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No increase in thyroid cancer among children and adolescents in Finland due to Chernobyl accident

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ABSTRACT

The aim of the study was to assess whether radioactive fallout from the Chernobyl accident in 1986 influenced thyroid cancer incidence among children and adolescents in Finland. The population was divided into two: those with thyroid doses less than 0.6 mSv and above 0.6 mSv. Cumulative incidence of thyroid cancer was identified from the Finnish Cancer Registry from a population aged 0–20 years in 1986 with a total of 1,356,801 persons. No clear difference in underlying thyroid cancer incidences rates were found during the pre-Chernobyl period (1970–1985) (rate ratio RR 0.95, 95% confidence interval CI 0.81–1.10). During the post-Chernobyl period (1991–2003), thyroid cancer incidence was lower in the more exposed population than in the less exposed population (RR 0.76, 95% CI 0.59–0.98). Our results did not indicate any increase in thyroid cancer incidence related to exposure to radiation from the Chernobyl accident.

1. Introduction

The nuclear power plant accident in Chernobyl took place on April 26, 1986 and led to release of vast amounts of radioactivity from the reactor, including 40% of the radioiodine in the reactor core (both iodine-131 and short-lived radioiodines).[1,2] The first plume contained most of the radioiodine and it was deposited mainly in areas adjacent to the plant (Belarus, Ukraine and parts of Russia). Due to the meteorological conditions at the time of the accident, the initial release was directed to the North-West, affecting parts of Northern Europe (Western Poland, Central Sweden and Southern Finland). Within Finland, Southern and Central parts of the country were the most affected areas and the highest ^{131}I deposition in surface samples was 420 kBq/m^2.[2] The external dose from the fallout was the highest in Central Finland due to wet precipitation that occurred from April 29 to May 1. On the other hand, the internal thyroid dose by inhalation was the highest near the south coast of Finland, where the radioactive plume descended to surface air in April 28.

After the Chernobyl accident, incidence of thyroid cancer has increased dramatically among populations of Southern Belarus and Northern Ukraine and the risk has been highest among those who were youngest at the time of the accident.[3–6] In the most contaminated areas of Russia, the standardised incidence ratio for those aged less than 18 years at the time of exposure was three times higher than for adults.[7] Furthermore, a dose–response relationship has been demonstrated between radiation and risk of thyroid cancer. This is consistent with studies of radiotherapy showing increased risk of thyroid carcinoma following high doses of radiation.[8]

The effect of ionising radiation on risk of thyroid cancer depends on age at exposure, being highest for the youngest

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ages at exposure. It decreases with increasing age, and exposure in adulthood is associated with little or no excess risk.[9] The spontaneous incidence of thyroid cancer is 3–4 times higher in women than men. However, gender differences in sensitivity for effect of radiation have not been consistent across studies.[8] Iodine deficiency prior to radioiodine exposure has been suggested to increase the risk of thyroid cancer. The results of two recent studies carried out in Belarus and Russia are consistent with this notion.[10,11] The risk of radiation-induced thyroid cancer reaches a maximum 15–25 years after exposure, remains increased for 10–20 years, and then declines gradually.[8]

So far, the only established long-term health consequence of the Chernobyl accident has been increased risk of thyroid cancer in the population of the regions adjacent to the reactor. Studies conducted outside the former Soviet Union have not demonstrated elevated incidence of thyroid cancer. The aim of this study was to evaluate whether the exposure to radiation from the Chernobyl accident has increased thyroid cancer incidence in Finland.

2. Patients and methods

2.1. Exposure

The mean population-weighted thyroid dose to Finnish children and adolescents (0–14 years of age) due to the Chernobyl fallout was estimated based on both internal exposure to ^{131}I (due to ingestion of contaminated milk and inhalation of airborne radioactivity) and external exposure (due to radioactive fallout of various nuclides). Only ^{131}I was taken into account in internal dose assessment, because of the short effective half-life and small amount of other iodine isotopes. Meteorological conditions, measurement data on ^{131}I concentrations in surface air and fresh milk as well as data on milk production and consumption were considered in estimation of internal exposure. External radiation was assessed based on a mobile survey with continuous measurements using a Geiger–Müller tube and spectrometer installed in a car.[12] The protective properties of being indoors and time spent indoors were taken into account.

The mean population-weighted thyroid dose was calculated for each 461 municipalities as a cumulative dose over the period of 60 months following the Chernobyl accident. Based on the thyroid dose estimation the population of the country was divided into two exposure groups, with 0.6 mSv as the cutoff value. Approximately 70% of the population had lived in Southern and Central Finland with the population-averaged thyroid doses higher than 0.6 mSv. The average thyroid doses were 0.2 and 1.1 mSv for lower and higher exposure groups, respectively.

Table 1 – Size of the population aged 0–20 years in the two exposure groups (thyroid dose ⩽0.6 and >0.6 mSv) in Finland in 1986

Age (years)	Thyroid dose		Total
	⩽0.6 mSv	>0.6 mSv	
0–4	94,501; 29.4%	226,905; 70.6%	321,406
5–9	94,971; 29.6%	226,168; 70.4%	321,139
10–14	89,610; 29.0%	218,956; 71.0%	308,566
15–20	118,971; 29.3%	286,719; 70.7%	405,690
0–20	398,053; 29.3%	958,748; 70.7%	1,356,801

2.2. Population and cancer incidence data

Population size by municipality, sex, calendar year and one-year age group was obtained from Statistics Finland for the years 1970–2003. The number of incident cases of thyroid cancer was obtained from the population-based Finnish Cancer Registry.[13] The data on morphology (papillary and non-papillary) was obtained for the years 1970–2003 and stage (localized, non-localized and other) for the years 1991–2000.

Possible underlying differences in the two populations were evaluated by analysing thyroid cancer incidence prior to the Chernobyl accident. In 1970–1985, 830 thyroid cancer cases occurred in the population aged 0–39. The study cohort in the post-Chernobyl period (1986–2003) consisted of 1,356,801 children and adolescents (Table 1). As it was a closed population, the age increased with time since the Chernobyl accident. The minimum latency between exposure to ionising radiation and development of thyroid cancer was assumed to be five years, and therefore the main analysis covered 479 cases during the period 1991–2003 (Table 2). For them, the place of residence in 1986 was obtained from the Population Register Centre in order to classify their exposure status.

Permissions to use the data of the Cancer Registry were obtained from STAKES – National Research and Development Center for Welfare and Health. No review by an ethical committee was needed since this was registry-based study with aggregate data. A notification to the Office of the Data Protection Ombudsman was made.

Table 2 – Thyroid cancer cases diagnosed after Chernobyl accident (1991–2003) in the two exposure groups (thyroid dose ⩽0.6 and >0.6 mSv) among those aged 0–20 years in 1986

Calendar time	Male			Female			Both		
	Thyroid dose (mSv)		Total	Thyroid dose (mSv)		Total	Thyroid dose (mSv)		Total
	⩽0.6	>0.6		⩽0.6	>0.6		⩽0.6	>0.6	
1991–1994	5	9	14	25	44	69	30	53	83
1995–1998	16	14	30	51	83	134	67	97	164
1999–2003	12	36	48	66	118	184	78	154	232
Total	33	59	92	142	245	387	175	304	479

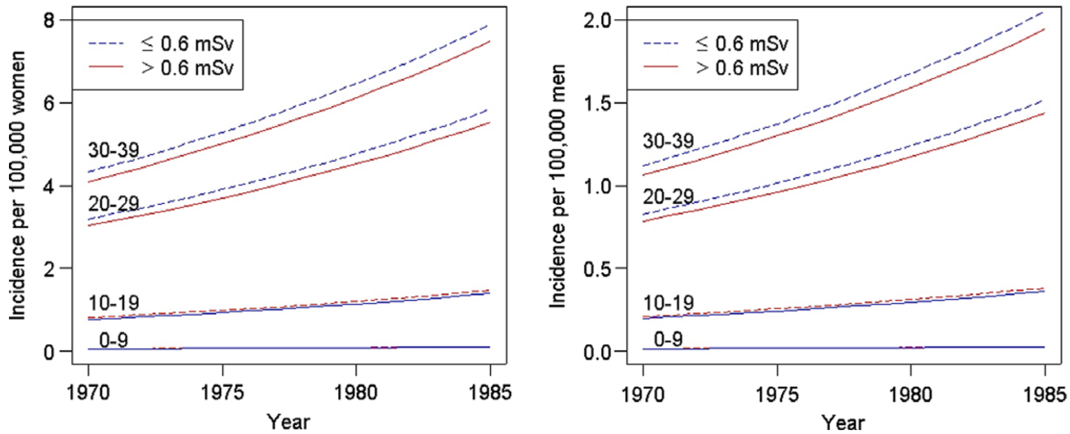

Fig. 1 – Model-based incidence trends of thyroid cancer during the pre-Chernobyl period in the two areas of exposure (thyroid dose <0.6 and >0.6 mSv) in Finland in four age groups in women and men.

2.3. *Statistical methods*

Thyroid cancer incidence during the pre-Chernobyl period (1970–1985) was compared between the two populations to take into account possible pre-existing differences in incidence and incidence trends. Time trends of spontaneous thyroid cancer incidence were examined by using log-linear Poisson regression model.[14] Calendar time was used as a continuous variable with age (0–9, 10–19, 20–29, and 30–39 years) and sex as categorical covariates. Model-based incidence trends are shown in Fig. 1.

The cumulative incidence of thyroid cancer during the post-Chernobyl period 1991–2003 was examined by plotting Kaplan–Meier estimate and statistical significance assessed using a log rank test.

Expected incidence of thyroid cancer by sex and age group for the post-Chernobyl period was obtained by linear extrapolation using Poisson regression based on the pre-Chernobyl data. Rate ratio for the thyroid cancer incidence during the study period was obtained by relating the observed and expected numbers of thyroid cancers in the two populations ($O_1/E_1{:}O_2/E_2$), with confidence intervals estimated under the assumption that the observed numbers of cases follow a Poisson distribution.

An marked increase in papillary thyroid cancer incidence in the early 1980s, especially in the Northern Finland, was leading to unrealistic number of the expected papillary cancers (1.4 times higher than the expected number for all thyroid cancers) for the years 1991–2003. Therefore, the expected numbers of papillary and non-papillary thyroid cancers were assumed to be a sum of the expected numbers of all thyroid cancer cases.

All analyses were performed using the R software packages.

3. Results

No substantial difference in thyroid cancer incidence was seen between the two populations during the pre-Chernobyl period (1970–1985) (rate ratio, RR = 0.95, 95% confidence interval CI 0.81, 1.10). The incidence trends of thyroid cancer were increasing similarly with calendar time for men and women, for all age groups, and for both exposure groups (Fig. 1, $P = 0.26$ for the interaction between calendar time and the exposure area). For papillary cancers, the increase in incidence with calendar time was more marked in the less exposed population than in the more exposed population ($P = 0.02$ for the interaction). For non-papillary cancers, the incidence trends decreased similarly with calendar time by the gender, the age group and the exposure groups.

During the post-Chernobyl period (1991–2003), 304 new thyroid cancer cases occurred in the more exposed population of Southern and Central Finland and 175 cases in the population of Northern Finland who were less affected by the fallout (Table 2). Of the 479 cases, nearly 81% occurred in women (female:male ratio 4:1) and 91% of all cancers were of papillary histology (92% in the less exposed and 91% in the more exposed population). Most cases occurred at ages above 20 years and the median age at diagnosis was 26 years (1st and 3rd quartiles 22 and 30 years).

The cumulative incidence of thyroid cancer following the Chernobyl accident was higher in the less exposed population than the more exposed population ($P < 0.001$, Fig. 2). Similar to

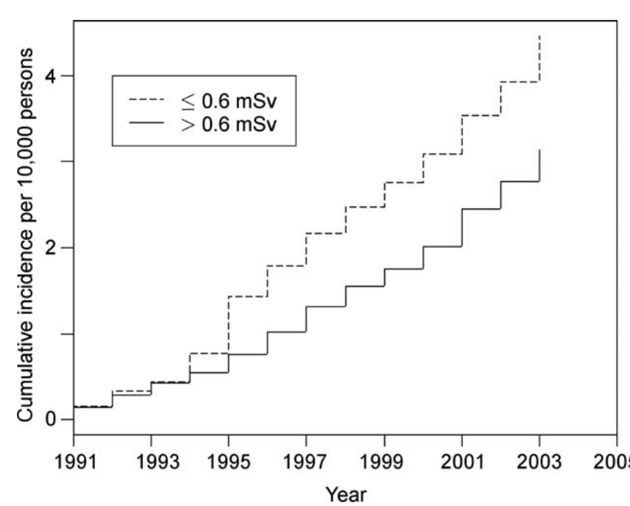

Fig. 2 – Cumulative incidence of thyroid cancers in two thyroid exposure groups (thyroid dose <0.6 and >0.6 mSv) during the post-Chernobyl period.

all thyroid cancers, cumulative incidence of papillary cancer as well as of localized and non-localised thyroid cancers increased more rapidly in the population with thyroid doses <0.6 mSv than that with >0.6 mSv.

The rate ratio (RR) was 0.76 (304 cases observed versus 529.5 expected in the more exposed and 175 versus 231.7 cases in the less exposed population, 95% CI 0.59–0.98). The results did not vary by morphological subtype (RR for papillary 0.74; 95% CI 0.57–0.96, and for non-papillary 1.18; 0.42–3.35).

4. Discussion

We analysed the effect of Chernobyl fallout on thyroid cancer incidence among children and adolescents in Finland, but found no indication of increased risk. The doses to the thyroid were low and therefore the finding was expected. Our study comprised the entire population of Finland aged 0–20 years at time of exposure, with more than 1.3 million subjects and almost 500 thyroid cancer cases. Yet, the statistical power of the study to detect an effect of low doses, given current risk estimates, was low. However, the primary purpose of the study was not estimation of dose–response, but monitoring of possible public health effect.

Thyroid cancer can be considered a sentinel indicator for ionising radiation exposure, as it is one of the cancers with highest risk coefficient per unit exposure when exposure takes place in childhood (good sensitivity) and it has few other risk factors (good specificity).

The radiation dose to the thyroid from the Chernobyl accident is of the same order as the variations in the external dose by natural background radiation, which is relatively high in Finland.[2] Along with the low doses of radiation, considerable uncertainty in thyroid dose assessment was a limitation of the study. This was primarily due to the complicated spatial distribution of surface-level air radioiodine concentration.

The result of current study is consistent with most of the results of other studies on Chernobyl fallout and thyroid cancer carried out in European countries outside the former Soviet Union.[15–19] No effect of Chernobyl fallout on thyroid cancer incidence was found in Northern Sweden, where exposure levels were comparable to Finland.[15] In Northern Italy, no increase in thyroid gland abnormalities, such as nodularity or cancer, were found among children born around the time of Chernobyl nuclear accident, when examined 10 years after the accident.[16] A recent French study concluded that no excess of thyroid cancer in Eastern France could be related to the fallout from Chernobyl.[17] No increase in childhood thyroid cancer was observed in five eastern European countries after the Chernobyl accident.[18] In a small study from the North of England, however, a temporal and spatial association with Chernobyl accident with thyroid carcinomas in children and young adults was suggested.[19] Radiation exposure estimation is a challenge and only in the French study[17] thyroid dose was estimated.

A difference between the two population sub-groups with different exposures emerged following the Chernobyl accident, but incidence increased more in the less exposed Northern Finland. The reason for this is unclear. Few risk factors are known for thyroid cancer. An increased thyroid cancer incidence may also reflect an increased number of diagnostic investigations and improved detection of a disease. These factors are suggested to be a main explanation for the observed evolution in the other studies.[20] However, in the current study both localized and non-localised thyroid cancers seem to be detected more in the less exposed area than in the higher exposed area. Medical practices can vary in the different parts of Finland, which may partly explain the regional difference in the incidence observed in the current study.

Regardless of uncertainty in the thyroid dose assessment, it was possible to divide the Finnish population by exposure levels. Comprehensive population and cancer data available due to the Finland's highly developed infrastructure provide a favourable setting for studying health effects of environmental exposure to low doses of radiation. No increase in thyroid cancer was found in the population more affected by the Chernobyl fallout.

Conflict of interest statement

None of the authors have financial and personal relationships with other people or organisations that could inappropriately influence (bias) this work.

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