Thyroid Cancer Detection by Ultrasound among Residents Aged 18 Years and Younger in Fukushima, Japan: 2011 to 2014

(Updated analysis of data through June 30, 2015, released by Fukushima Prefecture on August 31, 2015)

Toshihide Tsuda, M.D., Ph.D.
Professor of Environmental Epidemiology
Okayama University

WHO's Preliminary Dose Estimation (2012): 1

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%

Thyroid equivalent dose during 2011

Adults

WHO's Preliminary Dose Estimation (2012): 2

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	60%	100–200	Inhalation	50%
	External (groundshine)	30%		External (groundshine)	30%
	Ingestion	10%		Ingestion	20%
10–100	Inhalation	50%	10–100	Inhalation	40%
	External (groundshine)	30%		Ingestion	40%
	Ingestion	20%		External (groundshine)	20%
10–100	Ingestion	50%	10–100	Ingestion	60%
	Inhalation	30%		Inhalation	30%
	External (groundshine)	20%		External (groundshine)	10%
10–100	Ingestion	50%	10–100	Ingestion	60%
	External (groundshine)	30%		External (groundshine)	20%
	Inhalation	20%		Inhalation	20%
10–100	Ingestion	50%	10–100	Ingestion	70%
	External (groundshine)	30%		External (groundshine)	20%
	Inhalation	20%		Inhalation	10%
10–100	Ingestion	80%	10–100	Ingestion	90%
	External (groundshine)	10%		External (groundshine)	10%
	Inhalation	10%			
10–100	Ingestion	90%	10–100	Ingestion	90%
	External (groundshine)	10%		External (groundshine)	10%
1–10	Ingestion	40%	1–10	Ingestion	60%
	External (groundshine)	30%		External (groundshine)	20%
	Inhalation	30%		Inhalation	20%
1–10	Ingestion	100%	1–10	Ingestion	100%
<0.01	Ingestion	90%	<0.01	Ingestion	100%
	External (groundshine)	10%			
<0.01	Ingestion	70%	<0.01	Ingestion	80%
	Inhalation	20%		Inhalation	10%
	External (groundshine)	10%		External (groundshine)	10%

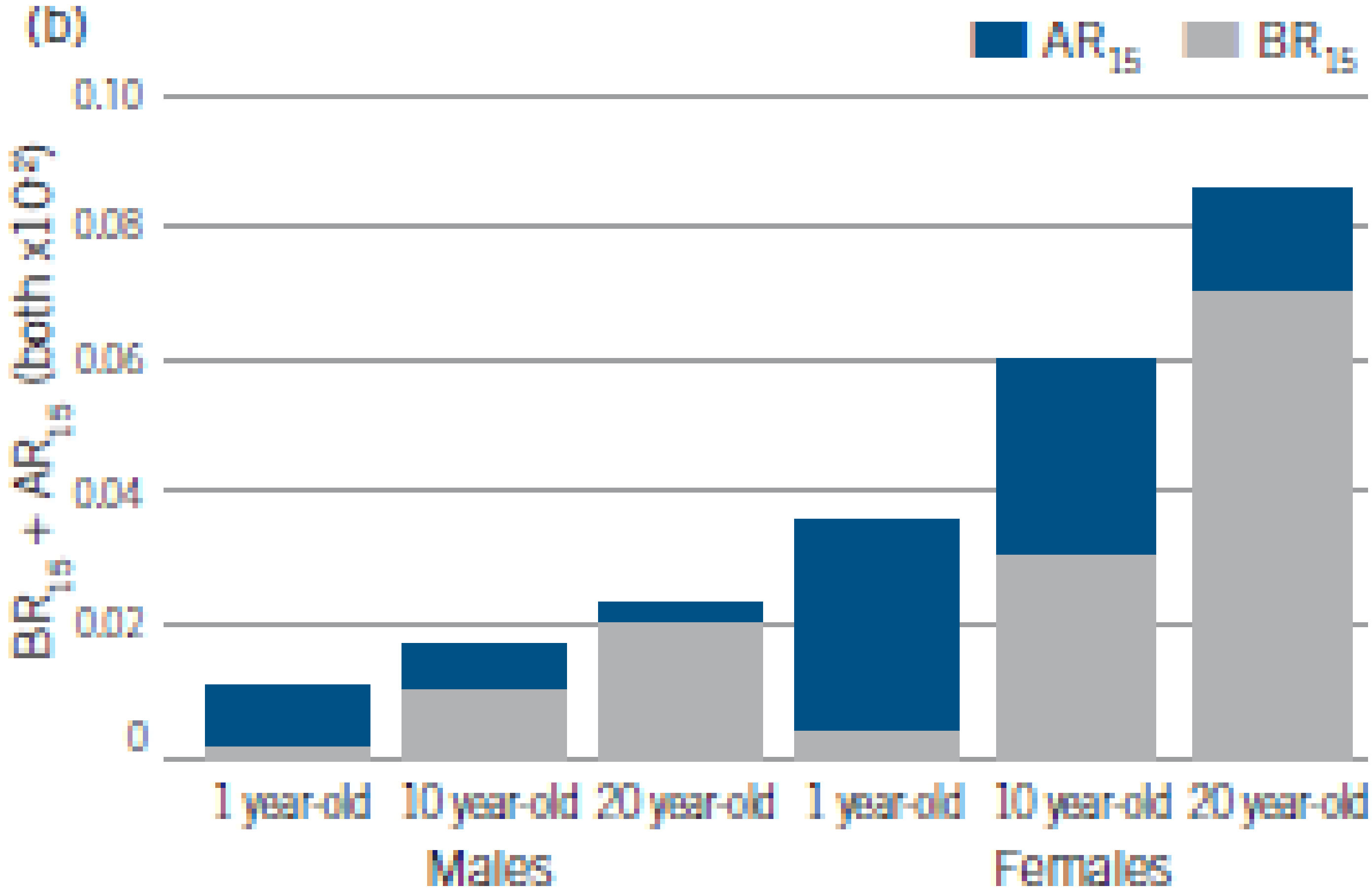
Thyroid equivalent dose during 2011

Age 10

Age 1

WHO's Health Risk Assessment (2013)

Expected increase in thyroid cancer risk over 15 years



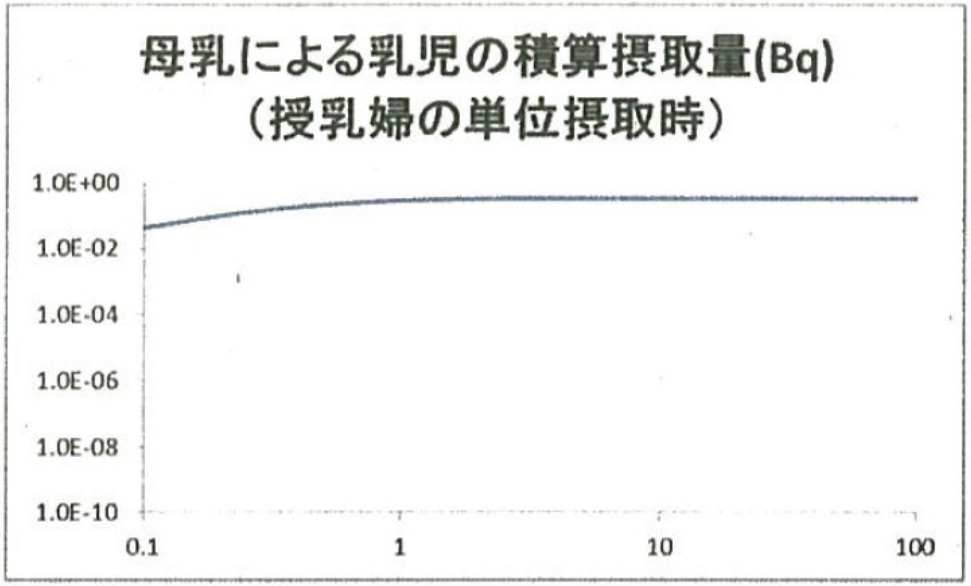
In the November 2011 draft of the WHO Preliminary Dose Estimation

- Thyroid equivalent doses for 1 y/o infants were estimated to be 300-1000 mSv in Namie Town, Fukushima, and 10-100 mSv in Tokyo and Osaka.
- The Japanese Government lobbied WHO for revisions, and the estimates for 1 y/o infants were eventually reduced to 100-200 mSv in Namie Town, and 1-10 mSv in Tokyo and Osaka.

(From the December 7, 2014 Asahi Shimbun GLOBE post)

Unno et al. (2012) and ICRP Publ. 67

Unno et al.: J. Obstet. Gynaecol. Res. Vol. 38, No. 5: 772–779, May 2012



⇒採取日（授乳婦が4月25日頃1 Bq摂取した場合、約40日後）までの乳児の積算摂取量
= 0.32 Bq

乳児の実効線量係数
= 1.8×10^{-7} [Sv/Bq]

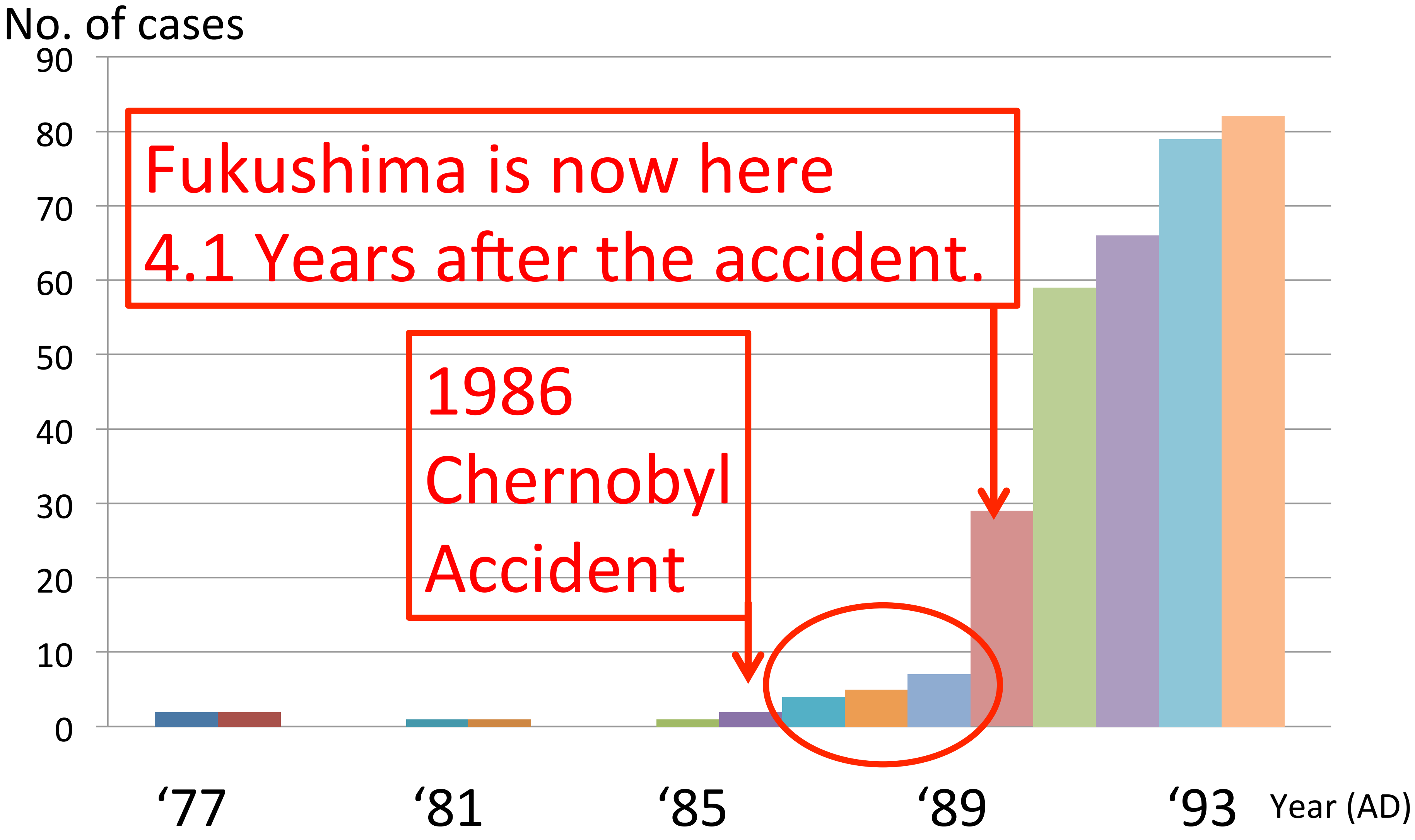
乳児の甲状腺等価線量係数
= 3.7×10^{-6} [Sv/Bq]

※ICRP Publl. 67

被測定者	授乳婦の摂取量 (Bq)	乳児の摂取量 (Bq)	実効線量 (mSv)	乳児甲状腺の等価線量 (mSv)
A	4.39E+05	1.42E+05	26	524
B	3.76E+05	1.21E+05	22	449
C	1.00E+06	3.24E+05	58	1199
D	2.76E+05	8.91E+04	16	330
E	2.89E+05	9.31E+04	17	345
F	2.89E+05	9.31E+04	17	345
G	2.89E+05	9.31E+04	17	345

授乳婦等価線量 (mSv)
189
162
432
119
124
124
124

Epidemic curve of thyroid cancer in Chernobyl (Belarus ≤ age 14)



Minimum Latency & Types or Categories of Cancer by CDC (May 1, 2013; Howard J, M.D., Administrator)

IV. Summary

The Administrator has selected minimum latencies for the following five types or categories of cancer:

(1) Mesothelioma—11 years;

(2) All solid cancers (other than mesothelioma, lymphoproliferative, thyroid, and childhood cancers) — 4 years;

(3) Lymphoproliferative and hematopoietic cancers (including all types of leukemia and lymphoma) — 0.4 years (146 days);

(4) Thyroid cancer — 2.5 years; and

(5) Childhood cancers (other than lymphoproliferative and hematopoietic cancers)—1 year.

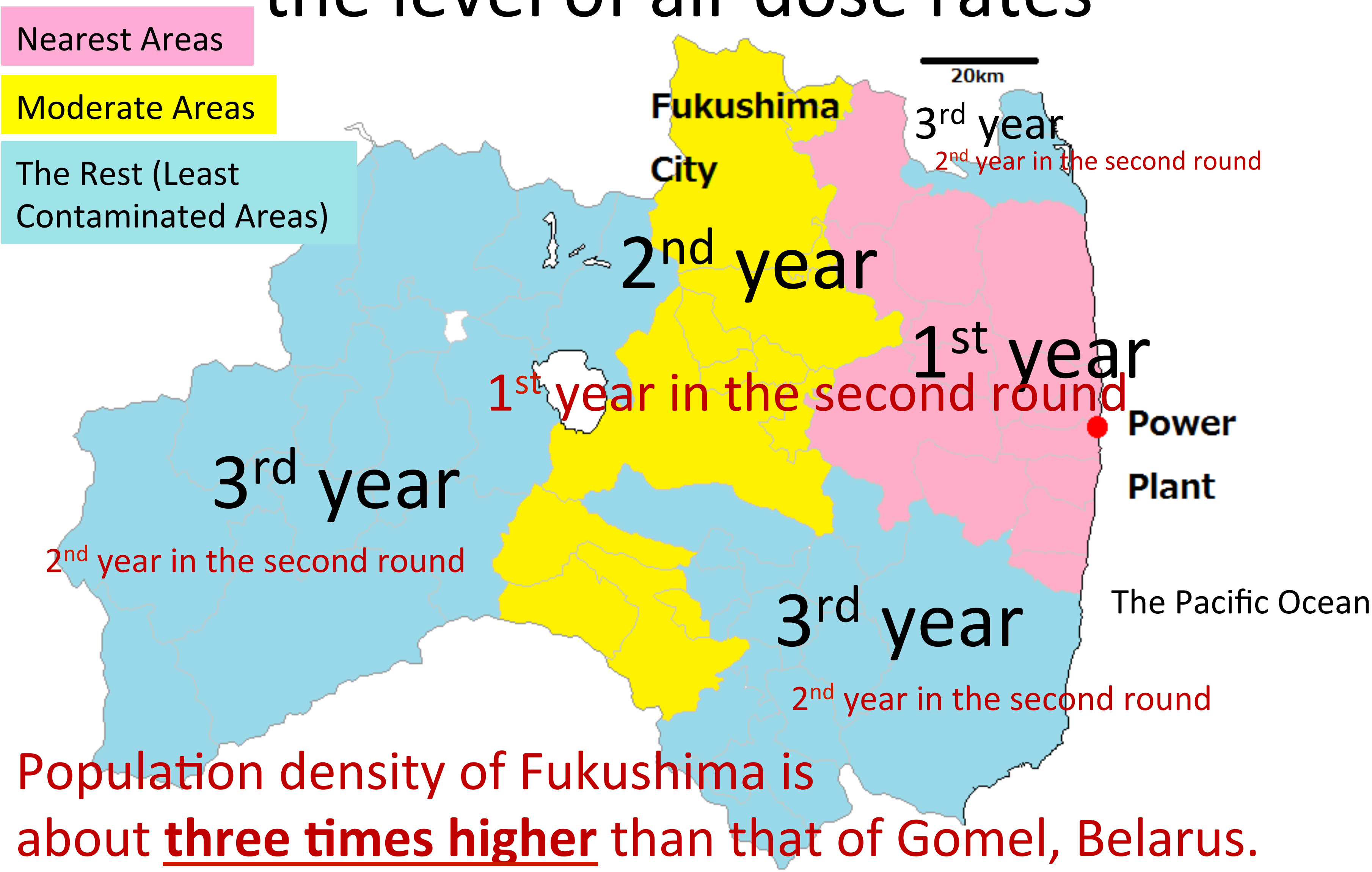
Thyroid cancer screening ≤ age 18

- Primary examination: All residents ≤ age 18 in 2011 (born between April 2, 1992 and April 1, 2011)
  - Screened by thyroid ultrasound.
  - Secondary examination when nodules with diameter ≥ 5.1 mm or cysts with diameter ≥ 20.1mm are detected.
- Secondary examination: for positive primary screening
  - More detailed ultrasound, then cytology by fine needle aspiration.
- When cancer cells were detected by cytology
  - Followed with observation, then operated.
  - Cancer confirmed by histological examination of the excised tissues.

Thyroid cancer screening schedule

- The first round (The Japanese fiscal year is from April 1st to March 31st of the following year).
  - Year 1 (FY 2011, ending on March 31, 2012)
    - The nearest areas to the Fukushima Daiichi NPP
  - Year 2 (FY 2012, ending on March 31, 2013)
    - The moderately near area including Fukushima City.
  - Year 3 (FY 2013, beginning on April 1, 2013)
    - Remaining areas (“Least Contaminated Area” by WHO 2012).
- The second round (from April 1,2014 to March 31, 2016)
  - Year 4 (FY 2014, ending on March 31, 2015)
    - The nearest area and the moderately near
  - Year 5 (FY 2015, ending on March 31, 2016)
    - Remaining areas (corresponding to the third fiscal year in the first round)

The order of screening according to the level of air dose rates



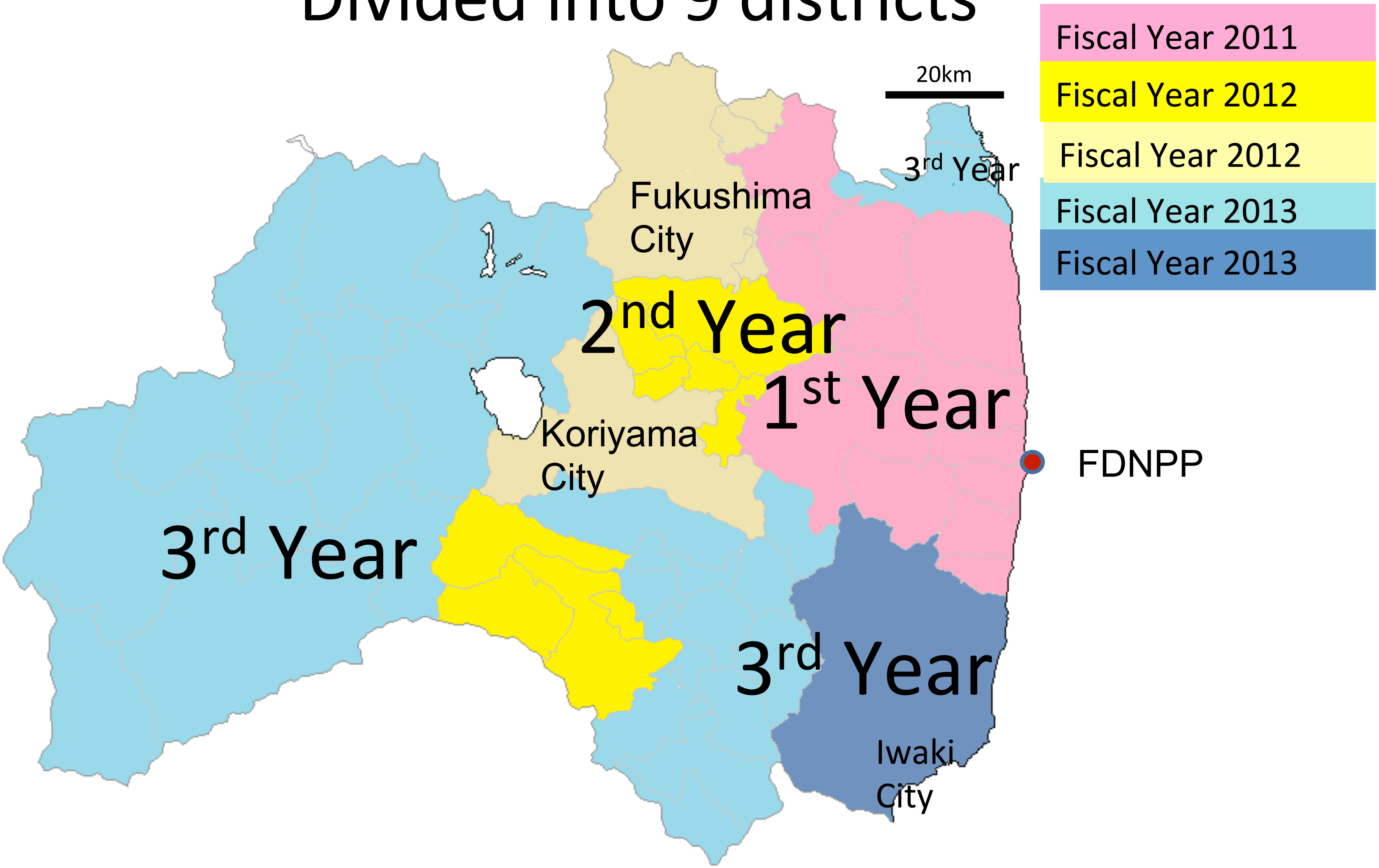
Population density of Fukushima is about **three times higher** than that of Gomel, Belarus.

Methods: comparison group

- Fukushima prefectural government releases the screening results about every three months.
  - The present data were released on May 18, 2015 with the results as of March 31, 2015.
- We divided the prefecture into 9 districts according to the screening schedule and location of cities with large population:

  ① Nearest Area, ② North Middle District, ③ Central Middle District, ④ Koriyama City, ⑤ South Middle District, ⑥ Iwaki City, ⑦ Southeastern Least Contaminated District, ⑧ Western Least Contaminated District, ⑨ Northeastern Least Contaminated District

Divided into 9 districts



Methods: External Comparison

- Age- and sex-specific incidence estimates of thyroid cancer from the Center for Cancer Control and Information Services, National Cancer Center, Japan (1975-2008).
  - The Japanese mean annual incidence among those aged 0-19 years from 1975 to 2008 (i.e. 3 per 1,000,000).
- Prevalence ≒ Incidence × Average Duration
  - In this case, "duration" is the duration from the date when thyroid cancer became detectable by screening and cytology to the date when it could have been diagnosed in usual clinical settings without screening.
- Poisson distribution was employed to estimate 95% confidence intervals.

Methods: Internal Comparison

- We employed the Southeastern Least Contaminated District as “reference district.”
- We estimated Prevalence Odds Ratio and its 95% Confidence Interval on the remaining 8 districts based on prevalence of the Southeastern Least Contaminated District.
- We employed MLE Odds Ratio (Mid-P) of “StatCalc” in EpiInfo 7 (released by CDC).

Divided into 9 districts

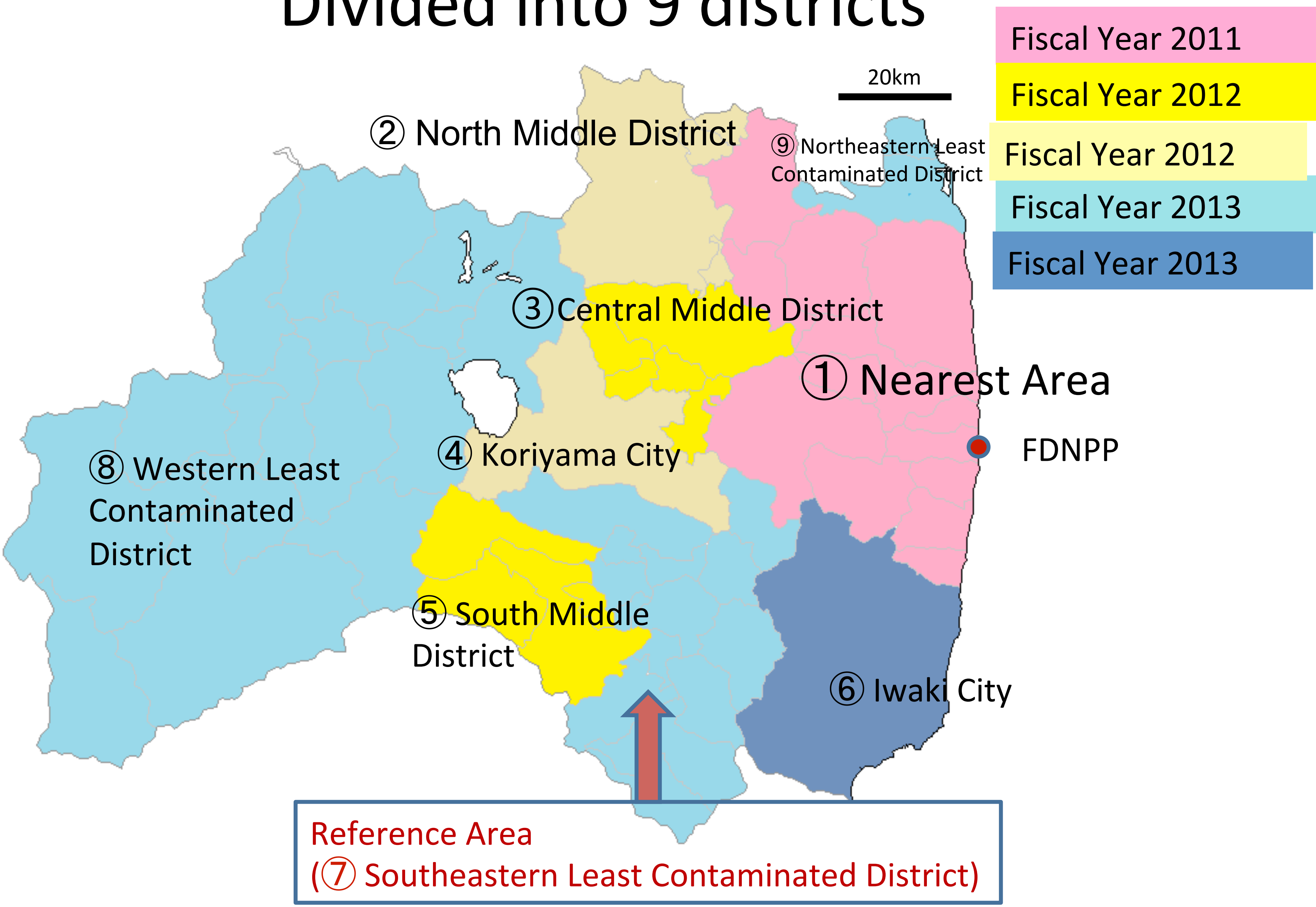


Table 1 (data as of June 30, 2015）

Areas	Population age ≤ 18	Participants in primary examination	Positives in primary examination	Participants in secondary examination	Thyroid cancer cases by FNA（No. operated）
Fiscal Year 2011	47,768	41,810 (87.5%)	221 (0.53%)	199 (90.0%)	15*(15*) +13**
Fiscal Year 2012	161,129	139,338 (86.5%)	988 (0.71%)	920 (93.1%)	56 (52) +12**
FY 2013 (Least Cont.)	158,788	119,328 (75.1%)	1,085 (0.91%)	989 (91.2%)	42 (32)
Total	367,685	300,476 (81.7%)	2,294 (0.76%)	2,108 (91.9%)	113 (99) +25**

*Including one benign case

**Additional Thyroid Cancer Cases in the second round

Table 2 (4 districts in Middle Area)

Districts	Population age ≤ 18	Examinees in primary examination	Positives in primary examination	Examinees in secondary examination	Thyroid cancer cases by FNA（No. operated）
North Middle	57,211	50,618 (88.5%)	312 (0.62%)	298 (95.5%)	12 (?) +9*
Central Middle	21,052	18,194 (86.4%)	115 (0.63%)	111 (96.5%)	11 (?) +2*
Koriyama City	64,380	54,063 (84.0%)	458 (0.85%)	415 (90.6%)	25 (?) +1*
South Middle	18,486	16,463 (89.1%)	103 (0.63%)	96 (93.2%)	8 (?)
Total	161,129	139,338 (86.5%)	988 (0.71%)	920 (93.1%)	56 (52) +12*

*Additional thyroid cancer cases in the second round

Table 3:
4 districts in the Least Contaminated Area

Districts	Population age ≤ 18	Participants in primary examination	Positives in primary examination	Participants in secondary examination	Thyroid cancer cases by FNA（No. operated）
Northeastern	8,246	6,359 (77.1%)	54 (0.85%)	49 (90.7%)	0 (0)
Iwaki City	62,293	49,429 (79.3%)	455 (0.92%)	422 (92.7%)	24 (?)
Southeastern (Reference)	38,322	29,820 (77.8%)	242 (0.81%)	221 (91.3%)	7 (?)
Western	49,927	33,720 (67.5%)	334 (0.99%)	297 (88.9%)	11 (?)
Total	158,788	119,328 (75.1%)	1,085 (0.91%)	989 (91.2%)	42 (32)

Table 4: External Comparison

	3/1,000,000*		Prevalence	
Areas and Districts	IRR**	(95% C.I.) **	per 10^6	Reciprocal
Nearest Area (FY 2011)	29.90	(16.73-49.31)	359	2,787.3
North Middle District	19.76	(10.21-34.51)	237	4,218.2
Central Middle District	50.38	(25.15-90.15)	605	1,654.0
Koriyama City	38.54	(24.94-56.89)	462	2,162.5
South Middle District	40.49	(17.48-79.79)	486	2,057.9
Iwaki City	40.46	(25.92 -60.20)	486	2,059.5
SE Least Contaminated District	19.56	(7.86-40.31)	235	4,260.0
Western Least Contaminated District	27.18	(13.57-48.64)	326	3,024.5
NE Least Contaminated District	0	(0.00-48.34)	0	-

*Comparison with Japanese mean   **Incident Rate Ratio（95% Confidence Interval）

Table 5: Internal Comparison and POR

	Cancer cases	No. in primary exam.	POR*	(95% C.I.) *
Nearest Area (Fiscal Year 2011)	15**	41,810	1.53	(0.63-4.01)
North Middle District	12	50,618	1.01	(0.40-2.73)
Central Middle District	11	18,194	2.58	(0.99-7.06)
Koriyama City	25	54,063	1.97	(0.88-4.91)
South Middle District	8	16,463	2.07	(0.73-6.00)
Iwaki City	24	49,429	2.07	(0.92-5.17)
SE Least Contaminated (Reference)	7	29,820	1	
Western Least Contaminated District	11	33,720	1.39	(0.54-3.81)
NE Least Contaminated District	0	6,359	0	(0-2.50)

* Prevalence Odds Ratio（95% Confidence Interval） **Including one benign case

The order of examination in the second round screening

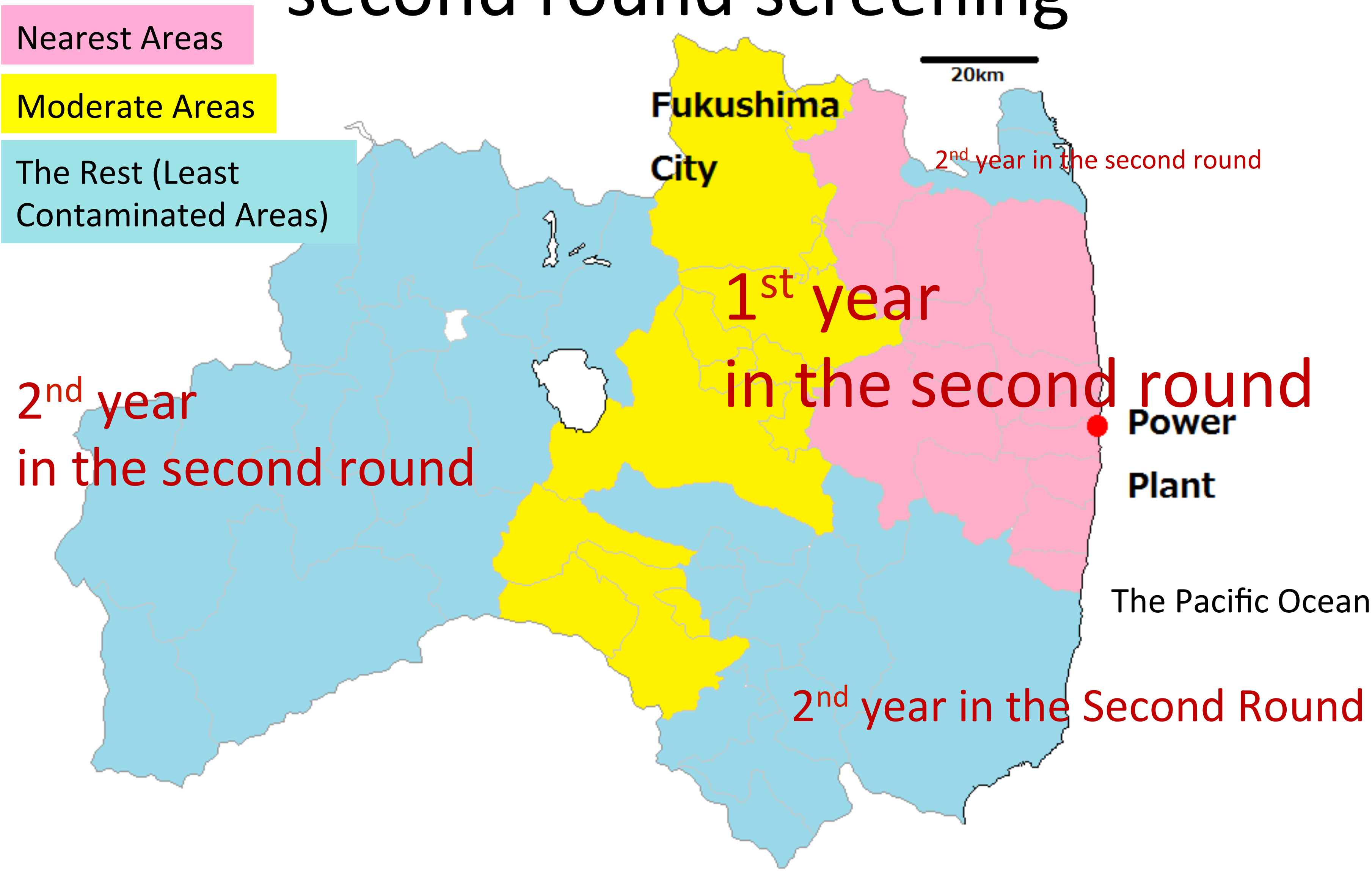


Table 6: Current results of the second round screening

Areas	Population age ≤ 18	Participants in primary exam.	Positives in primary exam.	Participants in secondary exam.	No. of FNA Examinees	Thyroid cancer cases by FNA（No. operated）
2014	216,779	149,065 (68.8%)	1,173 (0.8%)	752 (64.1%)	87 (11.6%)	25 (6)
2015	161,999	20,390 (12.6%)	50 (0.25%)	15 (30.0%)	1 (6.7%)	0 (0)
Total	378,778	169,455 (44.7%)	1,223 (0.7%)	767 (62.7%)	88 (11.6%)	25 (6)

Table 7: FY 2014 results in the second round

Districts/Area	Population age ≤ 18	Examinees in primary examination	Positives in primary examination	Examinees in secondary examination	Thyroid cancer cases by FNA（No. operated）
Nearest Area	49,454	31,285 (63.3%)	305 (0.97%)	242 (79.3%)	13 (?)
North Middle	59,492	43,792 (73.6%)	344 (0.79%)	278 (80.8%)	9 (?)
Central Middle	21,805	15,799 (72.5%)	110 (0.70%)	80 (72.7%)	2 (?)
Koriyama City	66,747	44,540 (66.7%)	328 (0.74%)	128 (39.0%)	1 (?)
South Middle	19,281	13,649 (70.7%)	86 (0.63%)	24 (27.9%)	0 (?)
Total	216,779	149,065 (68.8%)	1,173 (0.79%)	752 (64.1%)	25 (6)

Table 8: External comparison in the second round（latency of 2.5 years）

	3/1,000,000*		Prevalence	
Areas and Districts	IRR**	(95% C.I.) **	per 10^6	Reciprocal
Nearest Area	55.40	(29.50-94.74)	416	2,406.5
North Middle District	27.40	(12.53-52.02)	206	4,865.8
Central Middle District	16.88	(2.04-60.97)	127	7,899.5
Koriyama City	2.99	(0.08-16.68)	22	44,540
South Middle District	-	-	-	-
Iwaki City	-	-	-	-
SE Least Contaminated District	-	-	-	-
Western Least Contaminated District	-	-	-	-
NE Least Contaminated District	-	-	-	-

**Incidence Rate Ratio（95%Confidence Interval）

“Table 1” by Jacob et al. (2006)

Table 1. Number of thyroid cancer cases detected in various screening programmes in Ukraine and Belarus. ATA indicates age at the time of the accident, ATS age at screening.

Study	Area	Age group	Period	Number of cases	Prevalence (cases per 10^6 persons)
IPHECA [6]	Gomel	ATA $\leqslant$ 18	1990–1992	15	2200
	Kyiv and Zhytomyr	ATS $\leqslant$ 15	1992–1994	5	400
Sasakawa, First screening [7]	Gomel	ATA $\leqslant$ 10	1991–1996	38	1900
	Mogilev	ATA $\leqslant$ 10	1991–1996	2	80
	Kyiv	ATA $\leqslant$ 10	1991–1996	6	220
	Zhytomyr	ATA $\leqslant$ 10	1991–1996	9	310
Sasakawa, Second screening [8, 9]	Kyiv	ATA $\leqslant$ 18	1996–2000	25	2300
	Zhytomyr	ATA $\leqslant$ 14	1996–2000	11	1300
Belarus screening programme [10, 11]	Belarus	ATS $\leqslant$ 14	1990–1991	7	6400
	Gomel	ATS $\leqslant$ 18	2002	2	53
Ukraine–USA cohort study [12]	Kyiv, Chernihiv and Zhytomyr	ATA $\leqslant$ 18	1998–2000	43	3200
			2001–2002	21	1800*

* Incidence: new cases among persons who had been screened before.

Jacob P, Bogdanova TI, Buglova E, et al. : Thyroid cancer among Ukrainians and Belarusians who were children or adolescents at the time of the Chernobyl accident. J Radiol Prot 2006; 26: 51–67

Table 9: Prevalence of screening by ultrasound among children born after 1987 in Chernobyl and in the relatively low contaminated area

Author	Time of investigation	Age of subjects in the investigation	Area of the investigation	Number Of subjects	Thyroid cancer cases	Prevalence (95%C.I.) per 10^6
Demidchik et al. *1	2002年	14 years old and under	Gomel (born after 1987)	25,446	0	0 (0-145)
Shibata et al.*2	1998-2000	8-13 years old	Gomel (born after 1987)	9,472	0	0 (0-389)
Ito et al.*3	1993-1994	7-18 years old	Mogilev (relatively low contaminated)	12,285	0	0 (0-300)
Total				47,203	0	0 (0-78)

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

*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 diseases around Chernobyl evaluated by ultrasound examination and fine needle aspiration cytology. Thyroid 1995; 5(5): 365-368.

Excess thyroid cancer among children and adolescents

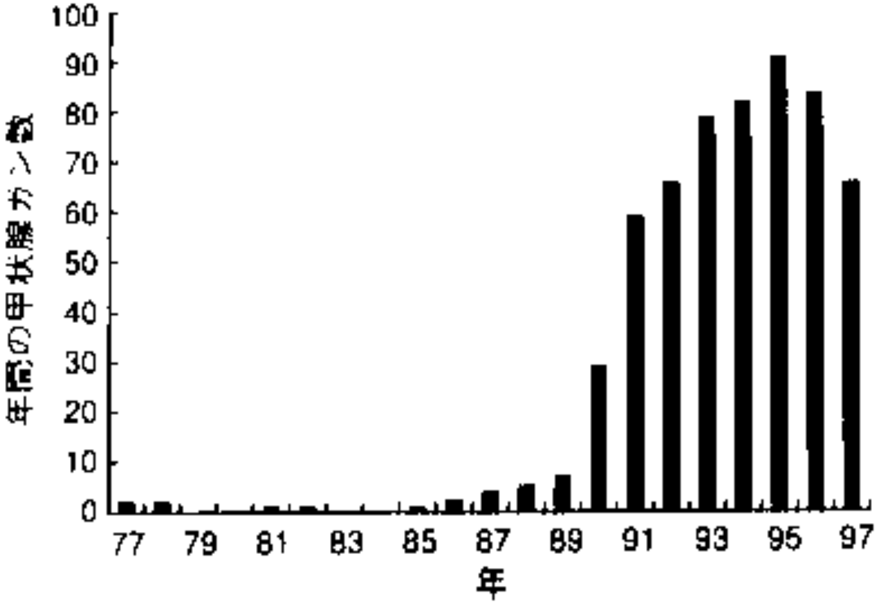


図 1　ベラルーシの小児甲状腺ガン数の変化

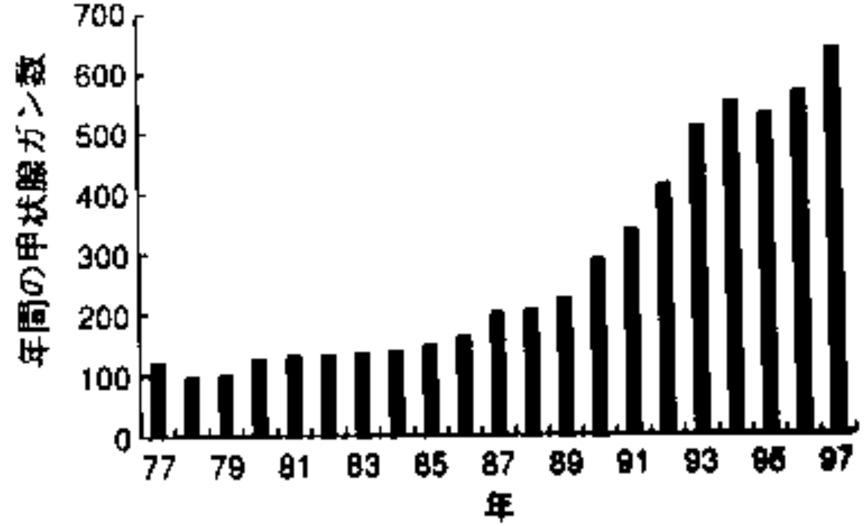


図 2　ベラルーシの青年・大人の甲状腺ガン数の変化

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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

Residents who were older than 18 in 2011 should also be monitored for thyroid cancer.

Thyroid cancer data analysis: Conclusions

1. In February 2013, WHO predicted excess cancers including thyroid cancer in Fukushima based on the WHO estimated doses, even though they had been reduced from the original due to lobbying by the Japanese government.
2. After the 1986 Chernobyl accident, thyroid cancer cases increased among children and adolescents during 1987-1989, in both Belarus and Ukraine.
3. Very few cases were observed in the screening among the unexposed population in Chernobyl
4. A statistically significant increase (11 times) of thyroid cancer has already been observed in the ongoing second round screening in Fukushima.
5. No data exists to deny the causal relationship between the nuclear accident and the excess thyroid cancer cases.
   - We must prepare for a large outbreak after 4-5 years, like the one that was experienced in Chernobyl.

Thyroid cancer data analysis: Recommendations

1. Adequately inspecting and ensuring medical resources in order to prepare for a potentially rapid increase in thyroid cancer cases.
2. Expansion of thyroid ultrasound examination to include:
   - those who were over age 18 at the time of the accident
   - residents in neighboring prefectures (especially south)
3. Investigating other cancers and non-cancer diseases.
4. Further analyzing the Chernobyl thyroid cancer data in order to evaluate the thyroid exposure dose due to radioactive iodine separately from the effect of air dose rate from radioactive cesium in order to assess the contribution of cesium to thyroid cancer.
5. Postponing the resettlement plan to return evacuees to their hometowns even when the exposure dose is reduced below 20 mSv annually by decontamination, especially if the plan is based on the "100 mSv threshold" theory.
6. Execution of further radiation protection measures, such as evacuation, especially for pregnant women, infants, toddlers, children, adolescents, and women with potential to get pregnant, in that order.

Epidemic curve of thyroid cancer in Chernobyl (Belarus under ≤ age 14)