Epidemiology of the Atomic Bomb Survivors and Chernobyl to Fukushima Accidents

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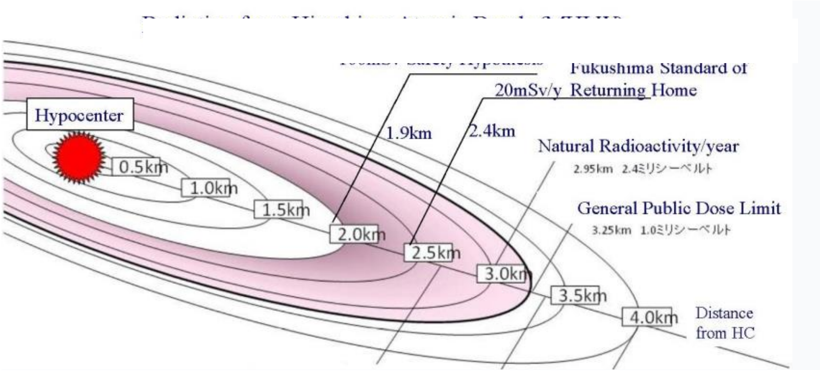
[ABSTRACT]

Four years have passed since the Fukushima nuclear accident. The government releases evacuation order in the area of radiation dose ≦20 mSv/year, and is trying to return the evacuees to their home town. Nuclear regulation authority claims "The difficulty to prove the obvious increase in health risk in 100 mSv or less is internationally recognized" and supports the evacuees return home policy. The Radiation Effects Research Foundation (RERF) is a scientific organization dedicated to studying health effects of atomic bomb radiation. The research results have been utilized as a source of basic information for establishing radiation protection standards. Epidemiology of the atomic bomb survivors is examined, and conclusions are summarized as follows. **1.** If we compare the radiation dose from Hiroshima atomic bomb estimated by DS86 and DS02 and the radiation dose standards, exposure dose of the 100 mSv safety hypothesis is equivalent to the exposure dose at 1.9 km from the atomic bomb hypocenter (HC). If evacuee in Fukushima return home in the evacuation released area ≦20 mSv/year, they shall have dose, in a year, equivalent to exposure dose at 2.4 km from the HC. Exposure dose of 100mSv and evacuation order release at ≦20mSv/year are not safe for resident's health. **2.** "Matters elucidated thus far by RERF studies" claims that the risk increases in proportion to radiation dose above around 100 to 200 mSv, but association remains unclear below that level ("100 mSv safety hypothesis"). This contradicts the results of the original papers: The dose-response appears to be linear, without any apparent threshold below which effects may not occur. **3.** In the life span study (LSS), the excess risk of survivors who were within 2.5 km of either HC at the time of bombing (Hibakusha) is derived by comparing with the risk for survivors who were at 2.5-10 km (non-Hibakusha), assuming that the exposure of the latter is nonsignificant. However, if the residual radiation and internal exposure are of considerable amount, non-Hibakusha might have been exposed by the radiation significantly. The excess cancer risk may have been estimated too low by comparing Hibakusha with non-Hibakusha exposed considerably by residual radiation. **4.** Excess cancer risk for exposure at 10 years old is higher by more than 5 times than that at 50. Young family with children can't go home if evacuation order is released at ≦ 20mSv/year. **5.** Atomic bomb survivors can have "Exposures Notebook" at around ≦7 km from HC with dose ≧ 0.5 mSv, and medical expenses are free. Fukushima residents who are exposed 20 mSv/year, cannot have any support for medical allowance except children. **6.** If we compare the evacuation standards and exposure managements of Chernobyl and Fukushima, human right to health seems not to be protected in Fukushima. This difference comes from the acceptance of 20 mSv/year dose safety standard based on 100 mSv safety hypothesis. **7.** Childhood thyroid cancer in Fukushima seems to increase at comparable speed to or faster than that in Chernobyl. From the good correspondence of the results of thyroid examination and the extent of radioactive I-131 deposition, childhood thyroid cancer may probably caused by radioactive exposure.

1. Radiation dose standards and the radiation dose from Hiroshima atomic bomb

Radiation from Hiroshima atomic bomb is estimated by DS86 and DS02 and it is shown in HP of MHLW (1). Exposure dose of 100mSv of 100 mSv safety hypothesis is equivalent to the exposure dose at 1.9km from the Hiroshima atomic bomb hypocenter (HC). Evacuation order in Fukushima nuclear accident is released in the area 20mSv/year. If they return home they shall have dose in a year equivalent to exposure dose at 2.4 km from HC, and have dose 100 mSv in 5 years at most. For those exposed within about 3.5km from atomic bomb HC (dose≒1 mSv), atomic bomb diseases, such as solid cancer, leukemia, and hyperparathyroidism, are authorized in principle by MHLV (11). Residents who were within 2.5km from HC are defined as Hibakusha in the Life Span Study (LSS) of RERF, because they had "significant" radiation exposure. Radiation standard of 20 mSv/year for evacuee returning home, equivalent to the exposure dose at 2.4 km from HC, can never be safe.

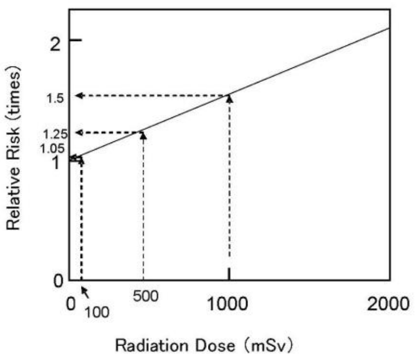
Fig. 1 Radiation dose from Hiroshima atomic bomb (1) and radiation protection standards



2. The 100 mSv safety hypothesis

We find the following guide in Matters elucidated thus far by RERF studies (2). The risk of dying from solid cancer increases in direct proportion to radiation dose above around 100 to 200 mSv, but association remains unclear below that level. We name this "100 mSv safety hypothesis".

Fig. 2 Cancer risk and radiation dose from RERF studies

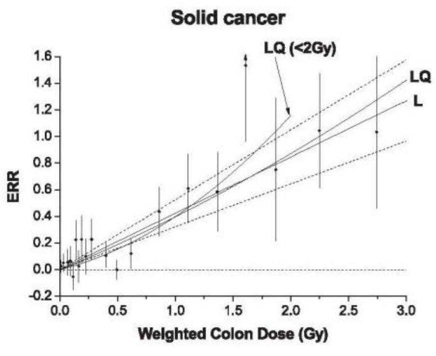


The same kind of guide for cancer risk and radiation dose relation is given by NIRS (National Institute of Radiological Sciences) and REA (Radiation Effects Association) (3).

3. Increased cancer risk by exposure 100 mSv or less is statistically significant

The 100 mSv safety hypothesis is based on LSS in RERF, and the result of important LSS researches is that "Increased cancer risk by exposure 100 mSv or less is statistically significant".

Fig. 3 Excess relative risk (ERR) of all solid cancer deaths in relation to radiation dose



① The first of three examples are the most recent and comprehensive research is introduced in Ref. (4a).
Studies of the Mortality of Atomic Bomb Survivors, Report 14, 1950–2003 (5). The data are shown left.

The abstract by RERF, that the dose range with a significant ERR was more than 200 mSv, contradicts with the result of the original paper as follows. The reason for this modification seems to be in the report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2010 (6). It is written in section 25 that statistically significant elevations in risk are observed at doses of 100 to 200 mSv and above. Correction of the result of LSS study by RERF follows UNSCEAR.

ABSTRACT by authors

<u>The estimated lowest dose range with a significant ERR for all solid cancer was 0 to 200 mSv,</u> and a formal dose-threshold analysis indicated no threshold; i.e., **zero dose was the best estimate of the threshold.**

ABSTRACT by RERF

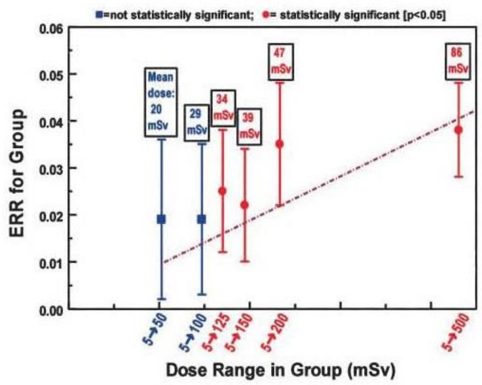
The best estimate of the threshold of a linear dose–response relationship was zero, but **<u>the dose range with a significant ERR was more than 200 mSv.</u>**

② Solid cancer incidence in atomic bomb survivors: 1958-1998. D. L. Preston et al. Radiation Res. Jul;168(1):1-64 (2007) (7). The data were consistent with a linear dose response over the 0-2 Sv range. There is <u>a statistically significant dose response when analyses were limited to 150 mSv or less.</u>

③ Cancer risks attributable to low doses of ionizing radiation: David J. et al. PNAS: 2003 Nov 100(24) 13761–13766. (8) Excess relative risk of the mortality from solid cancers in the LSS study is shown in Fig. 4. The first two data points (in blue) are not statistically significant compared with the comparison population who were exposed to 5 mSv, whereas the remaining four points of 34-86 mSv (in red) are statistically significant (ρρ <0.05).

Results of all the papers ①②③ of epidemiology of the atomic bomb survivors contradict with the 100 mSv safety hypothesis.

Fig. 4 Excess relative risk of solid cancer mortality



4. **Is the radiation exposure of non-Hibakusha in RERF definition truly no significant?**

In the LSS of atomic bomb survivors, Hibakusha, who were within 2.5km of either hypocenter at the time of bombing, is considered to have been under "significant" radiation exposure, and radiation exposure of survivors who were 2.5-10km (non-Hibakusha) is considered to be "no significant". The excess cancer risk is derived by assuming that <u>the excess risk of non-Hibakusha = 0.</u>

Let's see Fig. 5, the map showing the power of the Hiroshima atomic bomb by MHLW (9). Almost all people died at distance from HC R≦1 km, all buildings burned down and collapsed in 1 km≦R≦2 km range, and spontaneous combustion occurred at R≦3 km. Definition of Hibakusha who were exposed at less than 2.5 km, and non-Hibakusha exposed at 2.5 km≦R≦10 km are shown in the figure. People who are exposed by 100 mSv and Fukushima evacuees who are going back home at ≦20 mSv/year area correspond to Hibakusha in RERF definition. Non-Hibakusha who were within 3.5 km and have some disease can be certified promptly as atomic bomb disease (11).

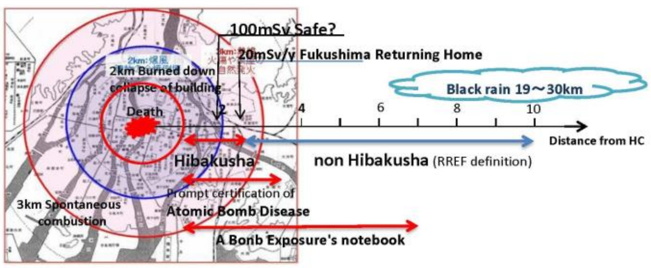
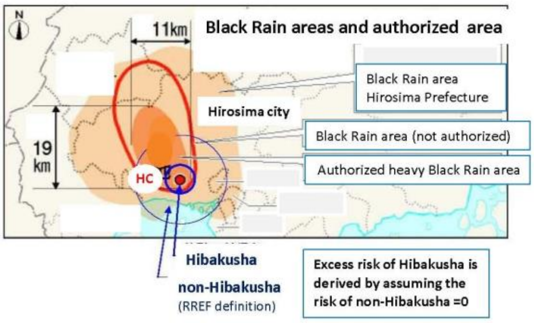


Fig. 5 Map showing the power of the Hiroshima atomic bomb

A part of "black rainfall area including radioactivity" in the north west of Hiroshima city was designated "physical check-up special case area", but the area which isn't designated yet is left (Fig. 6). The Peace declaration of Hiroshima city demands expansion of the "black rain areas" (10).

Fig. 6 Black rain areas and authorized black ran area including radioactivity



If the residual radiation and internal exposure were of considerable amount, non-Hibakusha might have been exposed significantly. The excess cancer risk may have been estimated too low by comparing Hibakusha with non-Hibakusha exposed considerably by residual radiation.

5. Radiation dozes and medical expenses of atomic bomb survivors and Fukushima residents

Radiation doze, medical expenses and allowance of atomic bomb survivors are compared with those of Fukushima residents. In Fukushima, evacuation order is released at space radioactivity below 20 mSv/year. Health check service and allowance for medical expenses are not provided for the residents except children. On the other hand, atomic bomb survivors in Hiroshima and Nagasaki can have ”Exposures Notebook” at around ≦7km from HC with dose ≧ 0.5 mSv, and medical expenses are free (11). For those exposed within about 3.5km from HC with dose ≧ 1 mSv, certification of atomic bomb diseases is granted promptly (12).

Table1. Radiation dozes and medical expenses of atomic bomb survivors and Fukushima residents

	Hibakusha(Atomic Bomb survivors)		Fukushima
	Exposure's notebook	Authorized Atomic Bomb Disease**	
Distance from Hypocenter	≦7 km	≦3.5km	Evacuation order release
Radiation dose	≧0.5mSv	≧1mSv	≦20mSv/year
Medical Expenses	Free	Special allowance ¥135,000/month	childhood thyroid cancer checkup 18 years or younger free
Number of People	201,000*	8,552(4%)	⇒ 0 as soon as possible

*Health care allowance ¥33,300/month for some kind of diseases(170,000 people)
**Authorized Atomic Bomb Disease : Solid Cancers, Leukemia, Hyperparathyroidism etc

In the table, radiation dose of atomic bomb survivors are estimated from Ref. 4b and Appendix 9 of Ref. 12b.
The 100 mSv dose safety hypothesis and the release of evacuation order in the area ≦20 mSv/y in Fukushima, completely contradict the reality for the health damage of atomic bomb survivors. What is the reason for this contradiction? Is the equality under the law protected?

6. Cancer risk for exposure at 10 years old is higher by more than 5 times than that at 50 years old

Excess risks of solid cancer incidence (7) and mortality (5) indicate that higher risks are associated with younger age at exposure.

Fig. 7 Excess relative cancer mortality risk (ERR) by age at exposure and attained age (5)

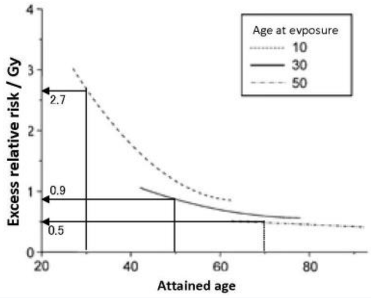


Table 2 Excess lifetime cancer risk of LSS cohort by RERF (13)

Excess lifetime cancer risk of LSS cohort

Age at exposure	Sex	Excess risk
10	man	2.1%
	woman	2.2%
30	man	0.9%
	woman	1.1%
50	man	0.3%
	woman	0.4%

In Fig. 7, ERR's, 20 years after exposure at 10 and 50 years old are in the ratio 2.7/0.5≒5.4. In Table 2, excess lifetime cancer risk for exposure at 10 and 50 years old are in the ratio 7 for men and 5.5 for women. Is it safe for a family with pregnant woman and children to live in≦20 mSv/year area?

7. Evacuation standards and exposure managements of Chernobyl and Fukushima nuclear accidents

In the precedent chapters, we have discussed if it's safe to live in the area of radioactivity ≦20mSv/year by comparing Fukushima with the radiation dose of atomic bomb survivors. Here, evacuation standards of Chernobyl (14) and Fikushima are compared.

Table 3 Evacuation standards: Chernobyl law vs. Fukushima

Evacuation standards Chernobyl and Fukushima

Annual radiation dose	Chernobyl law	Fukushima
≧ 50mSv	Forced evacuation zone	Forced evacuation zone
20〜50 mSv		Residence restricted area
≦ 20 mSv	Immigration obligation area	Evacuation order release
5〜20 mSv		Habitable including pregnant woman and children
1〜5 mSv	Immigration rights area	

By Chernobyl law, people do not live in the area of radioactivity ≧5 mSv/year. They have rights to live or immigrate in 1-5 mSv/year zones. In Fukushima, evacuee must go back to their home town of dose ≦20 mSv/year. Public exposure limit is kept at 1 mSv/year in Chernobyl, but in Fukushima, it is raised to 20 mSv/year. Ukrainian government revealed the serious health damage in the 2,360,000 inhabitants in the contaminated area of 1~5 mSv/year (14).

Table 4 Radiation exposure control Ukraine & Belarus versus Japan (15)

Exposure management Chernobyl and Fukushima

	Ukraine and Belarus	Japan
Forced evacuation	≧ 5 mSv/year	≧ 20 mSv/year
Immigration rights	1〜5 mSv/year	None
Contamination area specified	≧ 0.5 mSv/year	None
Victims registration	≧ 0.5 mSv/year	None
Medical expences	free	18 years or younger free
Recreation of children given by country	1 month/year	None

The difference between Chernobyl and Fukushima is clear. According to the Ukraine Law Article 16, Ukrainian government formed a database of 2,300,000 victims. The database is used to support the detailed examination and medical security of victims. Special Rapporteur on the right of health by Anand Grover of UN (Ref. 16, 46.47) reported as follows: In Ukraine, the 1991 law 'On the status and social protection of the citizens who suffered as a result of the Chernobyl catastrophe' limited radiation dose for living and working without limitations to 1 mSv/year. Is the right to health protected in Japan? What have we learnt from Chernobyl accident?

8. Childhood thyroid cancer in Fukushima and in Chernobyl

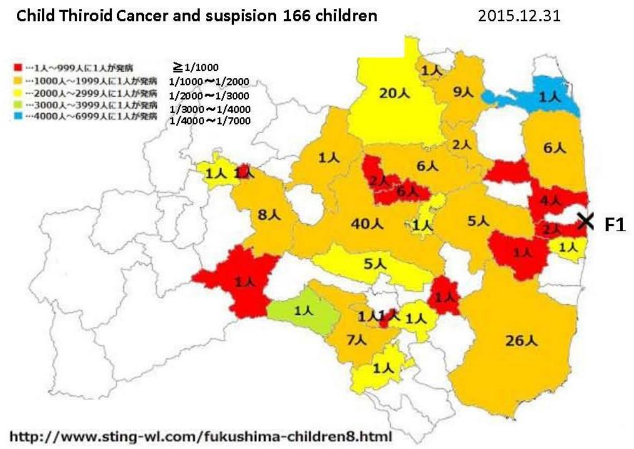
A. Childhood thyroid cancer in Fukushima

Fukushima prefecture carries out thyroid gland supersonic examination to watch health of children for long term (17). The reports of thyroid examination is given for the preceding examination Ⅰ (2011.10〜2014.3) in Ref. (18) and for the full scale study Ⅱ (2014.4〜2016.3) in Ref. (19).

The results of the thyroid check-up are divided into four categories. 'A1' means no nodule or cyst. 'A2' means that the size of the nodule present is less than 5.0 mm and/or the cyst is less than 20.0 mm. 'B' indicates that the nodules and cysts are larger than 5.1 mm and/or 20.1mm respectively. 'C' indicates an urgent need for secondary examination. When cancer cells were detected in fine needle aspiration in secondary examination cytology for 'B' and 'C', the patient was followed and operated on at an appropriate time (28). We define thyroid cancer cases detected by fine needle aspiration cytology as cases of "thyroid cancer". Among thyroid cancer suspected 138 children, 105 underwent surgery, 104 were found cancer, hence the proportion was more than 99% and possible error may be negligible.

Let' see the number of children of thyroid cancer in Fukushima reported in thyroid gland examination published on 2015.8.31. (18, 19)

Fig.8 Number of children of thyroid cancer and the morbidity in each area (20).



Morbidity of childhood thyroid cancer in Japan was stable at 0~3 in 1,000,000 children in 1986~2002, after the Chernobyl accident (20). The morbidity is 1/1000 in 6 areas in Fukushima, c.a. 300~1000 times of the natural morbidity. Two big cities Fukushima and Koriyama outside evacuation zone have 20 and 26 patients of thyroid cancer, respectively, with the morbidity 1/2000～1/3000.

Thyroid evaluation subcommittee pointed out that the morbidity of thyroid cancer in Fukushima is high by tens of times of order of the prevalence estimated from statistics. The reason was considered to be "over diagnosis or caused by exposure"(21). However, out of the total 96 surgery cases in Fukushima Medical University Hospital, Extra thyroid infiltration (pEX1) 39%, Lymph node metastasis 74%, Metastasis to the lung 3% (23). Very high morbidity seems not to come from over diagnosis. Tsuda et al. found that an excess of thyroid cancer detected by ultrasound among children in Fukushima within 4 years of the release, is unlikely to be explained by a screening effect. (28).

Outside Fukushima, 3 thyroid cancer patients are found in Kitaibaraki city of Ibaraki, with morbidity 1/1000 (22). Only 21% and 37 % children are healthy 'A1' in Matudo city Chiba (24) and in Kantou region (25), respectively. To see the possibility of thyroid cancer caused by radioactive exposure, two maps are shown below. (Figs. 9 and 10)

Fig.9 Amount of radioactive iodine I-131 deposition(26)

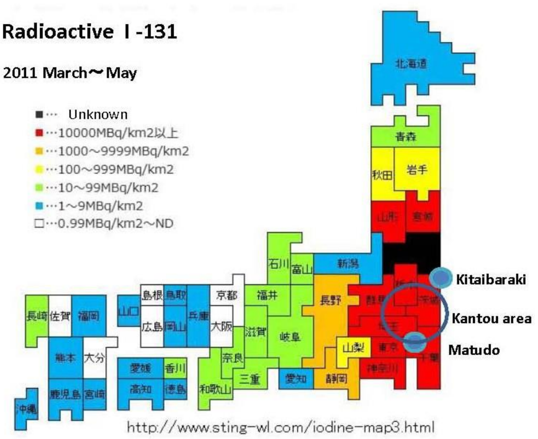
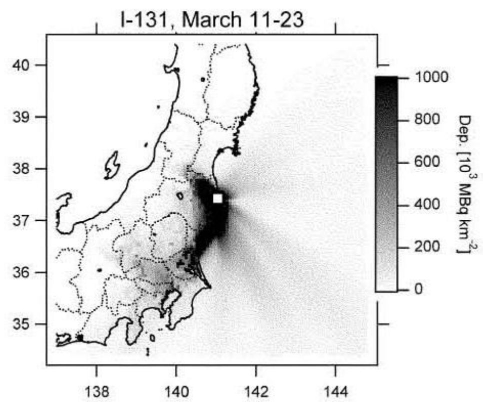


Fig.10 Simulated amount of radioactive iodine I-131 deposition (27)



Highly contaminated area around F1 nuclear plant expands to south over Kantou area. This corresponds to the results of thyroid check-ups in Kitaibaraki, Matudo, and Kantou area, which are shown by circles. Areas of high I=131 deposition extend widely from Fukushima prefecture to the surrounding area (southern Tohoku, Kanto, and eastern Chubu). From the good correspondence of the results of thyroid check-ups and the extent of radioactive I-131 deposition, thyroid cancer of children is possibly caused by exposure of the nuclear accident, internal exposure of radioactive I-131.

It is very important to remember the Report of the Special Rapporteur on the right of everyone by Anand Grover : The fallout from the accident seems to have reached prefectures other than Fukushima, he also urges the Government to expand the health monitoring to other affected prefectures, where radiation exposure is higher than additional 1 mSv/year (16).

B. Thyroid cancer morbidity in Fukushima is comparable to the one in Chernobyl

In order to see if the high morbidity of childhood cancer in Fukushima is the result of the screening effect, as it is often claimed, results of thyroid gland supersonic examination in Fukushima (18,19) and Chernobyl (29) are compared in Table 5. Morbidity of thyroid cancer per 10,000 children in Fukushima is 4.2 (2011-13) and 3.9 (2014-16). Among 51 children discovered in second check-up 2014-15, 47 were cancer free (A1 or A2) and 'B' were only 4, which shows that their thyroid cancer grew in two years. This strongly suggests that childhood thyroid cancer in Fukushima comes from exposure in the accident.

The period of thyroid gland supersonic examination in Chernobyl was 5-9 years after the accident, when thyroid cancer increased explosively as shown in Fig. 11. The morbidity/10,000 of childhood cancer 8.1 1-5 years after the accident in Fukushima and the one of 8.3 in in Kitaibaraki (Table 5A), are comparable to or higher than the morbidity 5-9 years after Chernobyl accident (mean value 5.3). Number of thyroid cancer patients in Japan may possibly increase explosively.

Table 5. Results of thyroid gland supersonic examinations in Fukushima and Chernobyl

A.Thyroid supersonic examination 1-5 years after accident 2015.12.31

	Checking Period	Number of subjects	Thyroid Cancer & suspision	morbidity /10,000
Fukushima	2011-2013	300,476	115	4.2
	2014—2015	220,088	51	*3.9
	2011-2015	300,476	166	8.1
Kitaibaraki Ibaraki Pref.	2014-2015	3593	3	8.3

*Estimated from the data of children who have finished second inspection

B.Thyroid supersonic examination 5-9 years after nuclear accident

		Number of subjects	Thyroid Cancer	morbidity /10,000
Total		120,332	64	5.3
Belarus	Gomel	19,660	39	19.8
	Mogyurofu	23,781	2	0.8
Ukraine	Kiev	27,691	6	2.2
	Jimitoru	29,033	9	3.1
Russia	Buriyansuku	20,167	8	4.0

A. The result of the examination 1-5 years after the Fukushima accident.

B. The result of the examination 5-9 years after Chernobyl accident by S. Yamashita (29).

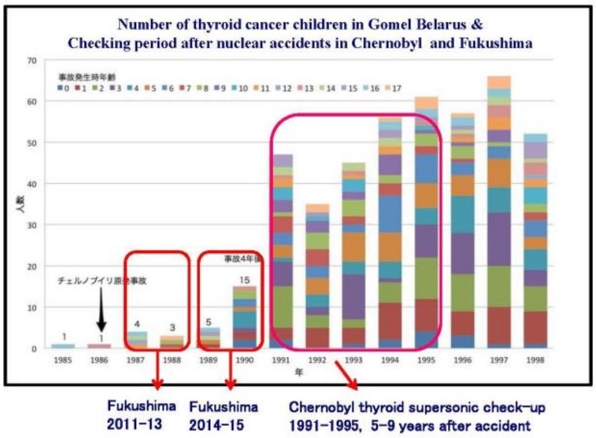


Fig.11 Number of thyroid cancer children in Gomel Belarus (29) and thyroid gland supersonic examination periods after nuclear accidents in Chernobyl and Fukushima. The examination in Chernobyl was 5-9 years after accident, when thyroid cancer increased explosively.

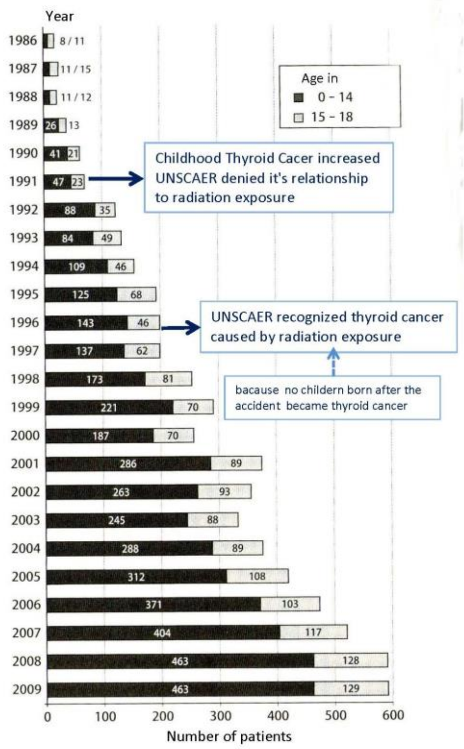
9. Radiation diseases by atomic bomb and by Chernobyl & Fukushima nuclear accidents

Diseases due to radiation dose are summarized in Table 6. For atomic bomb survivors, 7 diseases such as solid cancers, leukemia, hyperparathyroidism, hypothyroidism, etc. are recognized as atomic bomb diseases (12)　25 years after Chernobyl nuclear accident, Ukrainian government revealed the serious health damage, leukemia, cataracts, childhood thyroid cancer, myocardial infarction, to inhabitants in the contaminated area with exposure dose ≦5 mSv/year (14). However, UNSCEAR recognized only thyroid cancer of children to be the effect of exposure, and did not admit the other health hazards as the effect of exposure. Assertion of UNSCEAR is that Ukrainian government's claim has not been scientifically proven in epidemiological methods. Thyroid cancer was recognized as the effect of exposure without epidemiological proof, because the half-life of radioactive iodine I-131 is only 8 days, and effect of radiation disappears in a month. The morbidity of thyroid cancer of children who were born before the accident was very high, but no patients were observed among those who were born after the accident. UNSCEAR denied the relationship between thyroid cancer and radiation exposure for five years after the accident, but 10 years after the accident, childhood thyroid cancer was recognized as the effect of exposure by UNSCEAR, ICRP, IAEA, by the decisive fact that no children born after the accident became thyroid cancer.

Table 6 Radiation diseases by atomic bomb and by Chernobyl & Fukushima nuclear accidents

	Atomic Bomb	Chernobyl	Fukushima
Radiation disease	solid cancers	Ukraine government	thyroid gland supersonic examination
	Leukemia	Leukemia, cataracts,	
	Hyperparathyroidism	Childhood thyroid cancer	
	Myocardial infarction	Myocardial infarction	
	Hypothyroidism	Chronic diseases	
	Chronic hepatitis, liver cirrhosis	UNSCAR、IAEA,ICRP	
	Radiation cataract	Childhood thyroid cancer	

Fig. 12 Number of thyroid cancer children in Ukraine after Chernobyl accident (14), and the process of recognition by UNSCEAR as the effect of radiation dose.



Thyroid cancer was the special case caused by the radioactive iodine I-131, half-life of which is very short, only 8 days. Hence there was another way to prove that thyroid cancer is the effect of exposure. It is generally difficult to prove that a disease is caused by exposure by epidemiological way, because it is almost impossible to know the exposure dose of each people in Chernobyl and Fukushima. This may also be true of atomic bomb survivors except initial strong exposure dose. By imposing impossible epidemiological way, it becomes quite easy not to recognize a lot of health damages as the effect of exposure. As a result, international consensus comes out among UNSCEAR, IAEA, WHO, that only childhood thyroid cancer is the influence of the radiation exposure by Chernobyl nuclear accident. Policy of the Japanese government follows this consensus. Famous pollution diseases, ex. Itai-itai disease, Minamata disease, and Mesothelioma could never identified as coming from Cadmium contamination, Alkyl mercury compound contamination in the sea, Asbestos exposure, respectively, if the proof of statistically significant Morbidity-Cause relation were imposed as a necessary condition.

It should be noted from this graph that sum of thyroid cancer children 107 in Ukraine, 5 years after the accident, became 6072 in following 19 years. We should prepare for more cases expected in the future.

Conclusive remarks

Effect of radiation dose of ex. 100 mSv or 20 mSv/year, should first be determined by recognizing what occurred among atomic bomb survivors exposed at 1.9 km or 2.4 km from HC, respectively. The radiation dose of 20〜100 mSv corresponds to the dose of Hibakusha, and can never be considered to be safe. The result of the LSS of atomic bomb survivors, the dose of which is estimated by DS86 and DS02 model, showed that the estimated lowest dose range with a significant ERR for solid cancer was 0 to 200 mSv. However, a paragraph "but the dose range with a significant ERR was more than 200 mSv" was added by REEF so as to justify the 100 mSv safety hypothesis.

Is the radiation exposure of non-Hibakusha in RERF definition truly not significant? If the residual radiation and internal exposure were of considerable amount, statistical dispersion of the linear ERR-dose relation may have been very high around low dose range 0~100 mSv, which may help to create the 100 mSv safety hypothesis. The excess cancer risk may have been estimated too low by comparing Hibakusha with non-Hibakusha exposed considerably by residual radiation.

Increasing number of childhood thyroid cancer patients in Fukushima is comparable to or higher than that in Chernobyl. From the good correspondence of the results of thyroid check-ups in Fukushima and outside, and the extent of I-131 deposition, childhood thyroid cancer is possibly caused by exposure. We should expand the health monitoring to other affected prefectures, where fallout from the accident seems to have reached.

In order for an epidemiological study to be significant in the sense of UNSCEAR, the number of patients and that of deaths must be extraordinary large as in the case of LSS study of atomic bomb survivors. Result of the researches is carefully modified so as to justify the 100 mSv safety hypothesis. Statistical dispersion from linear ERR-dose relation in LSS, which is constituted from the agonies of so many atomic bomb survivors, is then used to force evacuees in Fukushima accident to go back to highly contaminated ≦20 mSv area. This kind of epidemiology is against humanity. We need epidemiological study which protects people's right to health.

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