10	<0.01
11	44	M	Jun. 12	trauma	22.2	7.01 ± 0.11	<0.01
12	76	F	Jun. 24	CHD	54.6	0.08 ± 0.03	<0.01
13	80	M	Jun. 29	suicide	8.6	0.01 ± 0.02	<0.01
14	67	F	Jun. 30	CHD	14.3	0.67 ± 0.08	<0.01
15	47	M	Jul. 10	suicide	5.4	0.23 ± 0.04	<0.01
16	71	M	Jul. 27	suicide	19.1	0.19 ± 0.03	<0.01
17	82	M	Aug. 8	CHD	3.9	<0.01	<0.01
18	65	F	Aug. 23	CHD	5.9	<0.01	<0.01

* Coronary heart disease.

study, however, the early uptake phase was not measured and the biokinetics was estimated from an effective half life.

In another study measurements were made on travelers from different parts of Europe, and activity levels (0–33 kBq) considerably higher than those observed by us were reported (*12*). None of the subjects had been in Sweden.

We have shown that thyroid uptake of iodine isotopes released from a nuclear power plant starts very soon in the population of an exposed area. Due to a continuous intake from contaminated food, there also remains a measurable activity (>10 mBq) in the thyroid for a period much longer than could be expected from the effective half-life (5–7 days) of ^{131}I. The absorbed doses due to iodine isotopes were very small in the investigated area and the individual increase in dose equivalent was very low, less than 0.1 mSv. The expected increase in incidence of thyroid cancer is also very low, < 0.1%.

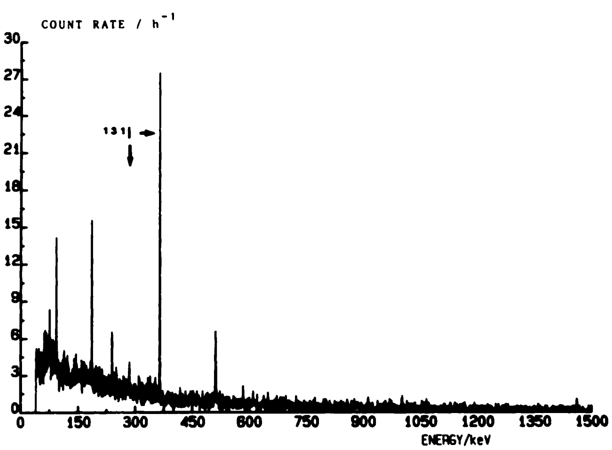

FIGURE 3
Pulse height distribution from Sample 9. Two peaks from ^{131}I are clearly distinguishable at 284 and 365 keV. Additional peaks from ^{234}Th (93 keV), ^{235}U (186 keV), ^{212}Pb (239 keV), annihilation radiation (511 keV) and ^{40}K (1462 keV) can be seen. No background correction has been made.

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