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Overview

Childhood and Adolescent Thyroid Cancer in Fukushima after the Fukushima Daiichi Nuclear Power Plant Accident: 5 Years On

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Abstract

The accident at the Fukushima Daiichi Nuclear Power Plant occurred after the Great East Japan Earthquake on 11 March 2011, releasing a large amount of radioactive materials into the atmosphere. Questions were raised regarding the health effects of radiation exposure, which led to increased anxiety among the Fukushima residents about the possible development of thyroid cancer. Thus, thyroid ultrasound examinations began for those who were from the areas where the radiation doses were highest, and will continue for the long term. In total, 300 476 subjects aged 18 years or younger at the time of the disaster were screened from 9 October 2011 to 31 March 2014. The participation rate was 81.7% of the total population of this age and in the affected area. Among them, the proportions of those who fell into the categories A1 (no nodules or cysts present), A2 (nodule $\leq$ 5 mm or cyst $\leq$ 20 mm diameter), B (nodule $>$ 5 mm or cyst $>$ 20 mm diameter) and C (immediate need for further investigation) were 51.5, 47.8, 0.8 and 0%, respectively; 2294 subjects in categories B and C were recommended to undergo a confirmatory examination; 113 were subsequently diagnosed with malignancy or suspected malignancy by fine needle aspiration cytology. The full-scale survey (second round survey) began in April 2014, and was completed by 30 June 2015, and comprised 169 455 subjects (participation rate; 44.7%). The proportions of those who fell into the categories A1, A2, B and C were 41.6, 57.6, 0.8 and 0% (no case), respectively; 1223 subjects in category B were recommended to undergo a confirmatory examination, 25 of these were subsequently diagnosed with malignancy or suspected malignancy by fine needle aspiration cytology. The thyroid cancers identified in this survey so far are unlikely to be due to radiation exposure, and are more likely to be the result of screening using highly sophisticated ultrasound techniques. However, it would be advisable to continue long-term screening to determine whether the risk of childhood and adolescent thyroid cancer due to radiation exposure increases or not.

Key words: Fukushima; radiation exposure; thyroid cancer; thyroid cyst; thyroid nodule; thyroid ultrasound screening

Statement of Search Strategies Used and Sources of Information

This paper reflects expert opinion and current literature accessed by the authors; no formal search strategy has been defined.

Introduction

The accident at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant (NPP) occurred after the Great East Japan Earthquake on 11 March 2011, releasing a large amount of radioactive materials into the atmosphere.

In terms of severity, the accident at the Fukushima Daiichi NPP was rated at level 7 on the International Nuclear and Radiological Event Scale [1], which matches the rating to the Chernobyl NPP accident in 1986. Between 4 and 5 years after the Chernobyl accident, childhood thyroid carcinoma in Belarus and Ukraine was shown to have increased as a consequence of prolonged exposure to radioactive iodine fallout, mainly through intake of food and cows' milk [2–5]. This appearance was the only significant effect of the radiation exposure after the Chernobyl accident on the health of the exposed residents. This late nuclear accident-related increase in childhood thyroid cancer caused great worry among the Japanese public in the first few months after the Fukushima disaster. This concern persisted even

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after realisation that the radiation exposure dose was very low compared with the dose resulting from the Chernobyl disaster [1,6–9].

Questions were raised regarding the health effects of radiation exposure, which led to increased anxiety among the Fukushima residents about the possible development of thyroid cancer. Due to these concerns and a strong request from central and local governments, the Fukushima Health Management Survey (FHMS) initiated several health protection surveys, including one that involved thyroid ultrasound examinations (TUE) of all child and adolescent inhabitants either resident in or visiting Fukushima at the time of the accident. The first aim of this survey was to evaluate the baseline rates of childhood thyroid nodules and cancer in Fukushima, because there was no epidemiological data, especially using ultrasonography, from children and adolescents before the accident, except in a few prefectures [10–15].

Thus, the baseline survey of TUE began on 9 October 2011 conducted by Fukushima Medical University in those areas where the radiation doses were relatively higher and will continue for a number of years [10–15].

This overview summarises the progress of the TUE, the challenges in carrying out this screening project and gives details of the thyroid cancers that have been identified during the last 5 years. It will also comment on the risk of thyroid cancer after the Fukushima accident.

Thyroid Ultrasound Screening of the Fukushima Health Management Survey

Schedule

The schedule was divided into two: the preliminary baseline survey (PBLS) and the full-scale survey (FSS). If radiation-induced thyroid cancer occurs in Fukushima, the latency would be expected to be at least 4 or 5 years, based on previous data from radiation exposure (from the Chernobyl accident, the atomic bombs in Hiroshima and Nagasaki, and radiotherapy to the neck). The FSS data could then be compared with data from the PBLS in order to determine any increase in thyroid cancer over time. The present investigation was designed as a cohort study. The PBLS was also divided into three schedules in different regions of the affected area. The first survey began in the financial year 2011 in the 13 evacuation zone municipalities around the Fukushima Daiichi NPP that represent the area with the highest spatial radiation dose immediately after the accident. The second survey was carried out in financial year 2012 in those areas with intermediate levels of radioactive contamination. The third survey was carried out in financial year 2013 in the lowest level of radioactivity (Figure 1a).

The FSS, second round survey, was also divided into two surveys. The first survey was carried out in financial year 2014 in areas with high levels of contamination and in some areas with intermediate levels. The second survey will follow in the remaining areas with intermediate levels of contamination and also in areas with low level contamination (Figure 1b). The FSS will then be repeated every 2 years for each subject until the age of 20 years, then every 5 years thereafter for the remainder of each subject's life. TUE was carried out first on those who were living in those areas of highest exposure at the time of the accident (Figure 1c) [10–14].

Diagnostic Criteria of the First Screening of Thyroid Ultrasound

The primary examination aimed at detecting nodules or cysts by ultrasonography [12,13] and used a classification system, divided into three categories. Those in category A were recommended to undergo another primary examination. This category was also further divided into two categories, A1 for those without nodules or cysts, A2 for those with nodules smaller than 5.0 mm and/or cysts smaller than 20 mm. Category B included those with nodules larger than 5.1 mm and/or cysts larger than 20.1 mm, who were then recommended to undergo a confirmatory examination. Category C subjects required immediate examination due to a finding of a large or suspicious thyroid tumour/lymph node. Mixed cystic-solid nodules are considered as 'nodules'. Some A2 category results may be reclassified as B after clinical examination.

Diagnostic Criteria of Confirmatory Examination

Where subjects were categorised as B or C, further tests were carried out. These comprised ultrasound and blood and urine tests followed by fine needle aspiration cytology (FNAC), according to the guidelines issued by the Japan Association of Breast and Thyroid Sonology (JABTS) (Figure 2) [16] and the Japan Society of Ultrasound Medicine (JSUM) (Table 1) [17].

According to guidelines of the JABTS and JSUM, FNAC is recommended for nodules more than 5 mm in diameter, if strongly suspicious for thyroid carcinoma from JSUM diagnostic criteria (Table 2); those larger than 10 mm in diameter and suspicious for carcinoma from the above criteria; all nodules over 20 mm in diameter; and all cystic lesions larger than 20 mm in diameter (Figure 2). These guidelines were followed to avoid unnecessary FNAC, especially for nodules larger than 5 mm but smaller than 10 mm.

If a benign lesion was detected, by either ultrasonography only or by ultrasonography and FNAC, the subjects were recommended to undergo a follow-up treatment under Japan's comprehensive medical coverage programme.

If a malignancy was suspected or detected by FNAC, the subject would require surgical treatment.

Results of Thyroid Ultrasound Examinations in Fukushima

Preliminary Baseline Survey

In the PBLS, 300 476 subjects (participation rate: 81.7%) aged 18 years or younger at the time of the disaster were

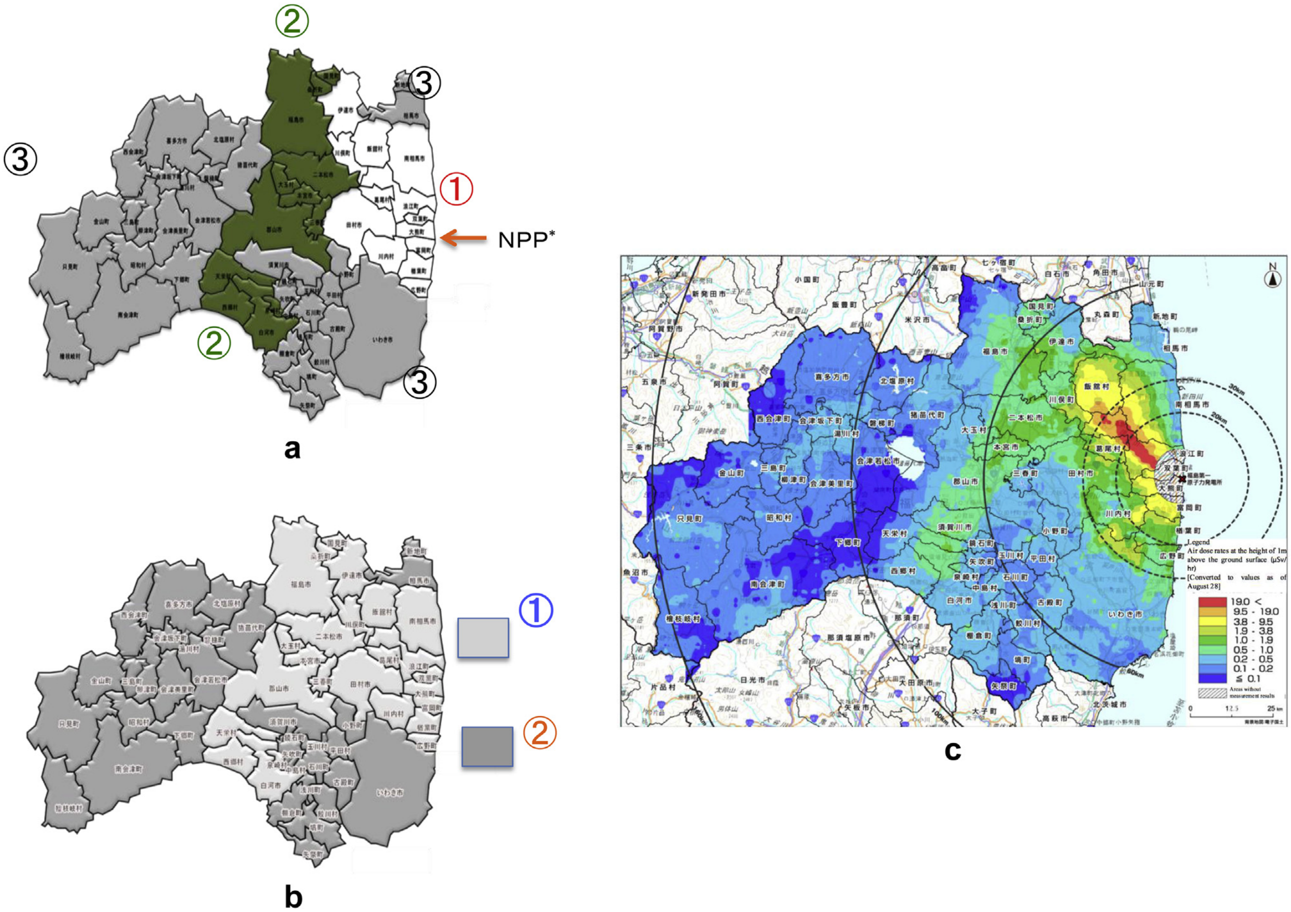

Fig 1. (a) Schedule of the preliminary baseline survey (PBLS). ① First survey, financial year 2011, from October 2011 to March 2012; ② second survey, financial year 2012, from April 2012 to March 2013; ③ third survey, financial year 2013, from April 2013 to March 2014. PBLS subjects were 367 685 residents of Fukushima Prefecture, including visitors, who were born between 2 April 1992 and 1 April 2011. NPP, nuclear power plant. (b) Schedule of the full-scale survey (FSS). ① First survey, financial year 2014, from April 2014 to March 2015; ② second survey, financial year 2015, from April 2015 to March 2016. In total, there were 385 685 FSS subjects. FSS subjects were PBLS subjects and newly added subjects who were born between 2 April 2011 and 1 April 2012. (c) Readings of the Airborne Monitoring Survey by MEXT in the western part of Fukushima Prefecture (air dose rates at a height of 1 m above the ground surface in Fukushima Prefecture). Thyroid ultrasound examinations were carried out first on those who were living in high-exposure areas at the time of the accident. (http://radioactivity.nsr.go.jp/en/contents/4000/3168/24/1270_0912_2.pdf).

screened from 9 October 2011 to 31 March 2014. Among them, the proportions of those who fell into each of the categories A1, A2, B and C were 51.5, 47.8, 0.8 and 0% (one person), respectively; 2294 subjects in categories B and C were recommended to undergo a confirmatory examination; 113 were subsequently diagnosed with malignancy or suspected malignancy by FNAC.

Full-scale Survey

The first time FSS, second round TUE survey of 169 455 subjects (participation rate; 44.7%) started in April 2014 and results had been received by 30 June 2015. The proportions of those who were classified as categories A1, A2, B and C were 41.6, 57.6, 0.8 and 0% (no case), respectively; 1223 subjects classified as category B were recommended to undergo a confirmatory examination. Of these, 25 subjects were diagnosed with malignancy or suspected malignancy by FNAC.

Age and Gender Distribution of Malignancy or Suspected Malignancy by Fine Needle Aspiration Cytology (Table 3, Figure 3)

In the PBLS, the mean age at diagnosis and at the time of disaster was 17.3 and 14.8 years, respectively; of these, 38 were male and 75 were female. There was no case aged younger than 6 years at the time of the accident. These results are similar to the results reported by Tronko *et al.* [5] in the first 4 years after the Chernobyl accident. It is interesting to note that the age distribution changed dramatically in Ukraine more than 4 years after the accident, with increasing numbers of thyroid cancers in those aged younger than 6 years at the time of the Chernobyl accident [5].

In the FSS, the mean age at diagnosis and at the time of the disaster was 17 and 9 years old; 11 were male and 14 were female; 4 years after the accident there were still no cases aged younger than 6 years at the time of the accident.

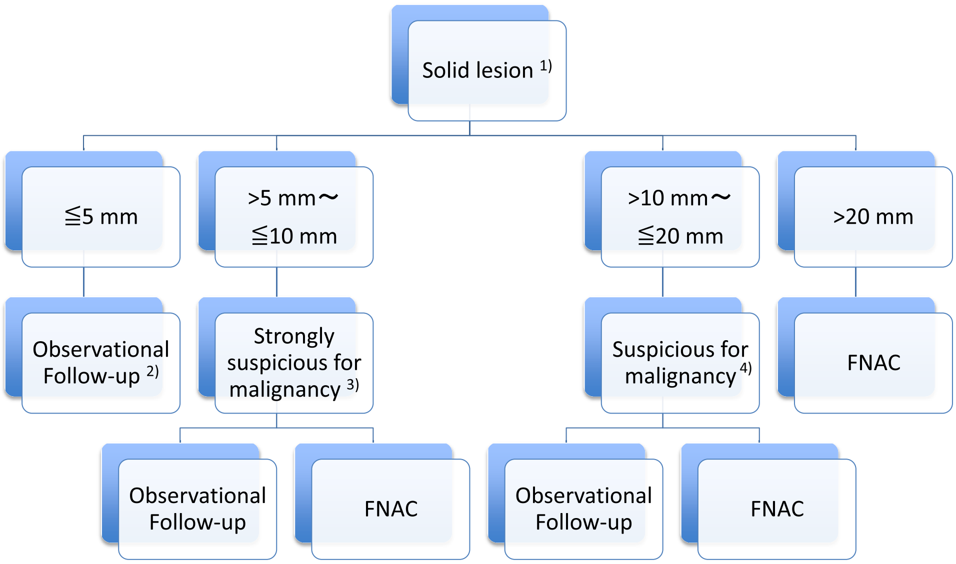

Fig 2. Ultrasound diagnostic criteria for thyroid nodules. A sonological flow chart for thyroid solid tumour evaluation by the Japan Association of Breast and Thyroid Sonology (JABTS). (1) For multiple nodules, each nodule should be evaluated using the criteria for solid nodular lesions. Observational follow-up is indicated for hyperplastic nodules, such as adenomatous thyroid nodules showing spongiform or honeycomb patterns. (2) Fine needle aspiration cytology (FNAC) is necessary when there are neck lymph node metastases or distant metastases, or high values of serum carcinoembryonic antigen or calcitonin. (3) When malignancy is strongly suspected according to the ultrasound diagnostic criteria for thyroid nodules by the Japan Society of Ultrasonics in Medicine (JSUM) (Table 1). (4) When there are one or more findings of malignancy according to the ultrasound diagnostic criteria for thyroid nodules by JSUM (Table 1) or positive blood flow (penetrating vessel) into a nodule by colour Doppler echogram.

Surgical Treatment of Thyroid Cancer

Of the 113 subjects diagnosed with or suspicious for cancer in the PBLS, 99 subjects have already undergone surgery. Papillary thyroid cancer (PTC) was confirmed in 95 cases and there were three cases of poorly differentiated thyroid carcinoma (PDTC) and one case in which the thyroid tumour was benign.

Of the 25 subjects diagnosed with or suspected for cancer in the FSS, six subjects have already undergone surgery; all were confirmed as PTC after surgery (Table 3) [18]. Most of these patients were operated in the Fukushima Medical University Hospital by specialists certified by the Japan Society of Thyroid Surgery (JSTS) and the Japan Association of Endocrine Surgeons (JAES) according to Japanese guidelines for the treatment of thyroid tumour by JAES and JSTS [19]. Confirmed results after FNAC were discussed in detail

Table 1
Ultrasound diagnostic criteria for thyroid nodules

	Primary				Secondary	
	Shape	Edge definition and character of the border	Internal echoes		Fine strong echoes	Marginal hypoechoic zones
			Echo level	Homogeneity		
Benign findings	regular	well-defined, smooth	high-low	homogeneous	–	regular
Malignant findings	irregular	ill-defined, jagged	low	heterogeneous	multiple	irregular/none

Table 2
Prevalence of thyroid cancer or suspected thyroid cancer diagnosed by fine needle aspiration cytology in Fukushima Prefecture

Area	Level of radiation exposure	Implementation fiscal year	No. subjects screened	Suspicious or malignant cases*	Proportion of suspicious or malignant cases (%)
①	High	2011	41 810	14	0.033
②	Medium	2012	139 338	56	0.039
③	Low	2013	119 328	42	0.035
		Total	300 476	113	0.038

* Excluding one suspected case found to be benign after surgery.

Table 3
Malignant or suspected malignant cases in the preliminary baseline survey (PBLS) and the full-scale survey (FSS) diagnosed by fine needle aspiration cytology (FNAC)

	PBLS*	FSS†
No. subjects screened	300 476	169 455
No. malignant or suspected malignant cases by FNAC	113	25
Male:female	38:75	11:14
Mean age at diagnosis (years)	17.3	17
Standard deviation, minimum–maximum	2.7, 8–22	3.2,10–22
Mean age at the time of disaster (years)	14.8	13.2
Standard deviation, minimum–maximum	2, 6–18	3.2, 6–18
Mean tumour size (mm)	14.2	9.4
Standard deviation, minimum–maximum	5.1, 5.1–45	3.4, 5.3–17.4
No. surgery	99	6
Benign thyroid nodule	1	
Papillary thyroid cancer	95	6
Poorly differentiated thyroid carcinoma (PDTC)	3	

* From October 2011 to June 2015.
† From April 2014 to June 2015.

with patients and guardian(s) accompanied by our support staff for mental health care, who could then elect active surveillance or surgery. Cases were reviewed by a panel of thyroid experts both pre- and postoperatively.

Thyroid Cancer Prevalence and Radiation Dose in Fukushima Prefecture

Suspicious or Malignant Cases on Fine Needle Aspiration Cytology by Estimated Radiation Dose

In the PBLS, among 113 cases diagnosed with malignancy or suspected malignancy on FNAC, 65 cases (57.5%) were also participants in the basic survey of the FHMS, which estimated individual external radiation dose. Of these, 45 (71.4%) had estimated radiation exposure doses below 1 mSv; the highest effective dose was 2.2 mSv.

There was no significant difference in the individual effective dose between these 113 cases and the other participants in the TUE [18].

Prevalence of Diagnosed or Suspicious Thyroid Cancer Diagnosed by Fine Needle Aspiration Cytology According to Area of Fukushima Prefecture

As mentioned above, the TUE started in those areas where spatial radiation dose just after the accident was

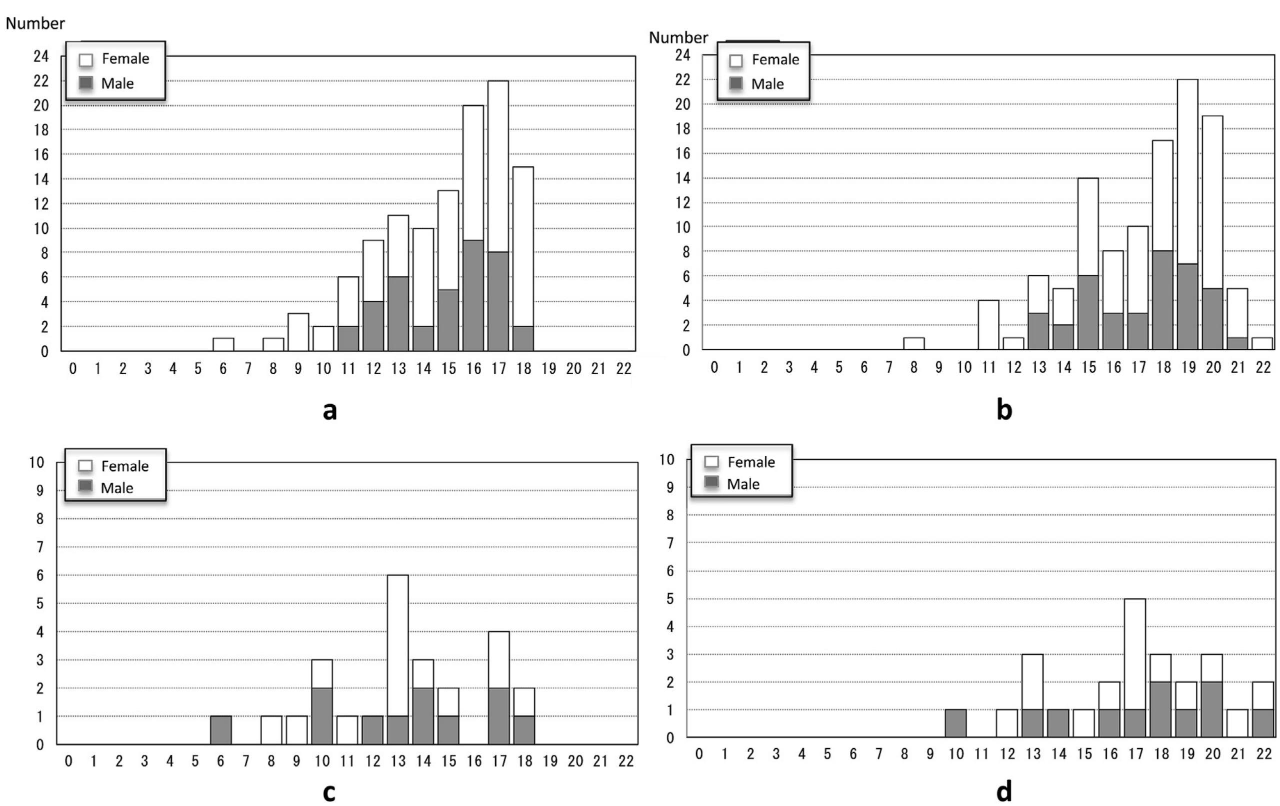

Fig 3. Age and gender distribution of subjects with malignancy and suspected malignancy diagnosed by fine needle aspiration cytology (FNAC) in the preliminary baseline survey (PBLS) and the full-scale survey (FSS). (a) Age as of 11 March 2011 in PBLS, (b) age as of confirmatory examination in PBLS, (c) age as of 11 March 2011 in FSS, (d) age as of confirmatory examination in FSS.

higher (Figure 1) [12]. Although these three areas were different in the level of radiation exposure, there was no significant difference in the proportion of suspicious or malignant cases on FNAC among these three areas (Table 2) [12]. Area 3 was also divided into Iwaki, Soma and Aizu, so the prevalence of diagnosed or suspected thyroid cancer was estimated in four geographical areas: the evacuation zone (1.1% exposed to 5 mSv or more), Nakadori (0.007% exposed to 5 mSv or more), Iwaki and Soma (0.004% exposed to 5 mSv or more) and Aizu (0% exposed to 5 mSv or more). There was no significant differences in thyroid cancer prevalence among the evacuation zone (33.5 per 100 000), Iwaki and Soma (43.0 per 100 000), Nakadori (37.2 per 100 000) and the reference area of Aizu (32.6 per 100 000), which had the lowest radiation level [13].

Genetic Alterations

In 68 patients where surgery had been carried out, thyroid tumour tissue was examined for the presence of driver mutations to clarify the pathogenesis of the tumour. *BRAF*^{V600E} was identified in 43 cases (63.2%), *RET/PTC1* in six (8.8%), *RET/PTC3* in one (1.5%) and *ETV6/NTRK3* in four (5.9%) [20].

Other Findings from Thyroid Ultrasound Screening

Ectopic Intrathyroidal Thymus

Ectopic intrathyroidal thymus (EITT) is thought to be a rare entity, but about 1% of the children had an EITT identified as a result of the large-scale screening carried out as part of the larger FHMS. Diagnostic criteria are based on the ultrasonographic appearance of EITT; round, oval, or polygonal hypoechoic or hyperechoic areas, with multiple granular and punctate echogenic foci (Figure 4A, 4B) [21]. The mean age was 7.0 years (range 0–18 years). There was no difference in the laterality of EITT. The incidence of EITT was inversely correlated with age and body mass index.

In the 10–14 age group, girls had higher odds ratio (0.46; confidence interval 0.27–0.78; $P = 0.004$) of decreasing prevalence of EITT. In addition, higher body mass index (odds ratio = 0.90; confidence interval 0.83–0.98; $P = 0.02$) was associated with a lower prevalence [21].

Colloid Cyst

Category A2 consisted most of cysts, especially small multiple colloid cysts, cysts with colloid clot (Figure 4C) [12]. These were characterised on ultrasound as a comet tail sign or cat's eye sign (Figure 4D). These colloid cysts are easily detected by ultrasound even when very small (1–3 mm). These findings are benign and it was therefore not necessary to do a further examination such as FNAC [12].

Thyroid Volume

The aim of the PBLS was to establish updated reference values for thyroid volume by ultrasound examination and epidemiological analysis in 0–19-year-old Japanese children. The subjects were 38 063 children who were examined by ultrasonography as the first PBLS of the FHMS

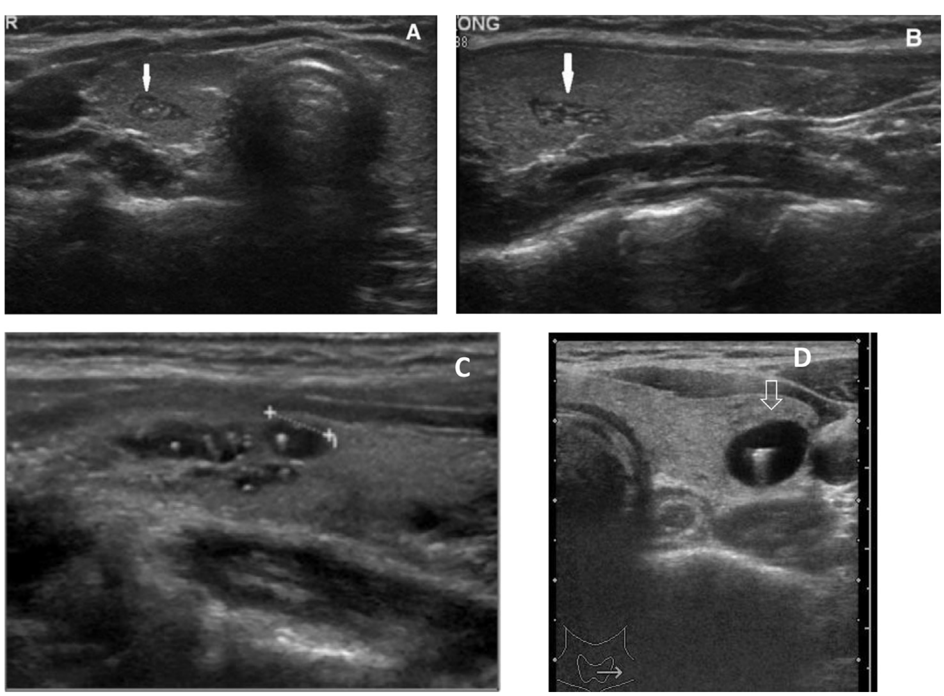

Fig 4. Thyroid ultrasonic findings characteristic for children. (A) Ectopic intrathyroidal thymus (arrow) in the right lobe of thyroid (transverse view) [21]. (B) Ectopic intrathyroidal thymus (arrow) in the right lobe of thyroid (sagittal view) [21]. (C) Multiple colloid cysts showing comet tail sign in the thyroid lobe (sagittal view) [12]. (D) Colloid cyst with comet tail sign or cat's eye sign.

between 9 October 2011 and 31 March 2012. The width, thickness and height of each lobe were measured and the volume of each lobe was calculated by the mean of the elliptical shape volume formula. Positive correlation was observed between thyroid volume and either age or body surface. The right lobe was significantly larger than the left lobe. The thyroid volume in females was larger than that in males after adjusting body surface area [22].

Discussion

The development of a comprehensive thyroid screening programme after the Fukushima accident has raised a number of issues. There were differing opinions on when the TUE should start and how frequently the children should be screened thereafter, and there are a number of considerations to be taken into account before agreeing the protocol for such a study.

Some parents wanted to carry out the TUE at shorter intervals – every year, every 6 or 3 months, rather than every 2 years. Some suggested that the TUE should be made 'on demand', i.e. anytime, anywhere in the neighbourhood. The reports of the primary examination of TUE were provided by post. Some parents requested a more detailed explanation of the results for their children. Several guardians would have liked to receive pictures of the ultrasound image for their child.

As the results of the study were made public, a number of other issues came to light. The first survey of the PBLS suggested a high frequency of subjects categorised as A2 (47.6%) in Fukushima. Most of the subjects classified as category A2 had cysts. This was regarded as an unexpected finding in Japan and elsewhere, and was initially interpreted as being a result of radiation exposure.

To obtain comparative data for increasing A2 in Fukushima, the Ministry of Environment entrusted the JABTS to carry out thyroid examinations using the same method used in Fukushima Prefecture among three prefectures, Aomori, Yamanashi and Nagasaki, which were geographically distant from Fukushima and not exposed to radiation from the accident. The same protocol as for the Fukushima TUE was used to study children aged between 3 and 18 years old in these three prefectures. The results showed that the frequency of those classified as A2 (56.6%) in the three prefectures was higher than that in Fukushima [23,24]. This indicated that the increased finding of thyroid cysts that comprised most of those cases classified as A2 depended on the precision of the screening rather than being related to radiation exposure.

The participation rate of those in the age group 16–18 years (at the time of the accident) in target municipalities for financial years 2011, 2012, 2013 in the PBLS were 74.1, 62.9, 36.2%, respectively [18]. The decrease in participation in this age group is even more marked in the FSS. The participation rate of age group 18–21 years (as of the date of primary examination) in target municipalities for financial year 2014 was 22.3%, the lowest of all the age groups [18]. The reasons for this decline in participation are probably changes in lifestyle with those older than 18 years moving away from the area for work or education and therefore it becomes more difficult to attend a clinic held during the week. We have therefore started providing venues for screening outside of the Fukushima area and provide additional opportunities to be screened either at the weekend or during seasonal holidays. In the younger age groups, parental/guardian pressure probably enforces attendance at the screening clinics.

The PBLS was completed with a high participation rate (81.7%) and the FSS, the second round screening, has already started. As a result, 113 and 25 subjects were diagnosed with a malignancy or suspected malignancy by FNAC in the two phases, respectively; 98 and six cases have already undergone surgery and been confirmed as thyroid cancer [18]. These results could be interpreted that in Fukushima, thyroid cancer in children and adolescents was increasing compared with before the accident. Does this really mean that these cases of thyroid cancer were a result of radiation exposure after the Fukushima Daiichi NPP accident? Our tentative answer is 'no'. The reasons from data obtained from the PBLS are as follows.

- Radiation doses in Fukushima were extremely low. Most of the target population for the TUE received doses below 1 mSv [18] and although it is difficult to measure the dose due to 131-I accurately because of its short physical half-life, further studies using whole body counters in 22 717 residents suggested that 99.9% had received doses of less than 1 mSv/year [12,13]. Initial estimations using the System for the Prediction of Environmental Emergency Dose (SPEEDI) assumed a continuous radiation intake from 12 to 24 March 2011 and suggested that the thyroid equivalent dose in a 1-year-old child in Iwaki city, Kawamata town and Iitate village might have reached 100 mSv. However, direct thyroid measurements of 1080 children in these three areas showed that none of the children had a level of 0.2 microSv/h (equivalent to 100 mSv). Instead the highest level recorded was 0.1 microSv/h (equivalent to 35 mSv) [8,25–27]. This compares with the estimated mean doses of 500 mGy (range 50–5000 mGy) for thyroid doses in those evacuated after Chernobyl. In Fukushima, the individual thyroid doses are unlikely to be above the recommended level for intervention of 50 mSv [2,6,8,9,12–14,25–28].
- The expected latency for radiation-induced thyroid cancer is 4–5 years [2–5]; only 4 years have passed since the Fukushima accident.
- The carcinogenic risk would be heightened if the subjects were young at the time of the accident, but the average age of these malignant or suspected malignant cases was 15 years old and the youngest age group (0–5 years) has shown no occurrence of cancer to date [2–5].
- There was no difference in the thyroid cancer discovery rate within the 4 year period.
- Unlike Chernobyl, most cases were diagnosed with classical type PTC, and there were no solid variant PTCs, which were typically shown in the radiation-induced

thyroid cancer after the Chernobyl accident [2–4,29]. The results of the FSS study were similar to those of the PBLS study.

For the FSS, the mean age was the same; tumour size was smaller, fewer tumours were identified compared with the PBLS (Table 3).

The FSS results showed a similar pattern to the PBLS with respect to age and gender, and those diagnosed with malignancy and suspected malignancy by FNAC. There were no cases in children aged 0–5 years old.

The results from the PBLS show that 25 participants with malignancy or suspected malignancy were categorised as A1 (10), A2 (13), and B (2). Among 25 cases, 23 cases (92%) were A1/A2 in the PBLS. This shows that most of these 25 subjects were detected for the first time in the FSS by ultrasonography [18]. Although ultrasound examination can easily detect even a 1 mm cyst, malignant solid tumour without a cystic component might be unable to be detected within 5 mm by ultrasound. Therefore TUE should be carried out repeatedly every 2 years.

If, however, the thyroid cancers detected are not the result of radiation exposure, we should be concerned about the effects of overdiagnosis as a result of the screening programme. In some countries, particularly in the USA and Korea, the rate of thyroid cancer has been shown to be increasing since 2000 [30,31]. Some of this increase is due to better diagnosis, as evidenced by the numbers of micro-PTC. We have therefore been careful in the TUE to recommend that tumours below 5 mm diameter should not proceed directly to surgery, in accordance with local guidance in Japan from JABTS, JSUM, JSTS, Japan Thyroid Association and JAES [32].

Unfortunately, a comparison between the frequency of thyroid cancer identified by sensitive screening procedures used in the TUE and statistics based on operations are made by less knowledgeable scientists. This has led to misrepresentation of the initial findings of the TUE in both the scientific media and the press. The subsequent surveys that will be carried out as part of the TUE should increase our understanding of thyroid cancer in a young population and will provide an opportunity to evaluate any effect of radiation exposure on thyroid cancer in this population.

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