The 4th Citizen-Scientist International Symposium
on radiation protection
National Olympics Memorial Youth Center
November 23, 2014

Analysis of Thyroid Cancer in Fukushima Children Ages 18 and Younger, and Future Tasks

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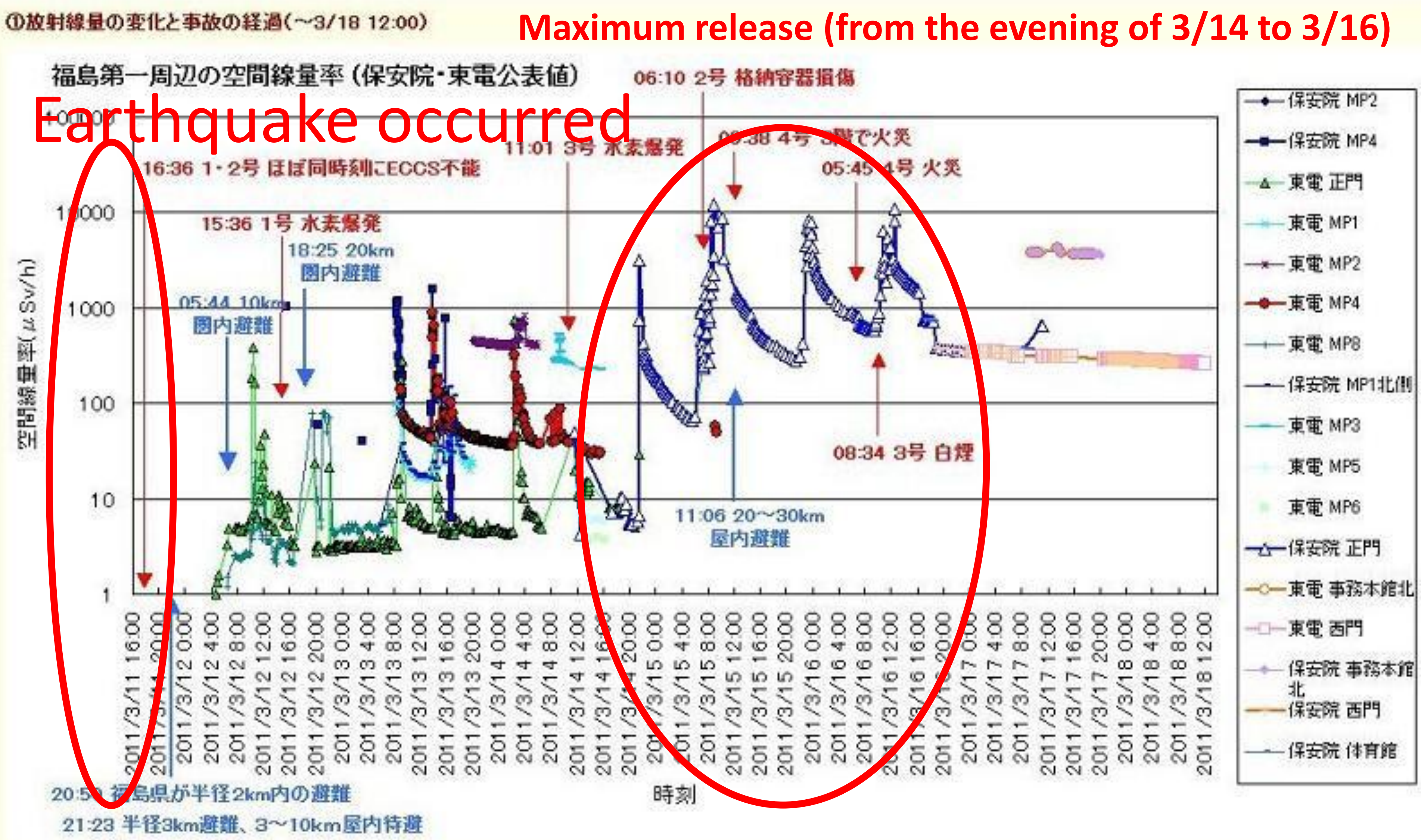
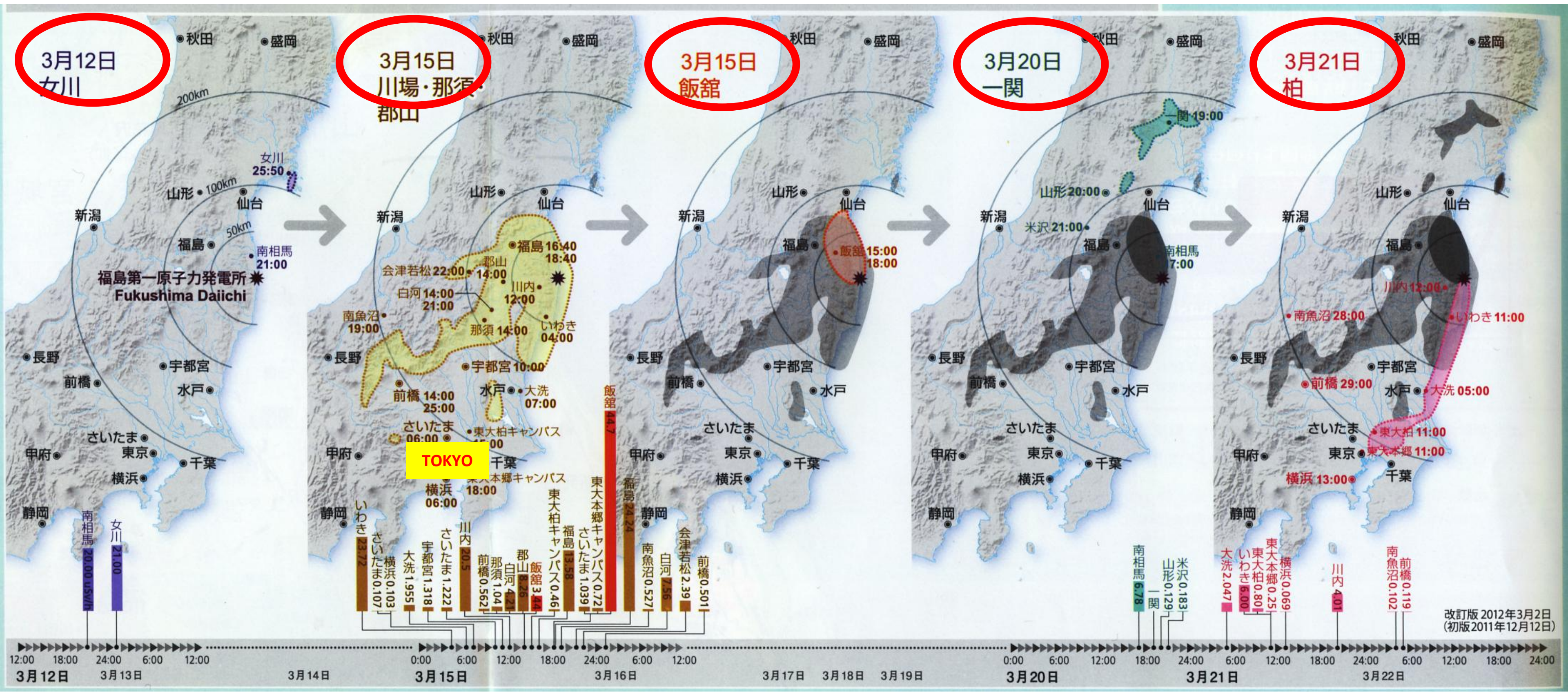
First: Gratitude to speakers from overseas

- In Western Japan where I live, people do not seem very interested in the 2011 earthquake or the Fukushima nuclear power plant issues.
- Other than those closest to me, only a few people on campus even know that I am analyzing and speaking out about the Fukushima radiation issues.
- I would like to express my sincere gratitude to those overseas, especially in Germany, for the interest in and the support on the issues in Japan, despite the lack of interest here.
  - In particular, information from the German chapter of IPPNW is extremely helpful.
  - We, in Japan (and in Western Japan), would keep trying our best, making an appeal to other international countries.

Air dose rate at Fukushima Daiichi Nuclear Power Plant (FDNPP) after March 11, 2011

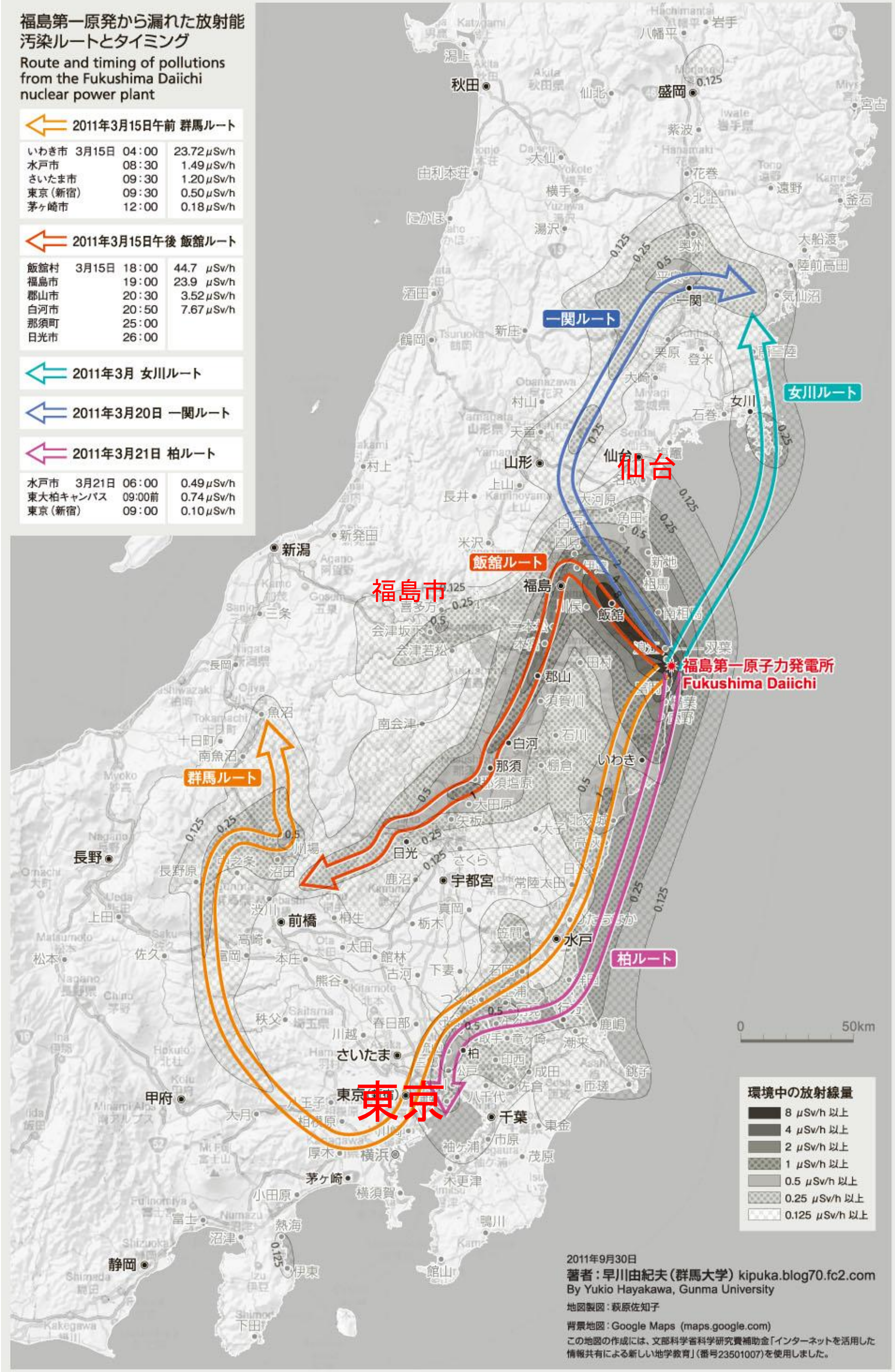


Radioactive plume from March 11, 2011 on



Author:

Professor Yukio Hayakawa
(Gunma University)



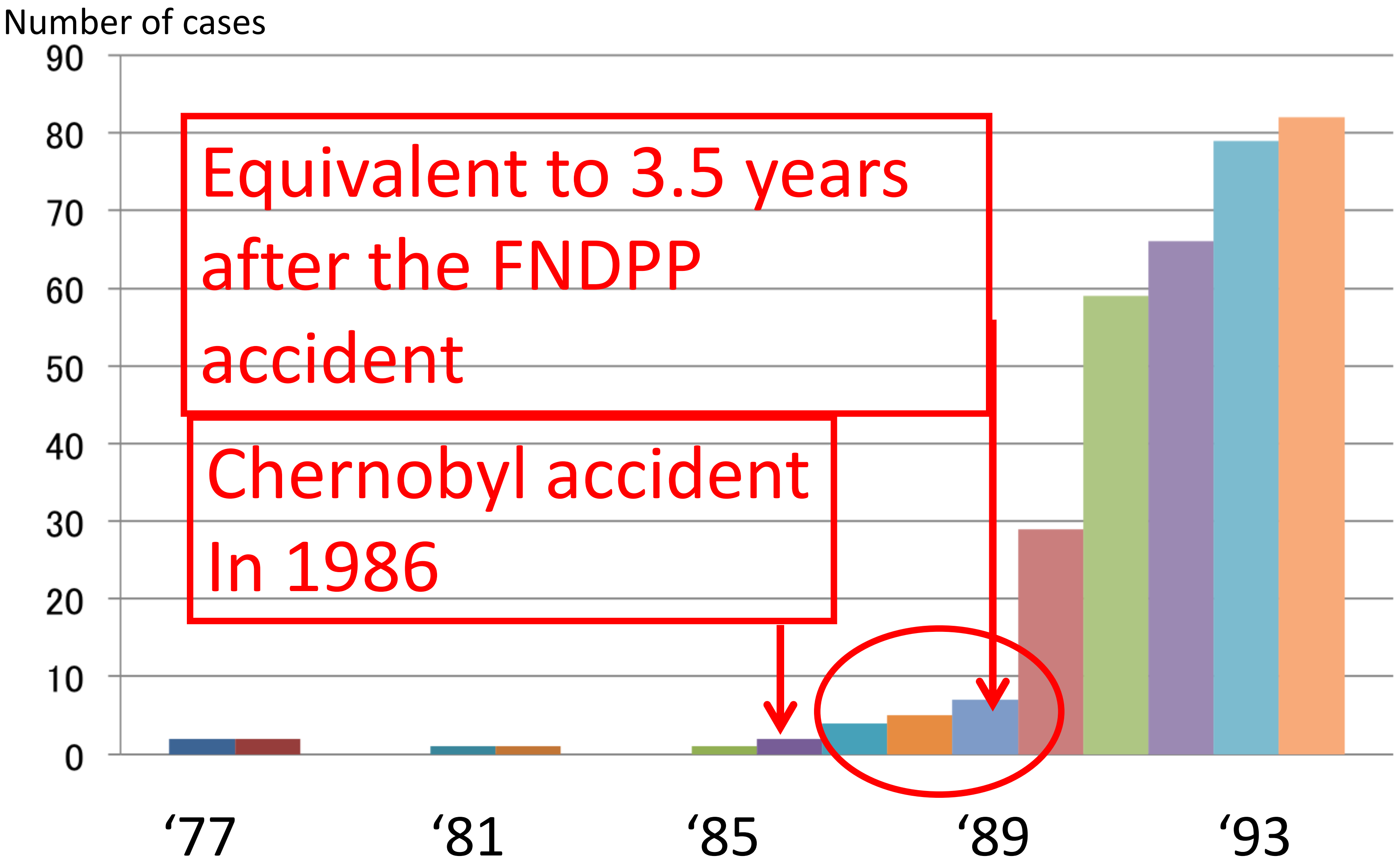
Radioactive plume after March 11, 2011

Summary

Author:

Professor Yukio Hayakawa
(Gunma University)

Epidemic Curve of Thyroid Cancer in Chernobyl (Belarus: ages ≤ 14)



Why analyze the thyroid cancer data? (purpose)

1. Public interest

   -Offer information based on current analysis

2. Predicting and grasping the spread as well as the extent of the outbreak in the future

   -Get a sense of how many cases could potentially be identified

3. Separating the effects of air dose rate and iodine 131

   -The biggest reason for discussion at the present time

   -To offer information for decision-making on evacuation and return

4. Biological monitoring

   -Reverse estimation of exposure dose from the incidence rate of cancer cases in each area

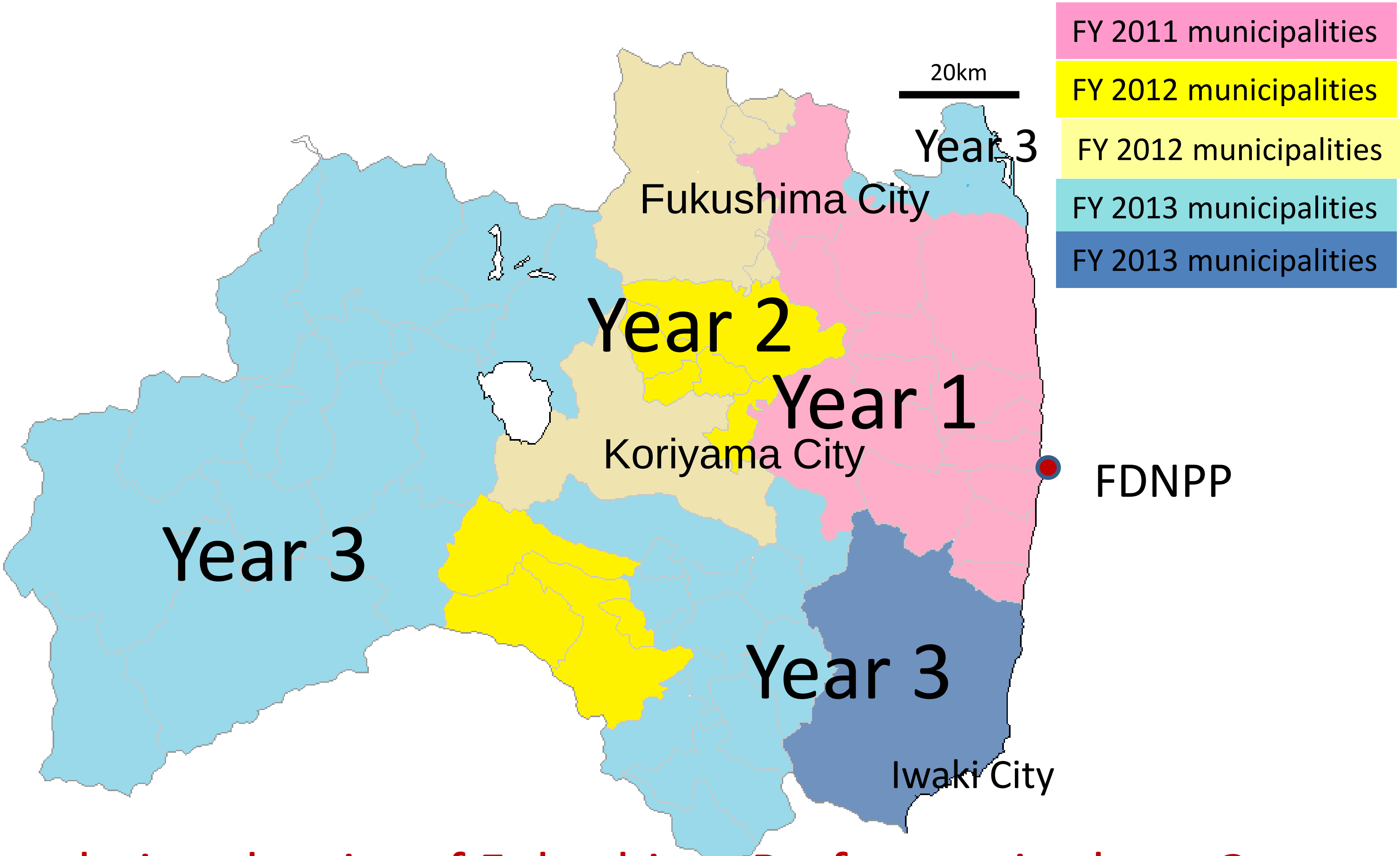
Thyroid cancer screening for ages ≤ 18

- Primary examination: All residents ages ≤ 18 as of 2011
  - Screening with thyroid ultrasound
  - Proceed to secondary examination if nodules with diameter ≥ 5.1 mm or cysts with diameter ≥ 20.1 mm detected
- Secondary examination: Those whose primary examination results were positive
  - Follow-up with thyroid ultrasound, then fine needle aspiration cytology (FNAC)
- When cancer cells are detected by FNAC:
  - Follow-up, then surgery
  - Considered "confirmed cancer cases" once cancer cells are histologically identified in excised thyroid gland tissues

Thyroid cancer screening schedule

- The Japanese fiscal year (FY) starts on April 1st and ends on March 31st of the following year.
  - Year 1: FY 2011 (up to March 31, 2012)
    - Municipalities nearest FDNNP
  - Year 2: FY 2012 (April 1, 2012 to March 31, 2013)
    - Municipalities at moderate distance (40-80 km) from FDNPP, such as Fukushima City and Koriyama City
  - Year 3: FY2013 (April 1, 2013 to March 31, 2014)
    - Remaining municipalities , such as Iwaki City (Southeast) , Soma City (Northeast), and Aizuwakamatsu City (West)
- After the fourth year on, screening is to be repeated in a two-year cycle, with nearest municipalities and Nakadori in the first year and the remaining municipalities in the second year.
  - The 2014 screening is being conducted in nearest municipalities and Nakadori.

Order of the first round of thyroid cancer screening



Population density of Fukushima Prefecture is about **3x higher** than that of Gomel, the Republic of Belarus.

External comparison: comparison group and data entry

Age- and sex-specific incidence rate estimates of thyroid cancer from the Center for Cancer Control and Information Services, National Cancer Center, Japan (1975-2008).

Average annual incidence rate in Japan among ages 15-19 from 1975 to 2008 (5 in 1,000,000).

- Employing a higher end value here. In reality, the average annual incidence rate amongst ages 0-19 from 2003 to 2007 is 2-3 in 1,000,000. This leads to underestimation of incidence rate.
- Selection of the comparison number in external comparison is not a critical issue as the increase in the amount of data allows for internal comparison. However, judging from the contamination situation within Fukushima Prefecture, internal comparison appears to be greatly underestimated. Thus external comparison becomes more meaningful.

External comparison: adjustment and estimation

- Prevalence ≒ incidence rate × average disease duration
  - In this case, “disease duration” is the period of time from the date when thyroid cancer becomes detectable by screening and cytology to the date when it can be diagnosed in usual clinical settings without screening.
- Several disease duration (years) scenarios were assumed for sensitivity analysis.
- Poisson distribution was employed to estimate 95% confidence intervals.

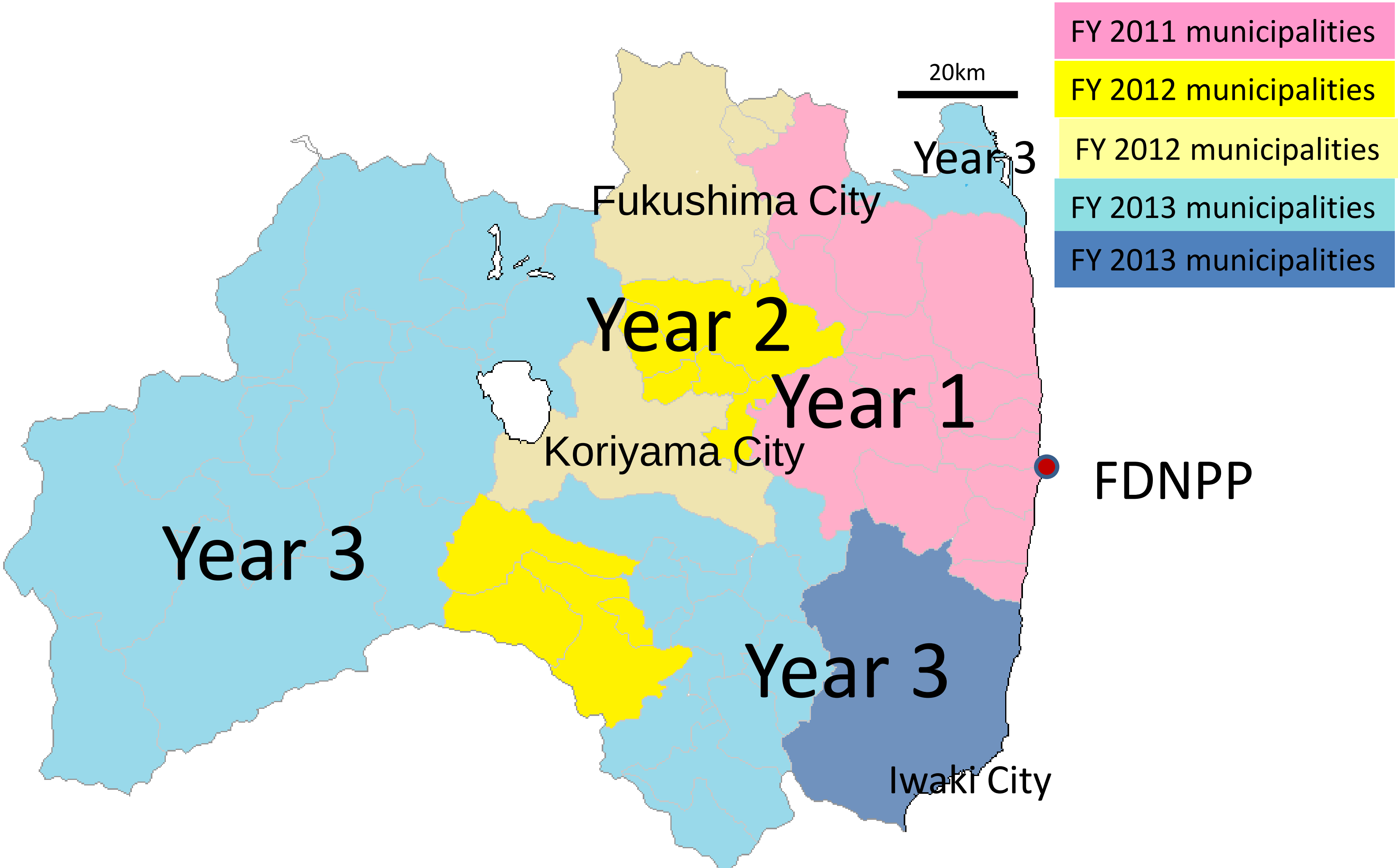
Internal comparison and regional division

- Year 1 (FY 2011) target areas were considered as one area. Year 2 (FY 2012: so-called Nakadori) target areas were divided into 4 divisions by population: Northern Nakadori (Fukushima City, etc.); Central Nakadori (Nihonmatsu City, Motomiya City, etc.), Koriyama City, and Southern Nakadori (Shirakawa City, etc.).

- Year 3 (FY 2013) target areas were divided into Iwaki City, Southeastern Fukushima Prefecture excluding Iwaki City, Western Fukushima Prefecture (Aizu region), and Northeastern Fukushima Prefecture (Soma region: Soma City and Shinchi Town).

- Fukushima Prefecture releases the examination results about every 3 months.
  - This analysis is based on data released on August 24, 2014.

Order of thyroid cancer screening



Population density of Fukushima Prefecture is about **3x higher** than that of Gomel, the Republic of Belarus.

Result 1

Target area	Population ages ≤18	Number of participants for primary examination	Number of positive cases after primary examination	Number of participants for secondary examination	Number of cancer cases excluding the benign case (surgical cases)
FY 2011	47,780	41,813 (87.5%)	221 (0.53%)	195 (88.2%)	14 (12)
FY 2012	161,144	139,209 (86.4%)	986 (0.71%)	891 (90.4%)	54 (41)
FY 2013	157,621	115,004 (73.0%)	1,030 (0.90%)	865 (84.0%)	35 (4)

Thyroid cancer in Chernobyl （Yamashita, 2000）

http://www.aec.go.jp/jicst/NC/tyoki/bunka5/siryo5/siryo42.htm

表2 ベラルーシ共和国ゴメリ州における小児甲状腺がん登録（年次別、時故当時年齢別推移）（Bel CMT国家がん登録による）

年	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	年次毎総数
1985	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
1986	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
1987	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	-	4
1988	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	3
1989	-	1	-	-	-	1	-	-	-	-	-	-	-	-	1	1	1	-	5
1990	2	2	-	1	4	1	2	-	2	-	-	-	-	1	-	-	-	-	15
1991	2	3	10	6	1	3	3	4	1	3	3	2	-	1	2	3	-	-	47
1992	-	5	3	2	3	4	3	4	4	3	1	-	-	-	-	1	-	2	35
1993	1	4	2	11	3	7	2	2	4	2	3	1	-	1	2	-	-	-	45
1994	2	9	5	1	4	7	9	3	2	5	-	2	-	-	2	2	2	1	56
1995	4	8	10	8	4	6	7	2	3	1	1	-	-	1	-	1	2	3	63
1996	3	6	9	10	9	5	3	1	3	1	-	1	-	1	1	1	2	1	57
1997	1	9	10	13	6	7	3	-	1	3	-	3	-	3	2	-	2	3	66
1998	1	8	6	4	5	3	4	2	2	-	4	2	1	3	1	4	2	-	52
総数	16	55	55	56	39	44	36	19	23	18	12	12	2	12	12	13	13	11	448

Result 2 (FY 2012: Nakadori)

Area	Population ages ≤ 18	Number of participants for primary examination	Positive cases after primary examination	Number of participants for secondary examination	Number of cancer cases (surgical cases)
North (Fukushima City, Koori Town, etc.)	57,221	50,662 (88.5%)	312 (0.62%)	290 (92.9%)	12 (?)
Central (Nihonmatsu City, Motomiya City, etc.)	21,052	18,168 (86.3%)	113 (0.62%)	108 (95.6%)	11 (?)
Koriyama City	64,383	53,962 (83.8%)	458 (0.85%)	398 (86.9%)	23 (?)
South (Shirakawa City, Nishigo Village, etc.)	18,488	16,457 (89.0%)	103 (0.63%)	95 (92.2%)	8 (?)
FY 2012 Total	161,144	139,209 (86.4%)	986 (0.71%)	891 (90.4%)	54 (41)

Result 3
(FY 2013: Aizu and Hamadori south/north)

Area	Population ages ≤ 18	Number of participants for primary examination	Positive cases after primary examination	Number of participants for secondary examination	Number of cancer cases (surgical cases)
North (Soma City, Shinchi Town)	8,227	6,151 (74.8%)	53 (0.86%)	48 (90.6%)	0 (0)
Iwaki City	61,834	47,759 (77.2%)	429 (0.90%)	364 (84.8%)	19 (?)
East-south (excluding Iwaki City)	37,831	28,535 (75.4%)	227 (0.80%)	202 (89.0%)	7 (?)
West (Aizu region)	49,729	32,559 (65.5%)	321 (0.99%)	251 (78.2%)	9 (?)
FY 2013 total	157,621	115,004 (73.0%)	1,030 (0.90%)	865 (84.0%)	35(4)

Table 2 External comparison
(average disease duration = 3 years)

	Compared with 5 in 1,000,000		Prevalence and the reciprocal	
	IRR*	(95% CI) *	× 10,000	Per person
FY 2011 Target area (Nearest area)	22.32	(12.92-37.23)	3.3	2,986.6
North (Fukushima City, Koori Town, etc.)	15.79	(8.80-27.43)	2.4	4,221.8
Central (Nihonmatsu City, Motomiya City, etc.)	40.36	(21.12-72.71)	6.1	1,651.6
Koriyama City	28.42	(18.43-42.44)	4.3	2,346.2
South (Shirakawa City, Nishigo Town, etc.)	32.41	(15.25-64.09)	4.9	2,057.1
Iwaki City	26.52	(16.47 -41.63)	4.0	2,513.6
Southeast area excluding Iwaki City (FY 2013)	16.35	(7.67-33.50)	2.5	4,076.4
Aizu region (West district: FY 2013)	18.43	(9.13-35.42)	2.8	3,617.7
Soma region (Northeast district: FY 2013)	0	(0.00-30.50)	0	-

*Incidence rate ratio (95% confidence interval)

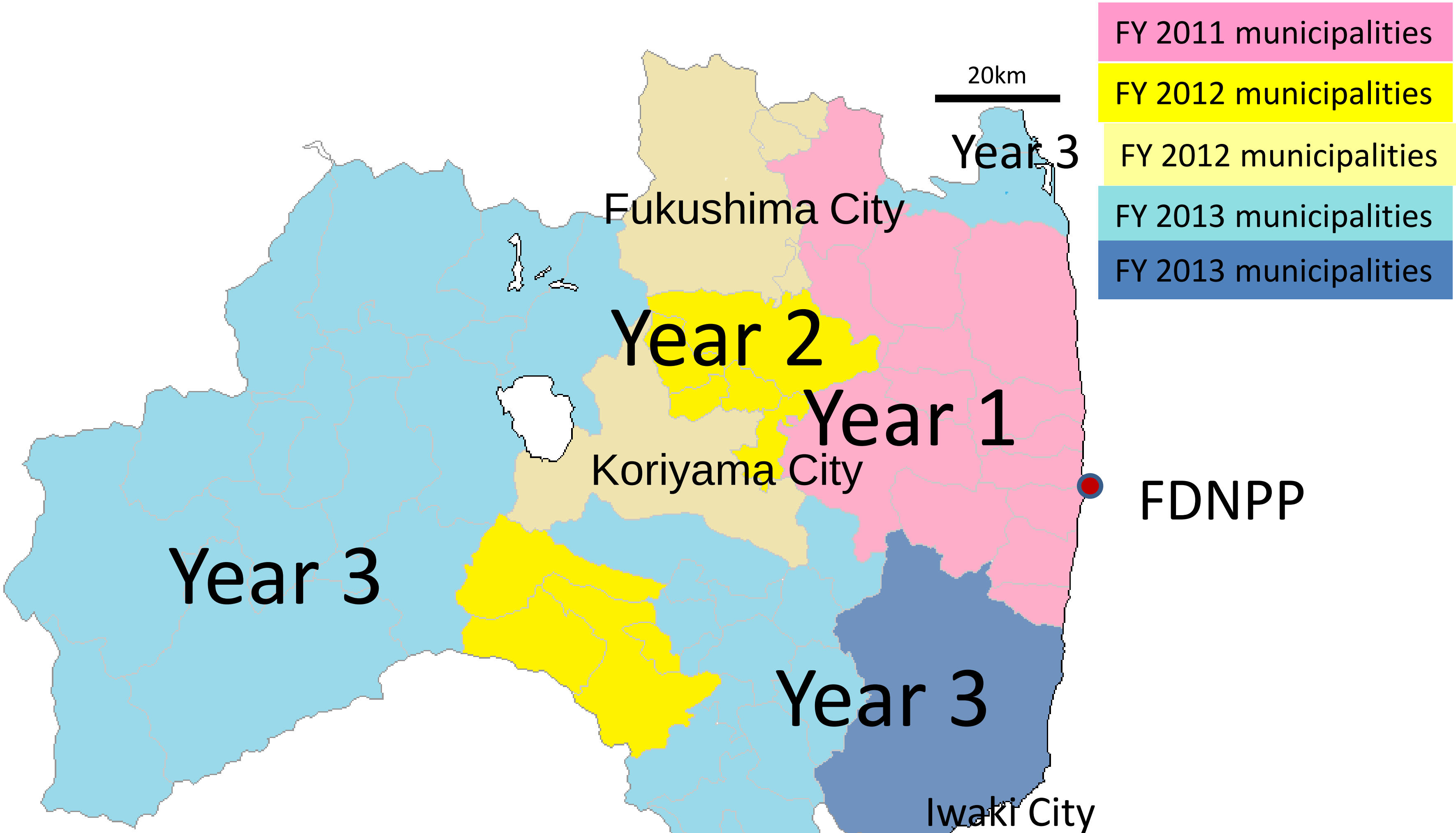
Table 3 Internal comparison
(Prevalence odds ratio with Aizu region as a reference)

	Cancer cases	Number in primary exam	POR*	(95% CI) *
FY 2011 Target area (Nearest area)	14	41,813	1.21	(0.52-2.92)
North (Fukushima City, Koori Town, etc.)	12	50,662	0.86	(0.36-2.11)
Central (Nihonmatsu City, Motomiya City, etc.)	11	18,168	2.19	(0.89-5.48)
Koriyama City	23	53,962	1.54	(0.73-3.51)
South (Shirakawa City, Nishigo Town, etc.)	8	16,457	1.76	(0.68-4.56)
Iwaki City	19	47,759	1.44	(0.66-3.34)
Southeast area excluding Iwaki City (FY 2013)	7	28,535	0.89	(0.33-2.38)
Aizu region (West district: FY 2013)	9	32,559	1	
Soma region (Northeast district: FY 2013)	0	6,151	0	0

* Prevalence odds ratio (95% confidence interval)

When the smaller value of 95% CI is > 1, it means so-called "statistical significance."

Order of thyroid cancer screening



As the spread of radioactive materials is not stopped at the border, cases outside Fukushima Prefecture need identified.
Population density of neighboring prefectures is higher than that of Fukushima Prefecture (3x higher than Gomel).

Table 4 Adjusted external comparison

(as we enter the fourth year)

Comparison with national incidence rate: 5 in 1,000,000	Before adjustment with duration of disease		After adjustment with duration of disease	
	IRR*	(95% CI) *	IRR*	(95% CI) *
FY 2011 Target area (Nearest area)	22.32	(12.92-37.23)	66.96	(38.75-111.70)
North (Fukushima City, Koori Town, etc.)	15.79	(8.80-27.43)	23.69	(13.20-41.15)
Central (Nihonmatsu City, Motomiya City, etc.)	40.36	(21.12-72.71)	60.55	(31.68-109.06)
Koriyama City	28.42	(18.43-42.44)	42.62	(27.65-63.67)
South (Shirakawa City, Nishigo Town, etc.)	32.41	(15.25-64.09)	48.61	(22.87-96.13)
Iwaki City	26.52	(16.47 -41.63)	26.52	(16.47 -41.63)
Southeast area excluding Iwaki City (FY 2013)	16.35	(7.67-33.50)	16.35	(7.67-33.50)
Aizu region (West district: FY 2013)	18.43	(9.13-35.42)	18.43	(9.13-35.42)
Soma region (Northeast district: FY 2013)	0	(0.00-30.50)	0	(0.00-30.50)

*Incidence rate ratio (95% confidence interval)

Excess thyroid cancer risks in adolescents and adults

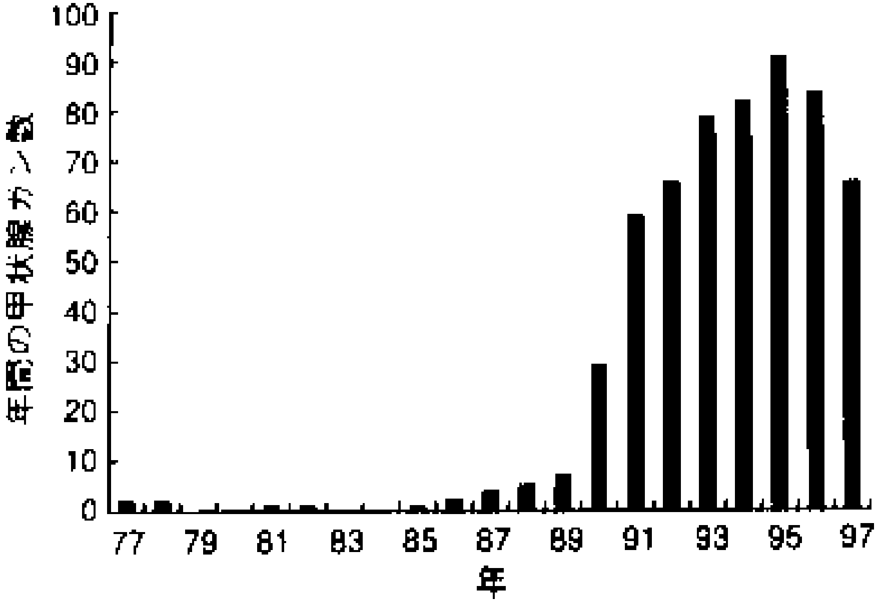


図１　ベラルーシの小児甲状腺ガン数の変化

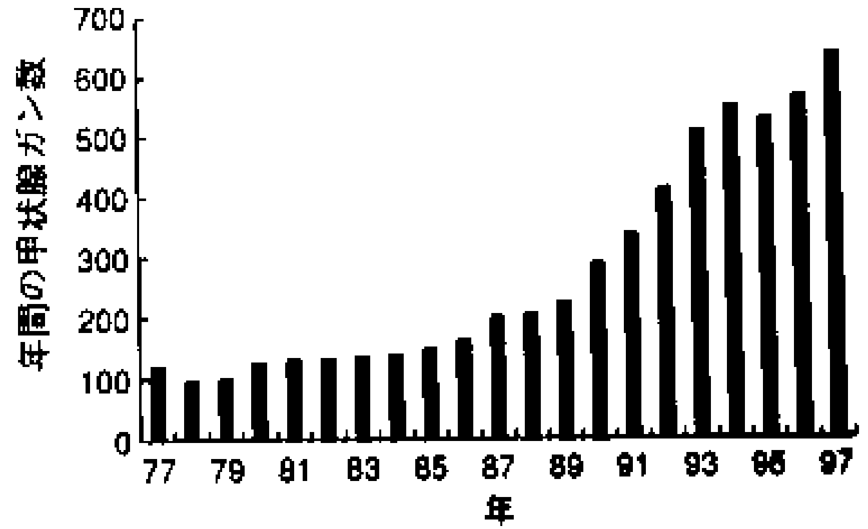


図２　ベラルーシの青年・大人の甲状腺ガン数の変化

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今中哲二編『チェルノブイリ事故による放射能災害』より

In regards to the thyroid cancer outbreak, it is ages > 19 that should be monitored rather than ages ≤ 18. The Chernobyl experience forecasts a large number of cases.

Quite a few prevalence data exist

Prevalence data

	Prevalence (# cases)	Age in 2011 (current age)
Nearest	0.00033(14)	0 (3)-18 (21)
Fukushima City	0.00024(12)	0 (3)-18 (21)
Koriyama City	0.00043(23)	0 (3)-18 (21)
Nakadori, Central	0.00061(11)	0 (3)-18 (21)
Nakadori, South	0.00049(8)	0 (3)-18 (21)
Iwaki City	0.00040(19)	0 (3)-18 (21)
Aizu region	0.00028(9)	
Okayama University (2012-2014)	0.00043(3) (palpation)	18-21? (target age)
Chiba University (2000)	0.00030(3) (palpation)	18-24? (target age)

Incidence rate data

	Incidence rate	Age (years)
Japan (1988-2008)	0.6×10^{-5} (male) 2.5×10^{-5} (female)	average 20-24
Japan (high sensitivity area) (1988-2007)	0.6×10^{-5} (male) 3.5×10^{-5} (female)	average 20-24
Okayama University (1988-2012)	1.3×10^{-5} (2 males) 10×10^{-5} (10 females)	18-24?
Tokyo High school	11.6×10^{-5} (1 female)	16-18

Mass screening data in unexposed populations in Chernobyl

Study name	Age at accident	Study period	Age at study	Study region	# of subjects	Cancer detected
Belarus Screening Program*1	Not yet conceived	2002	≦14	Gomel	25,446 (unknown method)	0
Shibata *2	Not yet conceived	1998-2000	8-13	Gomel	9,472 (ultrasound)	0
Ito*3	0-10	1993-1994	7-18	Mogilev	12,285 (ultrasound)	0
Ito*3	0-10	1993-1994	7-18	Bryansk	12,147 (ultrasound)	0
Ito*3	0-10	1993-1994	7-18	Zhitomir	11,095 (ultrasound)	1
Total					70,445	1

*1:Demidchik YE: Childhood thyroid cancer in Belarus, Russia and Ukraine after Chernobyl and at present. Arq Bras Endocrinol Metab 2007; 51: 748-762.

Created by Dr. Keiji Hayashi, modified by Tsuda

*2:Shibata Y et al: 15 years after Chernobyl: new evidence of thyroid cancer. Lancet 2001; 358: 1956-1966.

*3: Ito M et al: Childhood thyroid disease around Chernobyl evaluated by ultrasound examination and fine needle aspiration cytology. Thyroid 1995; 5: 365-368.

Thyroid cancer data analysis: Conclusion and proposal #1

1. The fact radiation-induced cancer can occur under 100 mSv is not widely known in Japan. Thus, due attention is not paid to thyroid cancer occurrence data.

2. In Chernobyl, thyroid cancer cases began to gradually increase 1-2 years after the accident in both Belarus and Ukraine, even before the marked increase occurred 4-5 years post-accident.

3. There is hardly any thyroid cancer case detected in the screening data of the unexposed populations in Chernobyl.

4. CDC sets a minimum latency period for thyroid cancer to be 2.5 years for adults and 1 year for children.

-Currently in Japan, only an average latency period is addressed, as in, “Cancer normally grows slowly.” The issue of a minimum latency period, which is the point of contention, is not al all discussed.

Thyroid cancer data analysis: Conclusion and proposal #2

1. Based on the knowledge from Chernobyl as well as what is known in Fukushima up to now, at least for thyroid cancer, medical resources need checked and fully equipped in order to prepare for a possible outbreak after Year 4.

2. Expansion of thyroid cancer screening and diagnosis:

   – To subjects who were ≧ 19 years of age at the time of the accident.

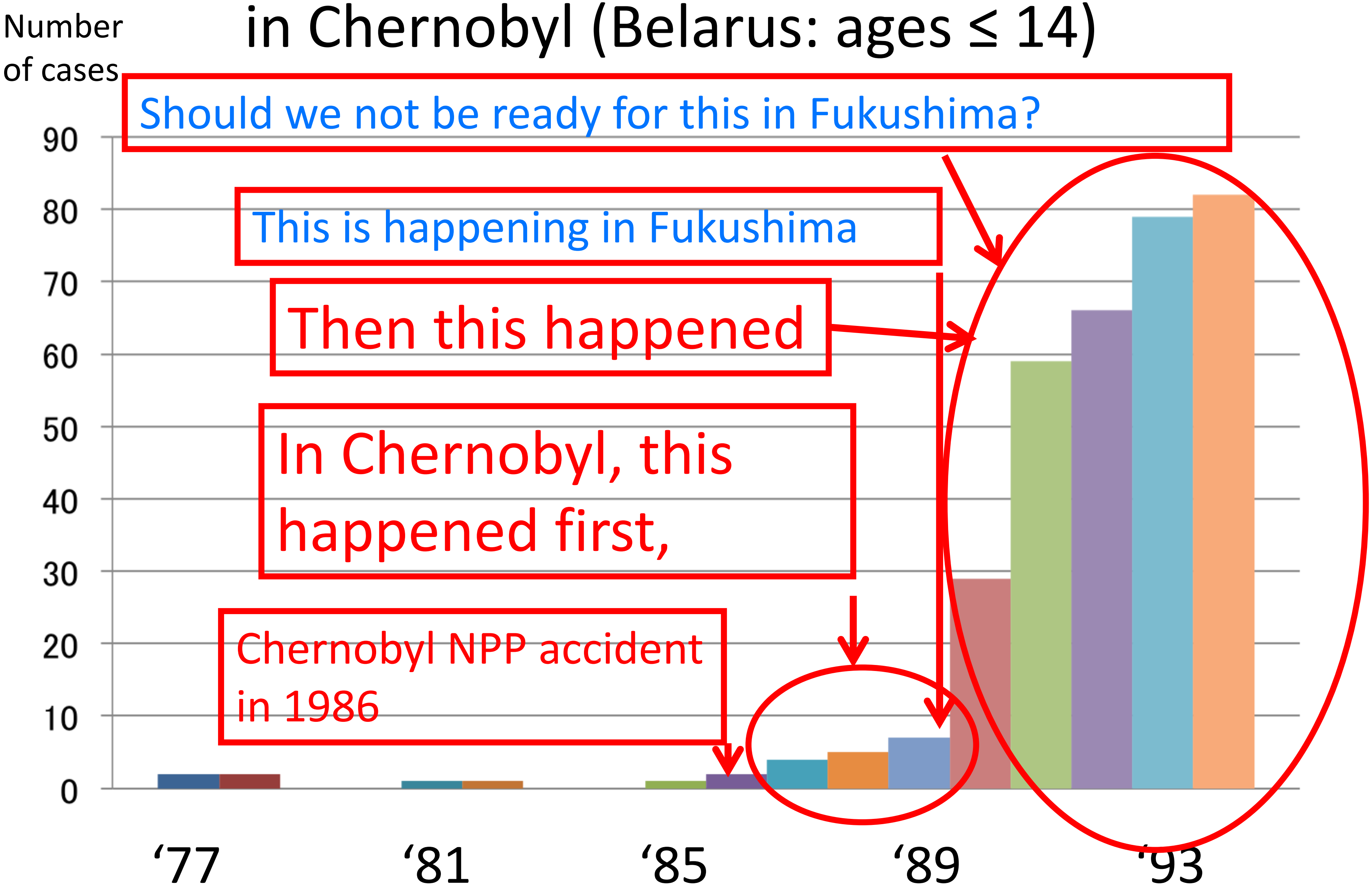
   – To non-Fukushima residents, especially in neighboring prefectures.

   – Currently, screening is the only way to identify thyroid cancer, but the participation rate could drop as the participants get older. An record booklet (like the one for the atomic bomb survivors in Hiroshima and Nagasaki) system should be established, along with a cancer registry, in order to identify and record all the cases.

Thyroid cancer data analysis: Conclusion and proposal #3

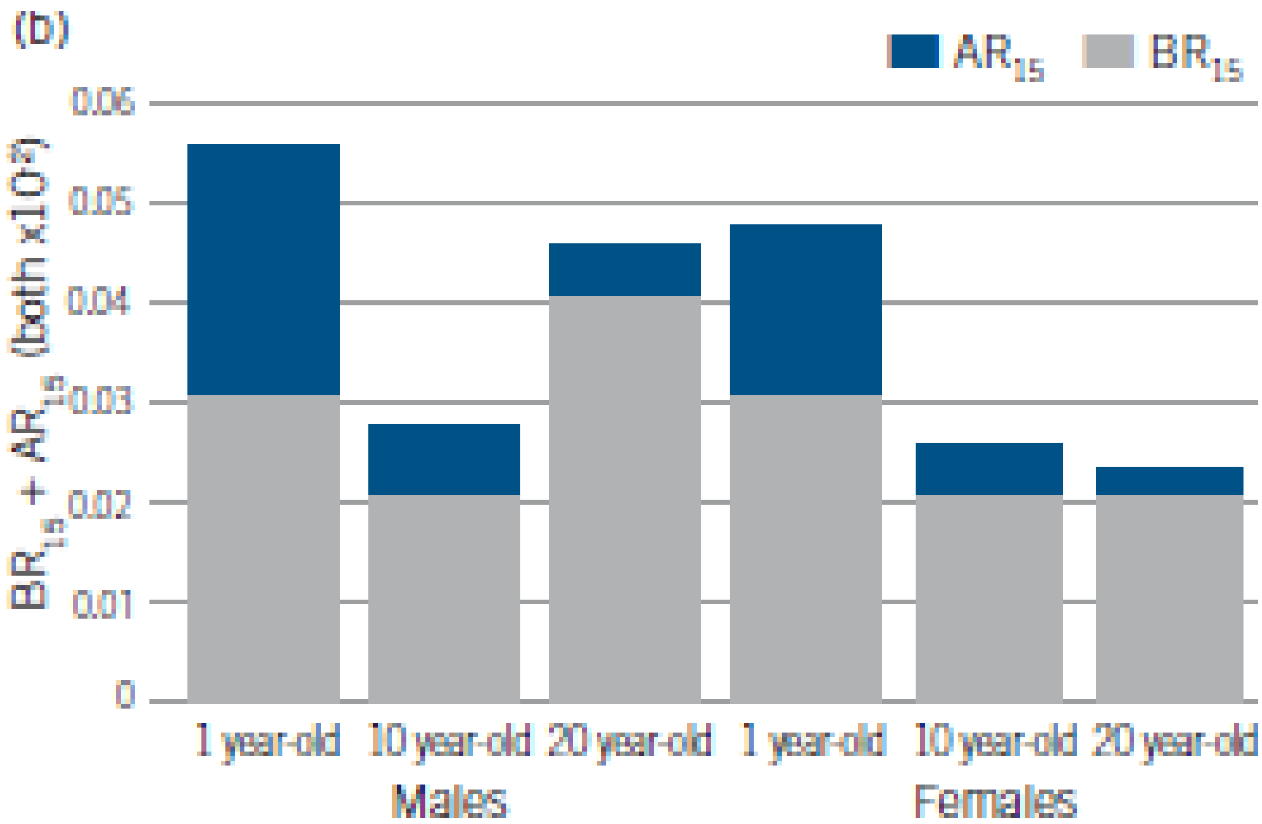
1. The fact the outbreak status of thyroid cancer is larger than anticipated implies a possibility the exposure dose is higher than expected, calling for an urgent need for studying non-thyroid cancers, such as other solid cancers and hematopoietic cancers, as well as non-cancer illnesses, and for establishing necessary countermeasures.
   - Establishment of ways, other than screening, to diagnose and record cases, such as an exposure record booklet system as well as a cancer registry.
2. Since air dose rates could be involved, in addition to iodine,
   - Evacuation planning and implementation should be considered for pregnant women, infants, toddlers, children, adolescents, and women with pregnancy potential, in that order.
   - Detailed analysis of the Chernobyl thyroid cancer occurrence data should be conducted.
   - Planning for return to areas with annual dose of 20 mSv should be postponed.

Epidemic Curve of Thyroid Cancer in Chernobyl (Belarus: ages ≤ 14)



WHO report (2013)

Increase in 15-year risk of leukemia



Summary: Persuasion

- As people tend not to listen, stick to the following talking points:
  - Such a statement as, “An exposure dose ≤ 100 mSv does not cause, or is not known to cause, radiation-induced cancer” is inaccurate.
  - WHO (2013) predicts an increase in thyroid cancer, leukemia, breast cancer and other solid cancers in Fukushima Prefecture.
- Emphasize and focus on the above 2 points.
  - The outbreak of thyroid cancer is included here.

WHO(2012) divides thyroid exposure to 3 major routes

Location	Committed equivalent dose		
	Adult Dose band, key pathways to nearest 10%[2,3]		
Fukushima prefecture, more affected locations (examples only, for location of measurements used see Figure 3)			
Futaba county, Namie town (committed dose from the first four months only[1])	10–100	Inhalation External (groundshine) Ingestion	50% 40% 10%
Soma county, Itate village (committed dose from the first four months only[1])	10–100	Inhalation External (groundshine) Ingestion	40% 40% 20%
Futaba county, Katsurao village (committed dose from the first four months only[1]),	10–100	Ingestion Inhalation External (groundshine)	40% 40% 30%
Minami Soma city	10–100	External (groundshine) Ingestion Inhalation	40% 40% 20%
Futaba county, Naraha town	10–100	Ingestion External (groundshine) Inhalation	40% 40% 20%
Iwaki city	1–10	Ingestion External (groundshine)	80% 20%
Rest of Fukushima prefecture (less affected)	1–10	Ingestion External (groundshine) Inhalation	80% 10% 10%
Neighbouring Japanese prefectures[4]	1–10	External (groundshine) Ingestion Inhalation	40% 30% 30%
Rest of Japan[5]	1–10	Ingestion External (groundshine)	90% 10%
Neighbouring countries[6]	<0.01	Ingestion External (groundshine)	90% 10%
Rest of the world	<0.01	Ingestion Inhalation External (groundshine)	70% 20% 10%

Inhalation exposure
External exposure
Oral exposure

Thyroid equivalent dose as of 2011

Adults

WHO(2012) divides thyroid exposure to 3 major routes

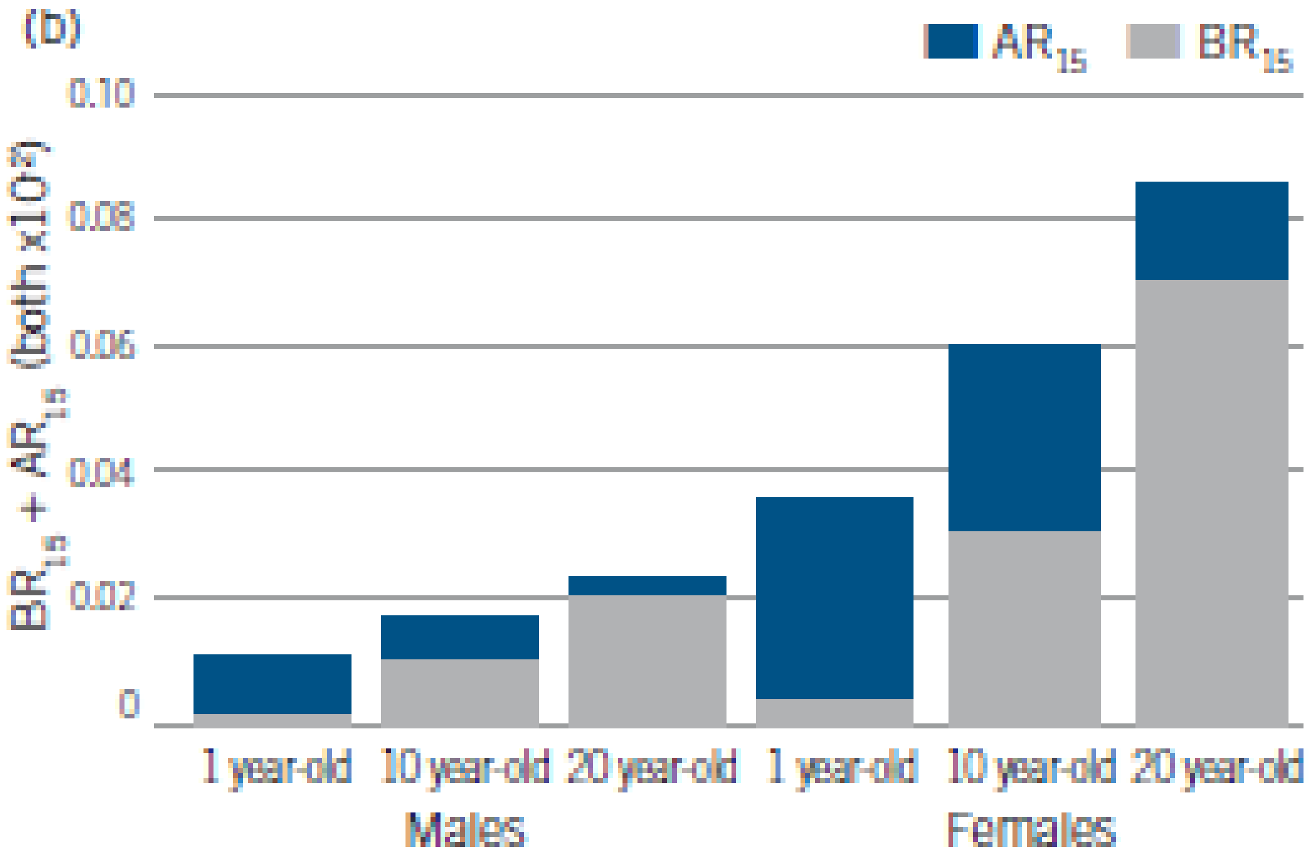
to thyroid in first year following accident, mSv					
Child (10 years) Dose band, key pathways to nearest 10%[2,3]			Infant (1 year) Dose band, key pathways to nearest 10%[2,3]		
10–100	Inhalation External (groundshine) Ingestion	60% 30% 10%	100–200	Inhalation External (groundshine) Ingestion	50% 30% 20%
10–100	Inhalation External (groundshine) Ingestion	50% 30% 20%	10–100	Inhalation Ingestion External (groundshine)	40% 40% 20%
10–100	Ingestion Inhalation External (groundshine)	50% 30% 20%	10–100	Ingestion Inhalation External (groundshine)	60% 30% 10%
10–100	Ingestion External (groundshine) Inhalation	50% 30% 20%	10–100	Ingestion External (groundshine) Inhalation	60% 20% 20%
10–100	Ingestion External (groundshine) Inhalation	50% 30% 20%	10–100	Ingestion External (groundshine) Inhalation	70% 20% 10%
10–100	Ingestion External (groundshine) Inhalation	80% 10% 10%	10–100	Ingestion External (groundshine)	90% 10%
10–100	Ingestion External (groundshine)	90% 10%	10–100	Ingestion External (groundshine)	90% 10%
1–10	Ingestion External (groundshine) Inhalation	40% 30% 30%	1–10	Ingestion External (groundshine) Inhalation	60% 20% 20%
1–10	Ingestion	100%	1–10	Ingestion	100%
<0.01	Ingestion External (groundshine)	90% 10%	<0.01	Ingestion	100%
<0.01	Ingestion Inhalation External (groundshine)	70% 20% 10%	<0.01	Ingestion Inhalation External (groundshine)	80% 10% 10%

Inhalation exposure
External exposure
Oral exposure

Thyroid equivalent dose as of 2011

10 y/o and 1 y/o

WHO report (2013)
Increase in 15-year risk for thyroid cancer



It will become noticeable in children. (WHO 2013)

Figure 16. Cumulative attributable risk (AR_{15}) and lifetime attributable risk (LAR) for leukaemia as a function of attained age for a female, one year age-at-exposure, in Location ①.

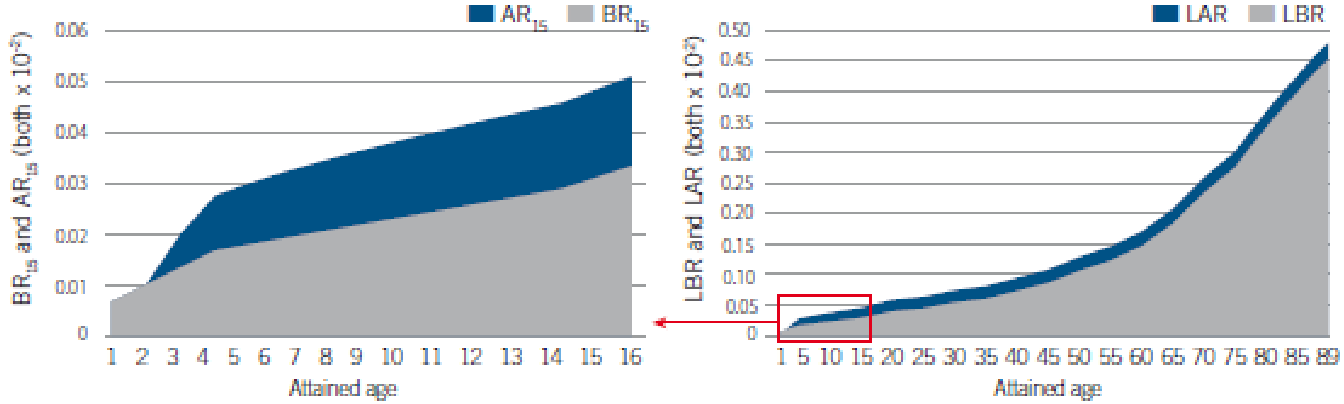
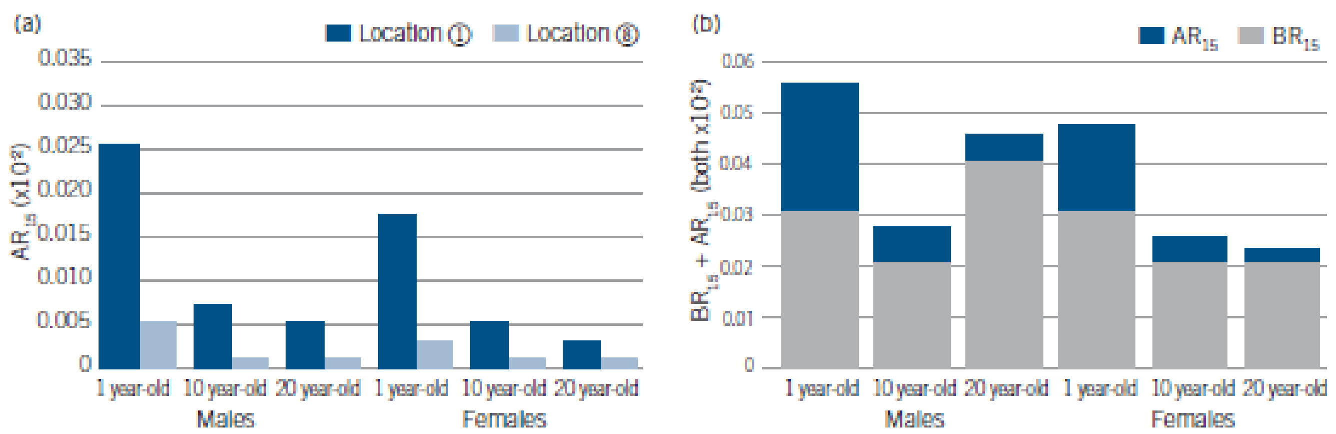


Figure 17. Leukaemia: cumulative attributable cancer risk over 15 years after exposure (AR_{15}) (a) for both genders and 3 age groups (infants, children and adults) in locations ① and ⑧; and (b) with cumulative baseline risk (BR_{15}) in location ①



Causality cannot be directly observed.

Invisible. No sound. No taste.

No smell. Cannot be touched.

Yet, you can’t just use the “Sixth sense.”

Cause is observable. Disease is observable.

However, causality is not directly observable.

The basic reasoning of science requires drawing an inference from the observed data.

In order to make causality visible

Rules in human data

Based on information on exposure and disease

$$\frac{\dfrac{\text{Number of exposed patients}}{\text{Number of exposed patients} \times \text{number of hours spent in exposed state or equivalent}}}{\dfrac{\text{Number of unexposed patients}}{\text{Number of unexposed residents} \times \text{number of hours spent in unexposed state or equivalent}}}$$

No outbreak if IRR is around 1

Degree of outbreak increases as IRR gets bigger

$$= \text{Incidence rate ratio (IRR)}$$

$$= \frac{\text{Incidence rate of the exposed}}{\text{Incidence rate of the unexposed}}$$

Reality Workings of Science Concept

Individual phenomenal

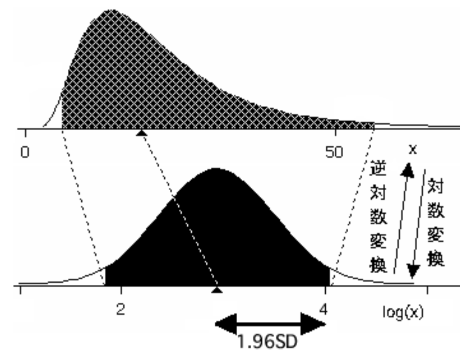
—Reality & concept—

General rules

Excel table data

	E	D	F
A	1	0	0
B	0	1	1
C	1	0	1

Text and probability



Statistics is the grammar for science, connecting the right with the left.

Observation
Description

Theory
General rules

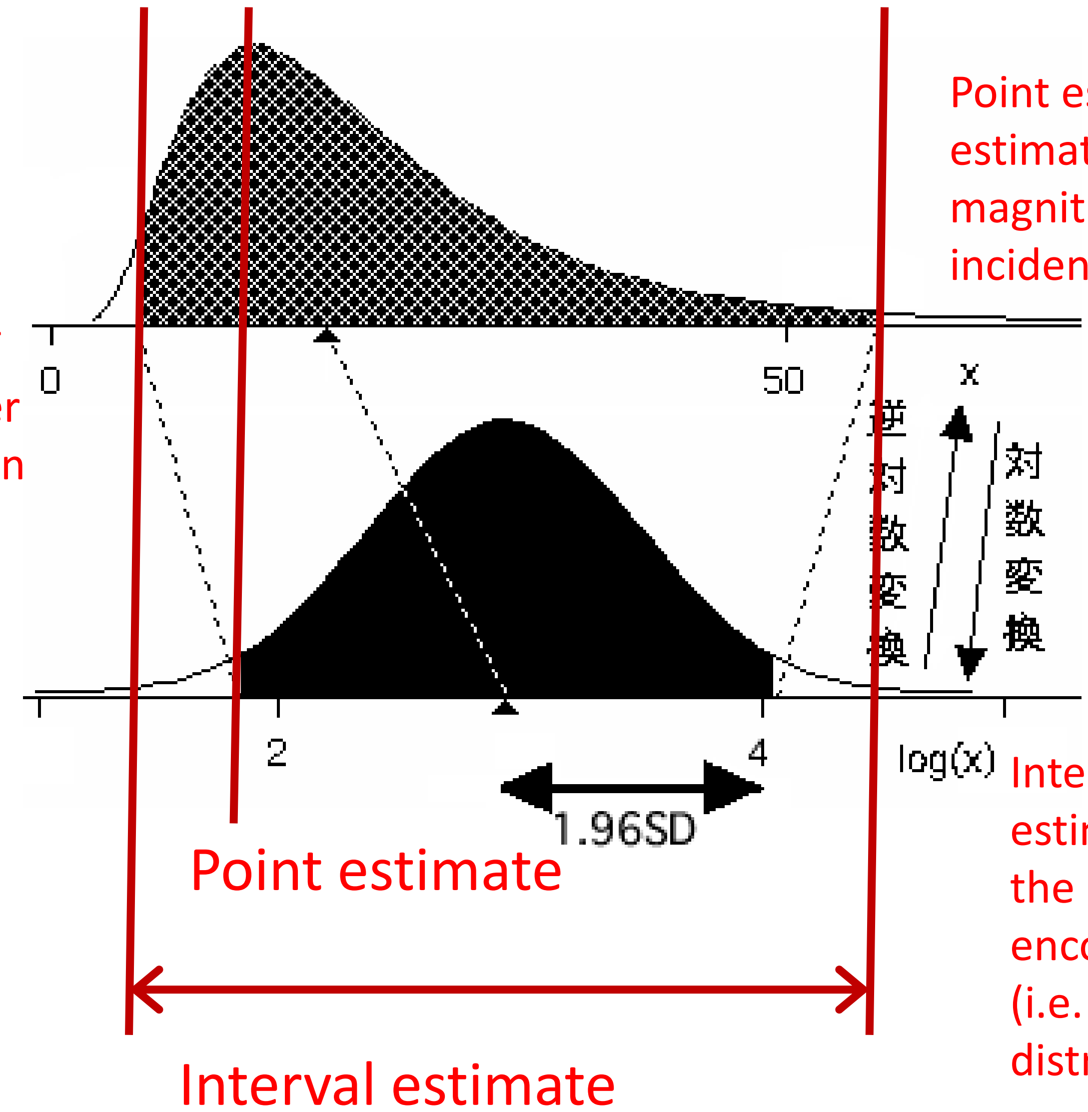
In medicine where humans are the target of observation, this role is played by epidemiology.

Quantitative general rules on the right have probability distribution.

What's important is to distinguish between the reality world on the left (observation) and the concept world on the right (general rules).

Point estimate and interval estimate for imagining probability distribution

If the lower limit of this interval is larger than 1X, it means an increase with statistical significance at the 5% level.



Point estimate is to estimate, "What is the magnitude of true incidence rate ratio?"

Interval estimate is to estimate the width of the estimator encompassing most (i.e. 95%) of probability distribution.