International Radiation Protection System: Protecting Children in the Community

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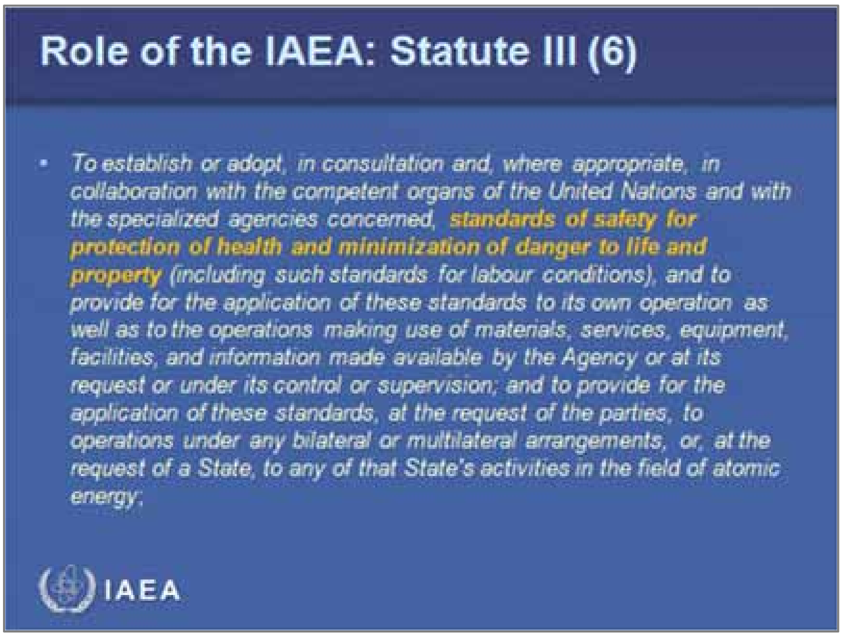
Thank you.　Konnichiwa!
I am very happy to be here. It's a great privilege to be here in Soma city and I was very pleased yesterday to see some of the very impressive remediation work that has been undertaken following the disaster here in 2011.

I want to talk a little bit about radiation protection of children because that seemed to be at the core of what the symposium was about. So in this presentation I will talk about the role of the International Atomic Energy Agency, the development of safety standards, radiation protection framework and how it applies to children, reference levels and dose limits because these dictate a lot of what we actually do, radiation risks to children, how radiation risks are estimated, and finally the conclusion.

I start with the role of the International Atomic Energy Agency. The International Atomic Energy Agency is celebrating its 60th anniversary this year. The IAEA is part of the UN family of organizations and it was established with a number of roles. One of its roles is to promote the peaceful use of nuclear energy but another of its roles is the establishment of standards, in particular standards for safety for the protection of health and the minimization of danger to life and property. The Department of Nuclear Safety and Security is the department charged with the development of these standards.

The Division that I lead sits within the Department of Nuclear Safety and Security. It establishes safety standards for use by member states.　And really in many senses the most important role we have is to assist in the implementation of standards through interaction with regulators, that includes the development of regulatory infrastructure and capacity building across the member states.



The general framework of how standards are developed begins with the evaluations of science conducted by the United Nations Scientific Committee on the Effects of Atomic Radiation, known as UNSCEAR. In turn, that evaluation of science is considered by the International Committee on Radiation Protection, ICRP, which many of you will have heard of, and that turns the science into recommendations for protection. And in turn, the IAEA's job is to take those recommendations and essentially put them in a form which is suitable for use by regulators.

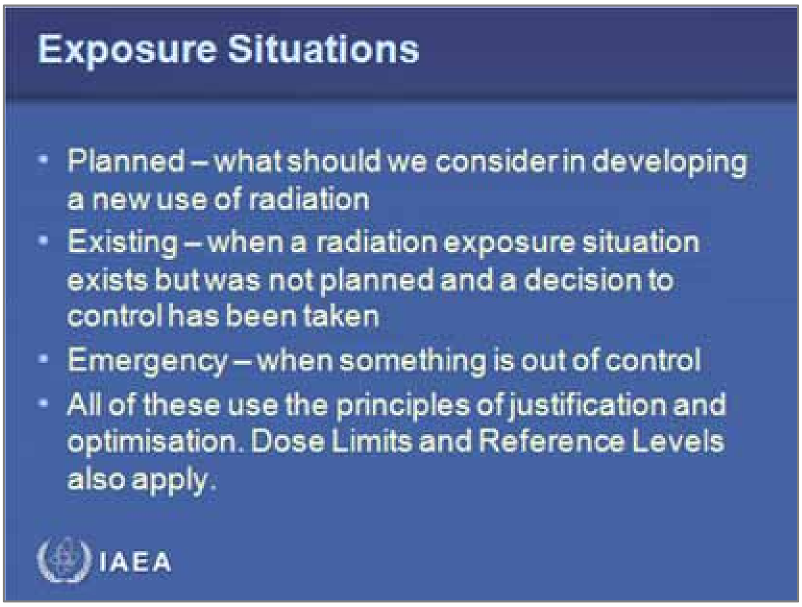
So, the framework for radiation protection that we have really talks about three types of exposure situations, and it is somewhat useful to look at these three types of exposure situations. The first type is what we call planned exposure situations and this is what applies if you are proposing to build a power plant or conduct any form of activity which involves the use of ionizing radiation.

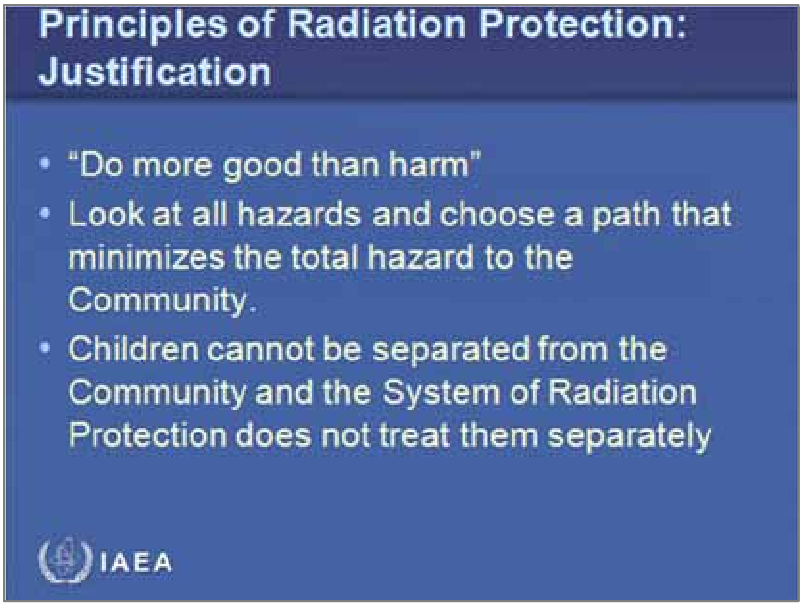
When there is a planned exposure situation, we have three principles that we follow. The first principle is justification, which I will explain a little bit more later; the second one is optimization; finally, the third one is limitation or the establishment of dose limits.

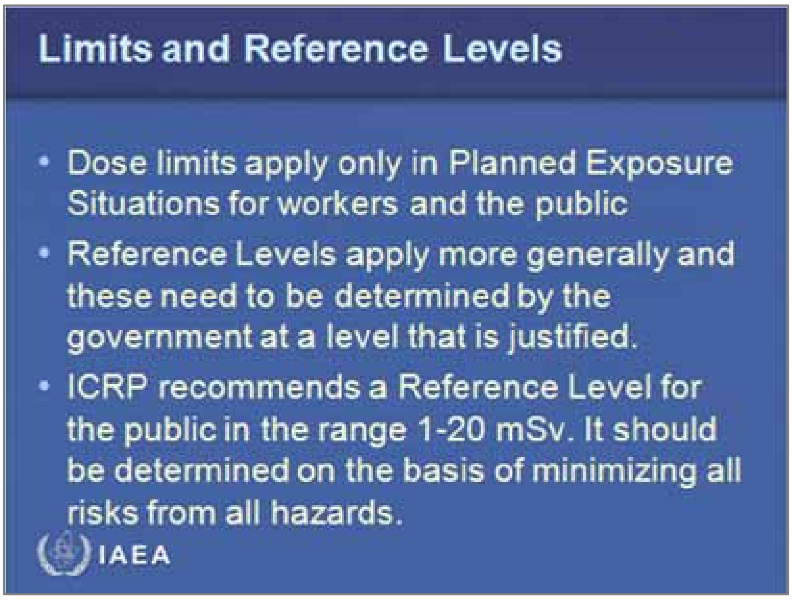
The second type of exposure situation is what we call an existing exposure situation and that's what happens when the radiation exposure situation wasn't planned or had not previously been regulated and I will come back to that in a while. And finally, we have an emergency exposure situation which is when something is out of control.

All three of the exposure situations use the principles of justification and optimization. In the case of planned exposure situations, we have dose limits and in the case of existing and emergency exposure situations, we have things called reference levels.

The situation now in Fukushima prefecture is an existing exposure situation. We had an emergency. There was something out of control. It is now under control. So the emergency is over. But we had a situation which we didn't plan to have and we have to deal with the radiation exposure from the situation we find ourselves in.







So what does justification and optimization really mean? Well, justification is actually a very simple concept. It simply says that a practice is justified if it does more good than harm. And in order to justify a practice, we should look at all the hazards that are involved and choose a path that minimizes the total hazard to the community.

Now this actually involves considering not just radiation hazards but all the other hazards that might be present. And it has been very constructive to me to look at the deep understanding of disasters that Japan has and how it understands the social impacts that disasters can have. These form an important part of the overall consideration of justifying what you do in the future. In fact, I think there are many situations in Japan where radiation exposure is now a very minor hazard in comparison to the other social problems that have arisen from the disasters.

In this context, I mentioned children because there is no separate framework for radiation protection for children. Radiation protection of children acknowledges that children have different sensitivities to radiation to adults. And certainly when one does assessments, one comes up with a different dose for children to what one might get for an adult. But in general children are considered in the same framework as all other people.

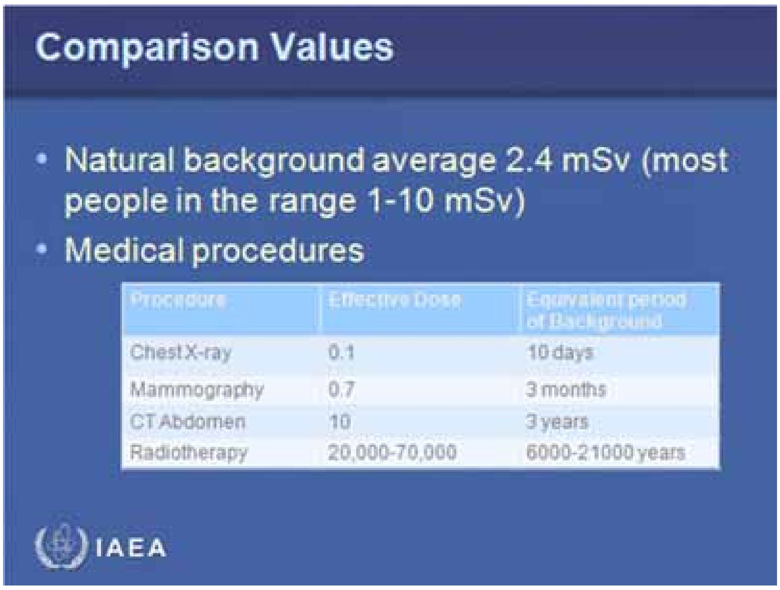
Optimization is ultimately again a very simple concept as well. Optimization simply asks the question can we do better with the resources that we have available. I can see already that in the social context some of Japan’s knowledge of disasters has recognized the fact that elderly people are particularly vulnerable in the aftermath of a disaster. So there have been practical steps taken to improve the social situation of elderly people. This is a form of optimization. Itis not applied to radiation of course; but nevertheless, it is exactly what we would call, in radiation protection language, optimization.

So how do we apply optimization? First of all, we make the decision that is something justified, is it going to do more good and harm, and is it the best option for the community. Then we often can do much better by empowering the community to improve the situation itself.

An area which causes lots of problems and misunderstandings are the concepts of limits and reference levels. Dose limits, as I have said before, apply only in planned exposure situations for workers and members of the public. So if I work in a hospital and I am doing radiography, then I am a worker and I have to fall within a worker dose limit. If I am building a plant of any type, then I have to make a consideration of whether I will expose members of the public to more than the public dose limit. And if I am going to expose them to more than public dose limit, I have to find a better way of doing the job I have to do.

Reference levels apply much more generally and these need to be developed by government at a level that is justified. In the case of reference levels for existing exposure situations, the ICRP recommends a reference level in the range of 1 to 20mSv. It should be determined on the basis of minimizing all risks from all hazards.

In Japan, the government has essentially chosen a reference level of 1mSv at the bottom of this range because of the extreme concern about radiation issues. It’s worth reflecting on whether that is actually the optimum reference level for the situation at hand.



We have talked a bit around 1mSv as being an important number in the symposium. I will try to put that into some context. The natural background worldwide averages 2.4mSv but it varies enormously from less than 1mSv in some places to much more than 10mSv in others. So this 1mSv which probably has more prominence than it deserves is really actually a very small dose which is used really prospectively for planning new facilities. And we should not get tied up too much about that. The more important concepts are those of justification and optimization.

As was indicated this morning, if one goes for a CT examination, one would get a lot more than 1mSv. In fact, depending on how big you are, it is typically something of the order of 10mSv. For a child, it might be a in a range of 2-5mSv. For me, it's probably considerable more. A chest X-ray is something like 0.1mSv; mammography 0.7mSv, and if you have to have radiation therapy, then the dose are really very, very large because they are designed to kill large numbers of cells and leave very few cancer cells alone.

Our understanding of radiation risks to children comes from a wide range of sources. In fact there was a very excellent volume produced by UNSCEAR recently on exactly this topic. And children are not like little adults. They actually have rather different presentations of cancers. Some cancers are much more prevalent in children than they are with adults for a particular radiation dose. The other area where we actually know quite a lot about childhood cancer is from the aftermath of Chernobyl.

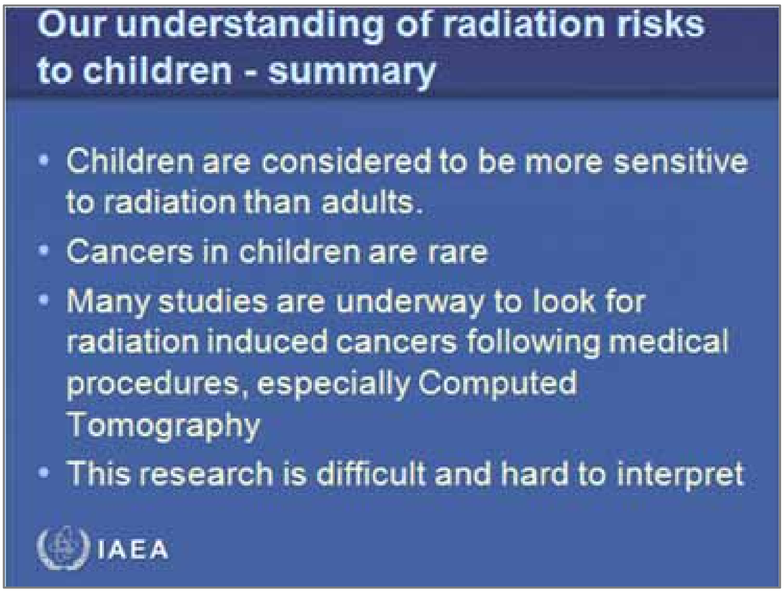
Now, Chernobyl was an accident which released a very large fraction of the core material from a very large reactor. It happened in an agricultural area where the economy was effectively a peasant economy where a lot of people were eating produce from their own farms and there was very little restriction of food to many of the population in the immediate area.

One of the lessons that was learned from Chernobyl was that ingestion of milk, green vegetables, and other foods is a critical pathway in the radiation exposure of children. While one might criticize a number of things that happened in Japan following the accident of Fukushima Daiichi Nuclear Power Plant, certainly restriction of food was effective and that has saved Japanese children from being highly exposed to radiation.

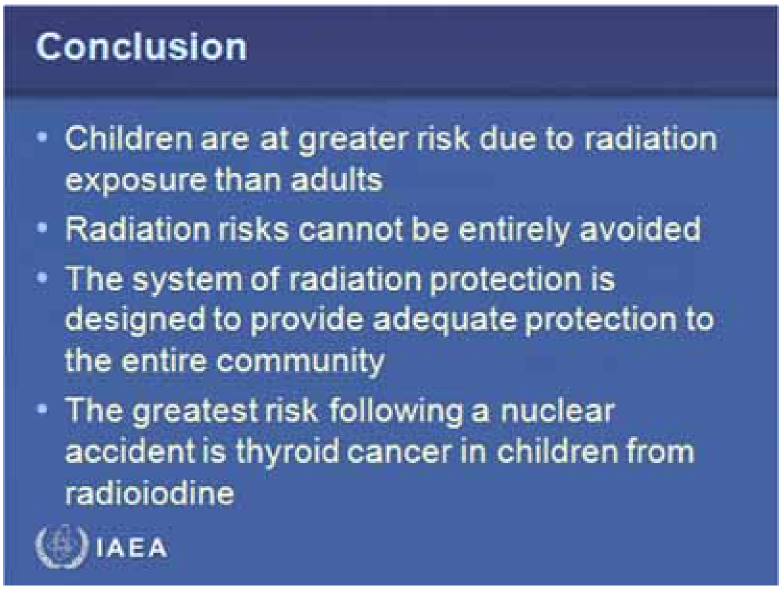
As a consequence of the accident, UNSCEAR indicated that it is very unlikely that there will be very discernible increase in cancers to the Japanese population. They do say, however, that it was possible that one might see an increase in childhood thyroid cancers. The UNSCEAR report indicated doses which we now recognize as being quite high compared to the situation as we understand it now. So I think it is reasonable to take those two pieces of information together and suggest that it is very, very unlikely that we will discern any increase in cancer from the Fukushima Daiichi Nuclear Power Plant accident.

The UNSCEAR report of 2013 also indicates that data about cancers or radiogenic cancers in children are really very limited. Children are more sensitive than adults with respect to radiation exposure but it varies greatly with age. And the data is still really quite uncertain, and that there needs to be additional research and the research should be focused around areas of high natural background after high-dose medical procedures and following radiation therapy.

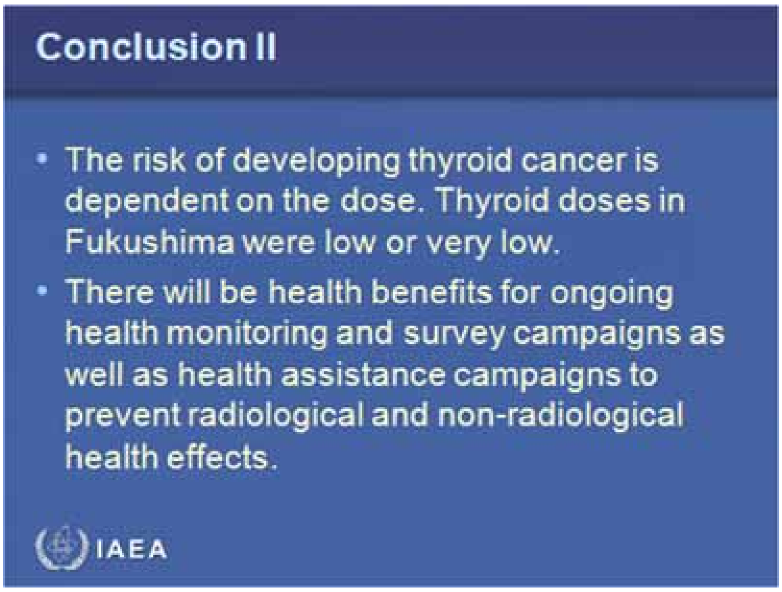
We also have data that we apply from the US and National Academy of Sciences who have examined the radiation-sensitive children and they also indicate significantly higher radiation-sensitivity of children than adults, significantly higher radiation sensitivity of women than men. But when it comes to the development of safety standards, because we are dealing with a large population, we do not differentiate between men, women, and people of different ages because we are trying to come up with a standard that is useful across the whole community.



So to summarize our understanding of radiation related to children, children are considered to be more sensitive to radiation than adults. Cancers in children are rare. Many studies are underway to look at radiation-induced cancers following medical procedures, especially computed tomography. And I think that it is worth just digressing for a minute to think about some of these studies because these studies involve looking at many hundreds of thousands of children who have had CT scans with doses of typically 5mSv.



These studies are some of the few studies that have the power to actually show effects of radiation at low doses of the sort that occurred in the Fukushima prefecture. Those studies are going to be long and hard. The ones that we have published so far have been disputed heavily in the scientific community and have shown really very, very small increases in cancer risk with the sorts of doses that come from CT which is of the order of 5mSv.

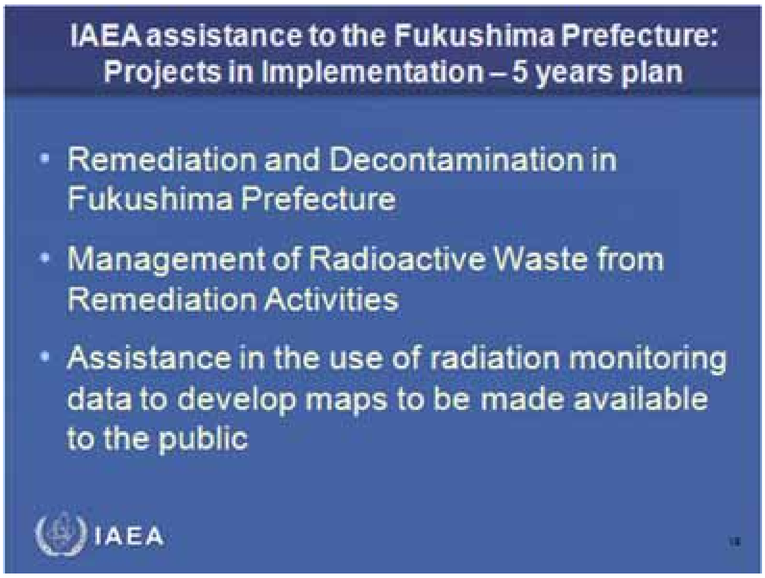


So I conclude by again saying that children are at greater risk due to radiation exposure than adults. Radiation risks cannot be entirely avoided. We are all radiated all of the time. Radiation is part of nature. The system of radiation protection is designed to provide adequate protection to the entire community. And the greatest risk following a nuclear accident is thyroid cancer in children from radioiodine; but fortunately, this can be mitigated by effective controls on access of children to milk, green vegetables and other foods.

Finally, the risk of developing thyroid cancer is dependent on the dose. The thyroid doses in Fukushima were low or very low. There will be health benefits for ongoing health monitoring and survey campaigns as well as health assistance campaign to prevent radiological and non-radiological health effects. But as has been mentioned already, we have to be conscious of the fact that not everything that we find as an abnormality in those health surveillance programs is actually going to be a cancer that needs prompt treatment.

Finally, the IAEA is heavily involved in working in Fukushima Prefecture. We have a range of projects underway at the current time looking at remediation and decontamination, largely with Fukushima Prefecture. Management of radioactive waste from remediation activities remains a matter of real interest to us and you have a lot of soil to worry about, you have a lot of water and storage that has to be dealt with. These are going to be ongoing problems.

We are working with the prefecture and the Ministry of Environment in fact in the use of radiation monitoring data to develop maps that can be made available to the public on our websites. So with that, I conclude. Thank you.



Post-nuclear evacuation and health risks in Fukushima

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Yes, thank you very much for introduction, Oikawa-sensei. Good morning, everyone. I am Shuhei Nomura, a Ph.D. candidate at Imperial College, London. I do really, really appreciate all of you here and those who organized this symposium for having me today. As this title suggests, I am going to talk about evacuation and health risks after the Fukushima nuclear incident.

But before getting into that, let me briefly introduce myself. When the incident happened 5 years ago, I was just a Master students at the University of Tokyo, Japan, and soon after the incident, my professor, who will also speak this afternoon, gave me a chance to visit Fukushima as a volunteer for health checkup. There I met a lot of people from this area including many of today's speakers. In these 5 years, I have been working for the disaster recovery with the local government and with the local hospitals and local health centers and many, many local staff. So in this session, I am going to introduce some of the research based at Minamisoma city and Soma city.

So this is the outline of my talk. The first topic is evacuation and mortality in elderly population and followed by chronic health risk. And finally, I will present other health challenges.

So the first topic, mortality associated with evacuation. You know, safe evacuation of elderly population is very, very important aspect of disaster planning and preparations. For example, in the case of the Hurricane Katrina in 2005 in America, some research suggested that evacuation can be associated with approximately twice the mortality risk in elderly people. So, in elderly population whether or not to evacuate after major disaster and when evacuation is really necessary, how to reduce the potential increase of mortality associated with evacuation are very, very well important issue at the local level and national and global level.

Fukushima incident also required evacuation of elderly population and provided a lot of important insight and lessons on this issue. So, to sum up the evacuation instruction by the central government after the incident, soon after the incident, the central government issued mandatory evacuation order for those living in the 20-kilometer radius of the nuclear power plant. A few days later the government also issued a voluntary evacuation instruction to the 20 to 30 kilometer zone. So after that, a lot of people evacuated from this area.

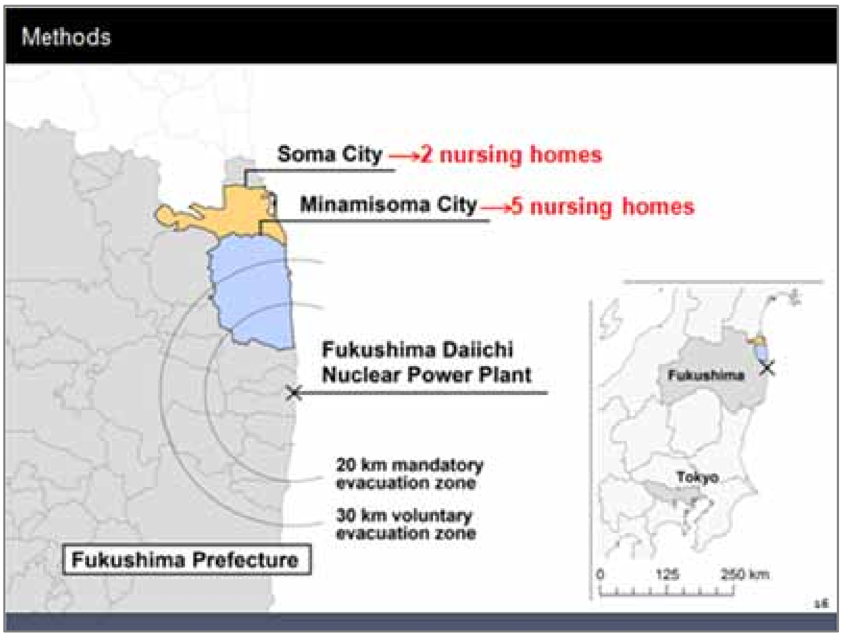
As of now there are some reports concerning the increased risk of mortality after the evacuation. This is from the National Diet of Japan Fukushima Investigation Commission where I worked as a research assistant before. It says that in the 20-kilometer zone, there were seven hospitals and from there after the incident 850 patients evacuated and sixty people died within 1 month after the evacuation.

Second one is from the Fukushima Medical University which said that in the 20-kilometer zone there were 32 nursing homes and from there about 2000 people evacuated and the mortality increased about 2.4 times in comparison with the previous year, 2010.

This is my paper using the data of Minamisoma city and we reported that after the evacuation, the mortality increased about 2.68 in the nursing home resident. The final one is from the newspaper article. As of the end of the 2013, 1-1/2 years after the nuclear incident, the number of death due to evacuation exceeded the total number of tsunami victims in Fukushima prefecture. So, the mortality due to evacuation was higher than the direct death of tsunami in Fukushima.

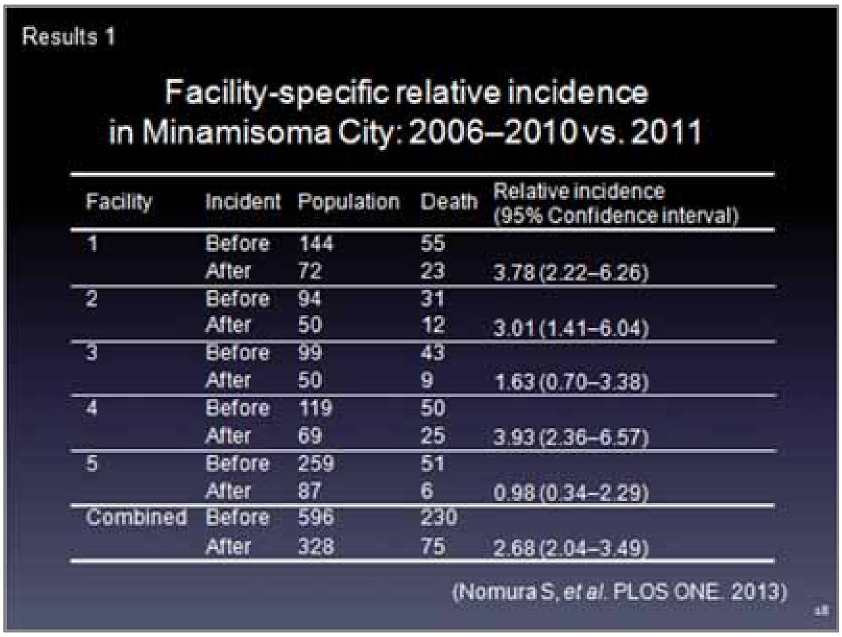
I am going to introduce my research work in more details. So, my study site, Minamisoma city and Soma city, and in total seven nursing homes participated in our study. Importantly, all the facilities in Minamisoma city evacuated after the incident; on the other hand, facilities in Soma city did not. So, this situation enabled us to conduct comparative analysis between evacuees versus non-evacuees in order to assess the mortality risk associated with evacuations.

It should be noted that after the nuclear incident in Fukushima, evacuation was not avoidable for the nursing home resident in Minamisoma city because of extreme anxiety about radiation exposure, lack of reliable information on radiation level and also they lacked human resource, medical supply, food stuff, and lots of resources.



I would like to repeat that the objective of this study was to evaluate the mortality associated with evacuation and the risk factors that affected the mortality increase. What we have to learn from this incident is how to reduce the potential increase of mortality associated with evacuation. Lessons learned from this incident can be applied to any type of disasters which will require evacuation of elderly population in the future.

This is the first result showing the relative risk of mortality after the incident in Minamisoma city by facilities that evacuated, so all of the facilities in this table evacuated after the incident. The main point is that the overall relative risk after the evacuation was 2.68. Another point is that there are huge variations of the increased mortality after the evacuation between facilities ranging from 0.98 to 3.93. And two facilities, facility 3 and 5, statistically did not increase the mortality even after the evacuation.


Results 1

Facility-specific relative incidence in Minamisoma City: 2006–2010 vs. 2011

Facility	Incident	Population	Death	Relative incidence (95% Confidence interval)
1	Before	144	55	
	After	72	23	3.78 (2.22–6.26)
2	Before	94	31	
	After	50	12	3.01 (1.41–6.04)
3	Before	99	43	
	After	50	9	1.63 (0.70–3.38)
4	Before	119	50	
	After	69	25	3.93 (2.36–6.57)
5	Before	259	51	
	After	87	6	0.98 (0.34–2.29)
Combined	Before	596	230	
	After	328	75	2.68 (2.04–3.49)

(Nomura S, *et al.* PLOS ONE. 2013)

This result may indicate that the mortality associ ated with evacuation highly depends on facility-specific evacuation procedures. This is the analysis that evaluated the effect of evacuation distance and evacuation number on the mortality. After the incident, many people evacuated several times like the first evacuation from the original facility to the evacuation site and second evacuation from there to another evacuation site. And by doing so, they were moving away from the nuclear power plant and looking for the facility best suited for them.

The point of this result is that initial evacuation from the original facility had about two times mortality risk of subsequent evacuations. Another point is that evacuation distance had no statistically significant impact on mortality. This result indicates that regardless of evacuation distance, many people died after the initial evacuation. Those who survived the initial evacuation could also survive the subsequent evacuations.

Then this is the analysis that incorporated the data of Soma city which did not conduct evacuation. So this is a comparative analysis between evacuees versus non-evacuees. The point is that in comparison with non-evacuation, initial evacuation from the original facility had about 3.4 times mortality risk, which is huge impact on mortality.

So this is the brief summary of evacuation study. First of all, I found a substantial increase of mortality after the evacuation and there are huge variations of the increased risk between facilities, which may indicate that the mortality associated with evacuation highly depends on each facility's specific evacuation procedures.

Results 2

Associations between evacuation distance/type and the post-incident mortality in Minamisoma City

Variable	Hazard ratio (95% Confidence interval)	P-value
Evacuation distance (km)		
less than 150	Ref	
150 to 300	1.01 (0.35–2.91)	0.99
more than 300	0.92 (0.41–2.07)	0.85
Evacuation type		
Initial	1.94 (1.07–3.49)	<0.05
Subsequent	Ref	

Adjusted for facility, sex, age, and care level in cox regression model

(Nomura S, *et al.* PLOS ONE 2013)

Results 3

Comparison of the post-incident mortality between evacuees and non-evacuees

Variable	Hazard ratio (95% Confidence interval)	P-value
Evacuation type		
None	Ref	
Initial	3.37 (1.66–6.81)	<0.01
Subsequent	1.93 (0.90–4.14)	0.09

Adjusted for sex, age, and care level in cox regression model

(Nomura S, *et al.* Preventive Medicine. 2015)

Summary

- Following the Fukushima incident, initial evacuation (vs. non-evacuation) had a substantial impact on mortality.
- Second and subsequent evacuations, which were more likely to have been pre-planned and carefully executed, did not show a significant impact on mortality risk.
- Current disaster plans for elderly care facilities do not necessarily meet the challenges of mass-displacement disasters
- Relevant authorities should support care facilities so that, during/following a disaster residents can shelter in place for at least sufficient time to adequately prepare initial evacuation.

(Nomura S, *et al.* Preventive Medicine. 2015)

Also, we found that initial evacuation from the original facility had a huge impact on mortality while subsequent evacuation has less impact, which may indicate the importance of well-preparedness of initial evacuation.

For example in Minamisoma city, as I mentioned, the facilities in Minamisoma evacuated because of anxiety about exposure to radiation, lack of resources, human, food, and other resources. And also, they could not prepare for proper transportation means like the vehicles for disabled persons. They had to use general vehicle for their resident which might impose huge burden in the elderly. Then as a result some facilities increased mortality after the evacuations.

On the other hand, the facilities in Soma did not conduct evacuations because they fortunately received external support from like NGO or distant facilities and then they did not have to conduct the evacuations. Then they did not increase the mortality after the incident.

The lesson is that evacuation may not be the best life-saving strategy for elderly people. But, you know, when evacuation is necessary, which can be happening any type of disasters, in order to avoid evacuation burden, especially the burden of the initial evacuation, arrangement of any evacuation procedures such as well-preparedness of evacuation site or proper transportation means are quite important, which critically determines the survival of elderly population.

Finally, I think that relevant authorities need to help and support the affected facilities in emergency time. In Japanese guidelines for emergency response, medical facilities are supposed to conduct evacuation themselves. But in emergency time the facilities will not be capable to prepare for and to implement evacuation themselves. They definitely need support.

If you are interested in our study or need more information about this topic, you can check this article which is already published. I have some brief summary written in Japanese. So if you need Japanese version, please let me know so and another article related to the study.

Let's move to the next topic, chronic health risk. So the health impact of evacuation is not limited to mortality of course. Evacuation has powerful influence on individual vulnerability to psychological stress or changes in socioeconomic status and thus on people's health, and Fukushima incident is no exception. Some research suggested elevated value for metabolic markers like BMI or blood pressure, particularly in evacuees and in the acute phase of the incident.

However, the long-term health consequences of evacuations are not clear because of difficulty of data collection or other reasons. So, the risks in the chronic health in long-term perspective at this present moment were unclear. However, the Soma city and Minamisoma city initiated evaluation of this chronic health risk in long-term perspective. Data was collected from the annual health checkup from 2008 to 2014 and we targeted diabetes and hyperlipidemia and hypertension.

First of all, in the analysis we classified the participants into evacuees and non-evacuees based on their home address at the time of the incident. So in this figure, the area colored in blue, yellow, and green were mandatory evacuation area after the incident. If the participants were living in these areas, they were regarded as evacuees.

Then I compared the disease risk between before and after the incident in order to see how much disease risk increased after the incident. And then that relative risk before and after the incident was compared between evacuees versus non-evacuees. This is the result of the relative risk of the diseases before and after the incident by evacuation status. The left is for evacuees and the right is for the non-evacuees. I apologize for the very busy table.

So in summary, increased risk of diseases was identified in diabetes and hyperlipidemia after 2013, 2 years after the incident. On the other hand, the hypertension did not increase the risk after the incident. This maybe indicates that hypertension was relatively easy to control even in the disaster setting just using a medicine.

When comparing these relative risks between evacuees versus non-evacuees, the significant difference was identified in only hyperlipidemia. So, this result indicates that the increased risk of hyperlipidemia after the incident was greater among evacuees than among non-evacuees.

A major disaster often social disruption through mass evacuation or changes in socioeconomic status which may result in reduced physical exercise, decreased access to medical care, and thus they have a powerful influence on human health.

In conclusion, my study also demonstrated that disaster impact may persist in long term with regard to particularly diabetes and hyperlipidemia. And also, evacuation has powerful influence on the risk in long-term perspective. So, all the disaster-related stakeholders including medical community should pay more

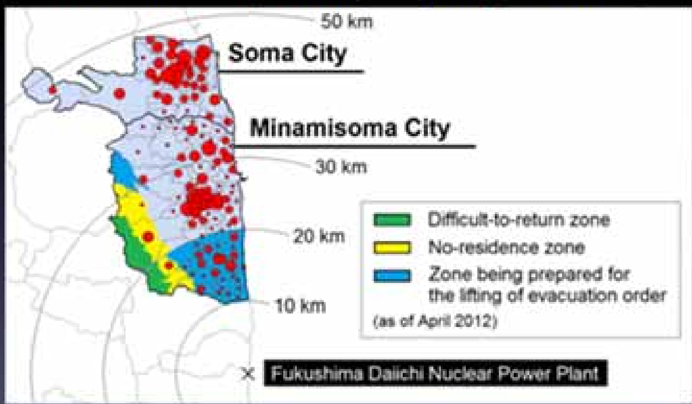
Methods 1

- Data source: annual public health check-ups (available only for those aged 40–74 years)
  - physical examination
  - blood sample test
  - self-report medical history and lifestyle survey
- Study period: 2008–2010 (pre-incident) and 20012–2014 (post-incident)
- Target diseases*:
  - diabetes
  - hyperlipidemia
  - hypertension

* based on the clinical guidelines for disease diagnosis or self-reported medication use

Methods 2

- Subgroup classification
  - Evacuees
  - Non-evacuees (including temporary evacuees)



The red circles show the geographical distribution of the health check-up participants in 2010, where the circles are proportional to the number of subjects living in each district

Results 1

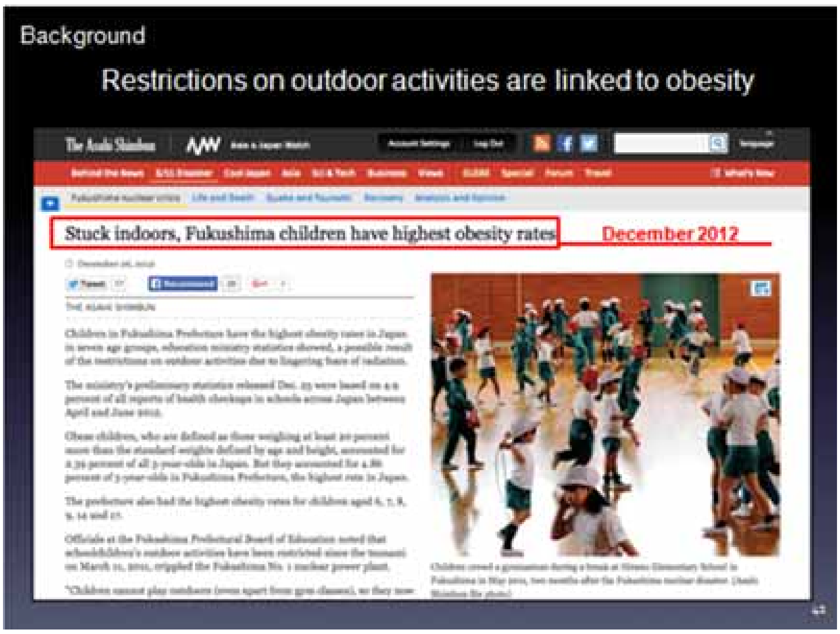
Pre- and post-incident relative risk of the diseases (versus baseline: 2008–2010)

	Evacuees (95% CI)	Non-evacuees (95% CI)
Diabetes		
2011	1.12 (0.70–1.79)	0.94 (0.81–1.10)
2012	1.21 (0.88–1.67)	1.11 (0.97–1.27)
2013	1.55 (1.15–2.09)**	1.33 (1.17–1.52)***
2014	1.60 (1.18–2.16)**	1.27 (1.11–1.45)***
Hyperlipidemia		
2011	1.10 (0.94–1.27)	1.00 (0.95–1.05)
2012	1.16 (1.05–1.29)**	1.03 (0.98–1.08)
2013	1.30 (1.18–1.43)***	1.12 (1.07–1.17)***
2014	1.20 (1.08–1.32)**	1.14 (1.09–1.20)**
Hypertension		
2011	1.05 (0.91–1.21)	1.05 (1.01–1.10)
2012	1.04 (0.94–1.14)	1.03 (0.99–1.07)
2013	1.10 (1.00–1.21)*	1.01 (0.97–1.05)
2014	0.94 (0.85–1.05)	0.95 (0.91–0.99)*

* p<0.05, ** p<0.01, and *** p<0.001 for given year versus baseline (2008–2010), adjusted for age

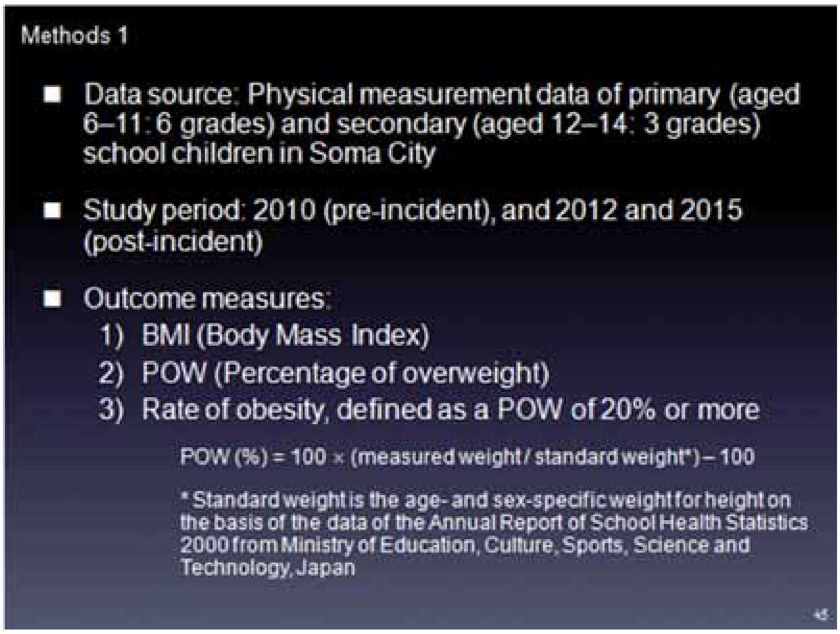
(Nomura S, *et al.* BMJ Open. 2016)

attention to the chronic health control in long-term perspective and even at this present moment.
If you want more information, you can check this article which is already published. I also have a Japanese version. If you need that kind of version, you can ask me.



Finally, I will quickly introduce a new study of Soma city which is about obesity in school children after the Fukushima incident. This is not an evacuation study but there are some increasing concerns about this topic. So then I am going to speak a bit on this topic today.

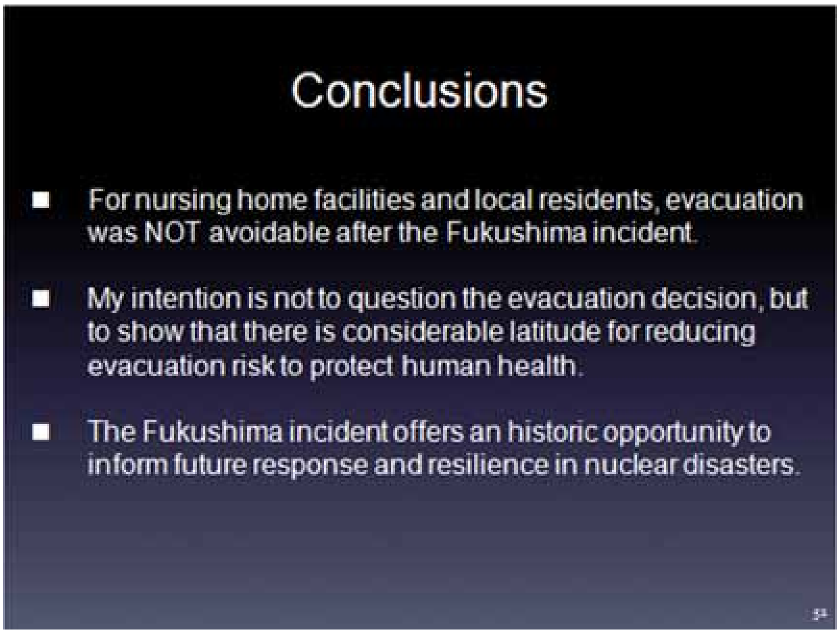
As many speakers already mentioned earlier, one of the major public concerns after the Fukushima nuclear incident is the radiation exposure in the children. And many people like many parents and many schools teachers, they were worried about particularly their outdoor activities. And as a response to the incident, many schools in Fukushima prefecture including Soma city and Minamisoma city imposed restriction on the outdoor activities by cutting or shortening physical exercise classes. However, as a result of these restrictions, another concern has raised in Fukushima which is that obesity level in school children might increase in Fukushima.



Then in order to answer this concern, Soma City is going to evaluate the obesity level in the school children in the city by comparing the obesity level before and after the incident. As you may know, in Japan – every school in Japan measured the physical status of the school children almost every year and Soma city also conducted the measurement in 2010, 2012, and 2015 and we are going to use this data.

We set three health outcomes as an indicator for obesity level: the BMI, the percentage of overweight, and obesity rate. The definitions are a little bit too technical, so I want to skip this. But the BMI is popular and maybe easy to understand.

The analysis will be undertaken soon. I think this is the old version. This is not what I sent. Briefly, you can say that this is BMI. This is percentage of overweight and this is obesity rate. As you might see, the significant difference was not observed. There is only small shift in BMI, percentage overweight, and obesity rate. Statistically, these are not significant. So based on this data, we might be able to say that in Soma city the restrictions on the outdoor activities did no t much affect the obesity level in school children. But at the next step, we are going to evaluate this data in more detail and will release the result to the public as soon as possible.



So this is the final slide. So regarding evacuation and health risks, I would like to repeat that after the Fukushima nuclear incident, evacuation was not avoidable for the nursing home resident and the local people because of anxiety about exposure to radiation. They also lacked reliable information on exposure level. They lacked human resource, food, and medical supply.

What we have to learn from this Fukushima incident is how we can reduce the evacuation-related health risks. The lesson learned from this incident would be used for any types of disaster, will inform the future disaster planning all over the world beyond Fukushima, beyond Japan. Also, these lessons will be used for the health measurement for the local people at this present moment.

Thank you very much all the people who made a huge contribution to our study and those who organized this super-symposium. I really appreciate you. Thank you very much.

Empowering the young - radiation protection in Fukushima -

Ryugo Hayano Professor, Department of Physics, University of Tokyo

Thank you very much, Mr. Chairman. Because this symposium is about children, I chose to speak with this title, How to Empower the Young Generation of Fukushima in Terms of Radiation Protection?

I started to think about this 2 years ago when I took three students from Fukushima High School to Geneva. There is a laboratory called CERN. That's the world's largest particle accelerator laboratory which hosted a radiation protection workshop for high school students. There were about 200 students including the three from Fukushima High School. These three students gave very wonderful presentation about the status of Fukushima. One of these students in fact is Mr. Oikawa, the son of our chairman.

Well, after the presentation they were surrounded by all the audience, the French and German students. They all asked these Fukushima High School students 'Are you really from Fukushima?' 'We thought after the accident it is not possible anymore to live in Fukushima.' That was quite a shock to me and also to the students. So we thought we have to do something about it.

Well, in fact the CERN is where I work. I am a physicist. But the reason I am here today is because of my Twitter account. I started to tweet about the Fukushima accident after March 11th and the number of my Twitter followers increased from 3000 to more than 150,000 within a few days. That had many side-effects including the fact that I got connected to medical doctors in Fukushima including Dr. Tsubokura.

So, our collaboration started and the collaboration is about the assessment of the internal exposure risks of Fukushima people, which after some time resulted in the paper.
This machine is called the whole-body counter. There wasn't any such device (in Fukushima) immediately after the accident. Now there are more than 50 such devices around Fukushima. Typically, you stand in this box for 2 minutes. This is heavily shielded. From the end of 2011, we started to measure Fukushima people using such

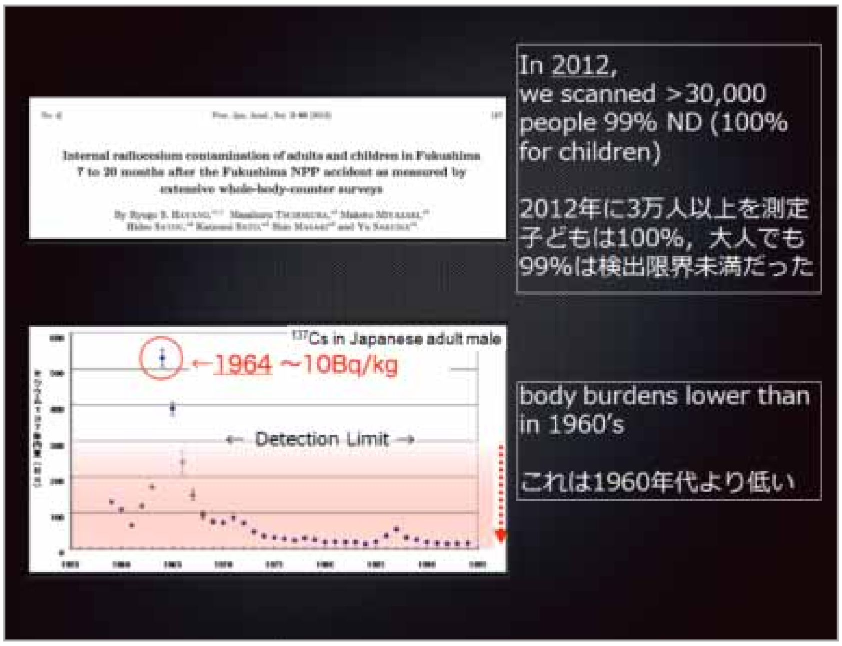
devices. And during 2012 we together measured more than 30,000 people.

Surprisingly, 100% of children were below the detection limit; and even for adults, 99% were below the detection limit as of 2012. For me this was my first medical paper that I authored.

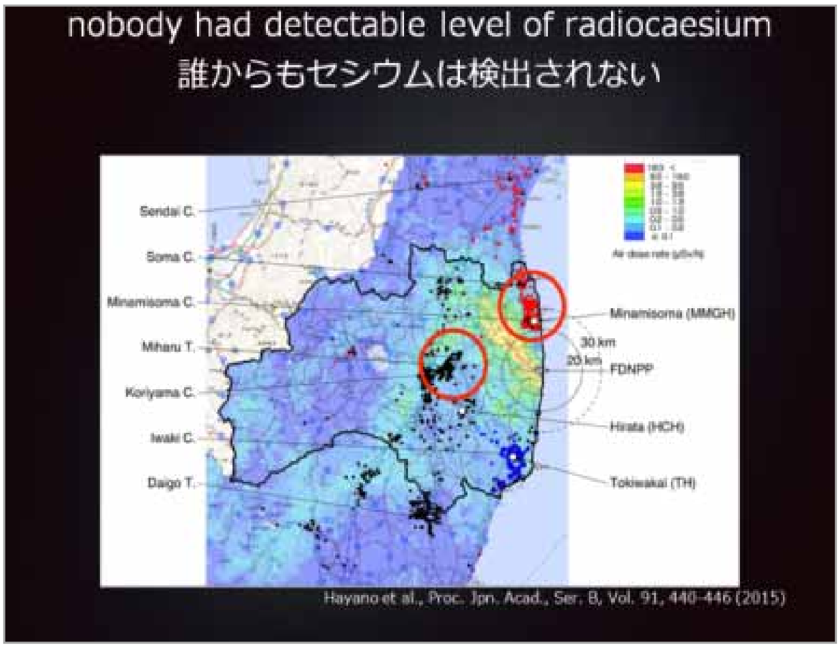
Well, the detection limit of the whole-body counter that we used is about 300 becquerel (Bq) per body. This is the detection limit, and almost everybody were below this limit. In 1964, as Dr. Tsubokura already explained, average Japanese adult male had about nearly 600 Bq in the body as a result of global fallout, that's about A-bomb and H-bomb test.

So already in 2012, the majority of Fukushima people were below this level. However, many people, especially parents, were still unconvinced and especially the most frequently asked question was 'How about our children?'. Remember, the whole body counter that I showed, you have to stand for 2 minutes and the geometry was optimized for measuring the radiation workers at the nuclear facilities of course. So it was impossible to measure small children who cannot stand.

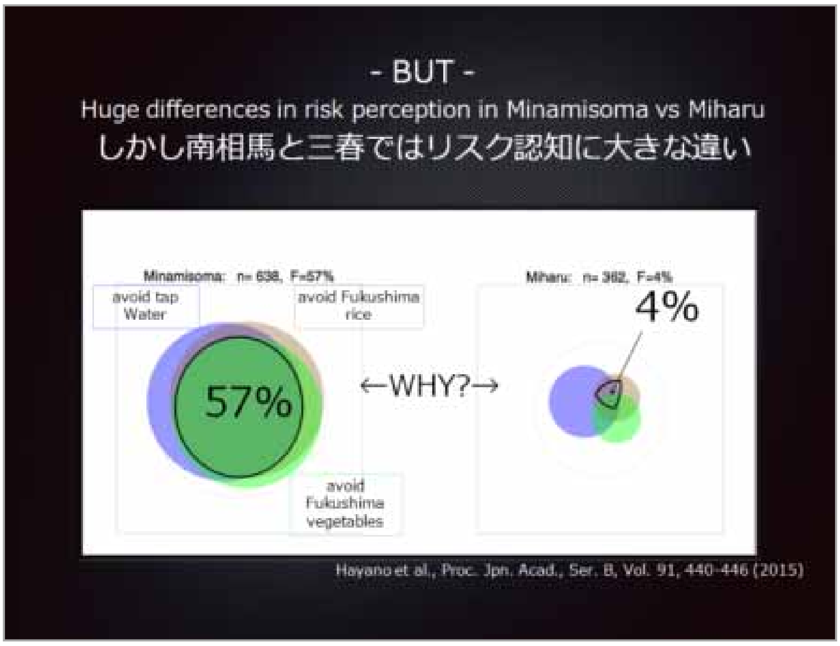
So we stated a project to make a baby scan. It's the special device for measuring small children. But this is not just a measurement tool - Well, it is a very good measurement tool. The detection limit is now below say 30 Bq per body instead of 300. This is about 10 times more sensitive - But this is a communication tool. The parents come to the hospitals to have their children measured and it is a wonderful timing for doctors like Dr. Tsubokura to talk to or listen to those parents. So this is why we made this.



It has a hyper-adjustable belt and the mother comes with the children and the mother can watch the baby and the baby can watch the mother. The scan is done in about 4 minutes or so. So, the first unit was installed near Koriyama city at the end of 2013 and the second unit in the spring of 2014 in Iwaki, then the third unit in Minamisoma in the summer of 2014.



So far we have measured about more than 5,000 babies and we haven't found anybody who had detectable level of cesium. This shows the distribution of where those babies came from, so some of them actually came from around Sendai. Well, this is good news but this is not the end of the story.



I now compare the situation of Minamisoma and a town of Miharu which is about 40 to 50 km to the west of Fukushima Daiichi Nuclear Power Plant. As Dr. Tsubokura has already explained, we asked the parents to fill out the questionnaire before taking the test. We asked about the evacuation situation, situation of their food, water and so on. And this is what we found.

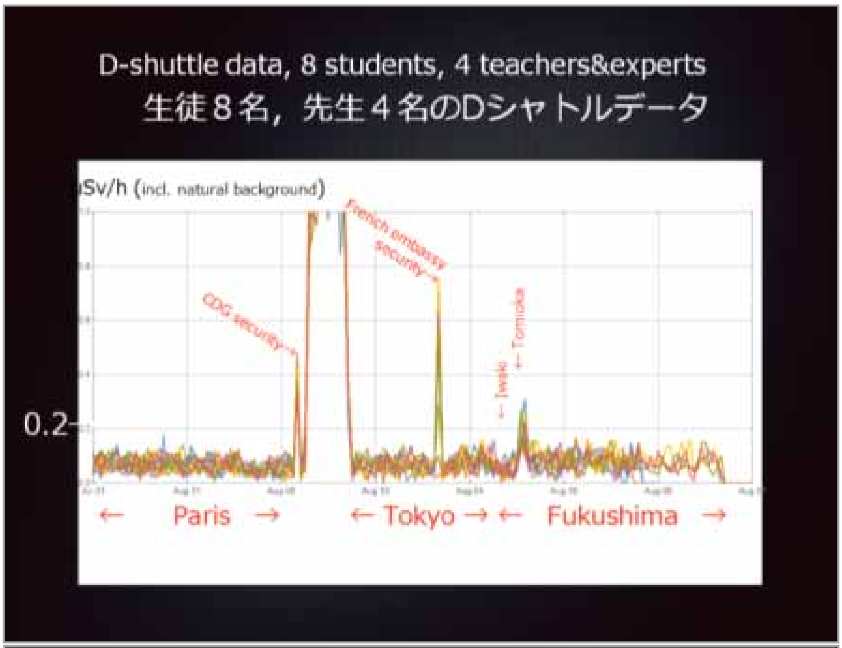
The area of the circle is drawn in proportion to the number of people. So in Minamisoma, the majority of people said that they avoid tap water. This was already discussed by Mayor Sakurai yesterday. A large fraction also say they never eat local rice. And again, a large fraction of people said they avoid Fukushima vegetables. And in fact, about 60% of them avoid all three. That's the situation in Minamisoma.

But the situation is quite different in the town of Miharu. Only 4% avoid water and rice and vegetables. Well, if you understand why, please tell me. I don't quite understand. I have some theories but I cannot prove this. But it is important to understand why there is such a large difference in risk perception among the parents at Minamisoma or the Soso area and other places in Fukushima.

Let me now switch to external exposures. Already in the fall of 2011, many municipalities started to distribute this person dosimeters, usually called the glass badges, initially to children and to pregnant women. This is the compilation of the first year measurement from Fukushima city, Minamisoma city, and Soma city. Already in the first year nobody exceeded 10 mSv per year.

One mSv per year is the long-term goal set by the Japanese government, and in 2011 about 50% of the children were already below 1 mSv per year, and that number increased for instance in Fukushima city to more than 96% in 2014. So, external exposure is lower than what most people think and have steadily decreased over time. But in fact, it is higher than the internal exposure level, because internal exposure is almost negligible.

Well, the glass badge is a common method used by almost all the municipalities. But you just get one number printed on a piece of paper after 3 months of measurement, which is not so informative. You cannot really correlate this one number to your behavior. So, I started to use the device called D-shuttle which is the electronic dosimeter with which you can measure and record the person dose every hour with a time stamp.



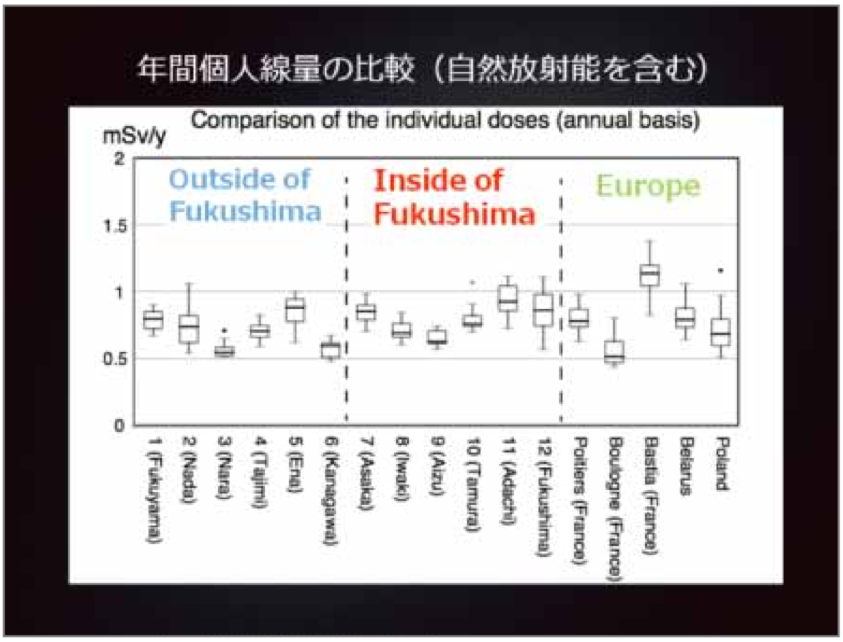
Let me show you an example how this device can be used. We sent these units to France last summer and French students came to Fukushima with this D-shuttle in the summer of 2015. This is the result. There are eight students and four teachers, 12 people in total came to Fukushima and this is an overlay of the 12 D-shuttle readouts. Then there is this tiny peak while they were still in Paris. They went to the airport and the dosimeter was X-rayed. That's this tiny peak.

As you may all know, during flight, due to the cosmic ray radiation, the radiation level is very high. It overshoots. Then they came to Tokyo and then there was a peak while they were still in Tokyo. Why? We all got invited by the French embassy downtown Tokyo and we have to go through the security gate. The dosimeter was again X-rayed. And the next day we all got on the bus and drove to Iwaki. Then you notice there is a peak. Why? French students wanted to see the effect of tsunami. So we proposed to take them to Tomioka station which was devastated by the tsunami. And this is 10 km south of Fukushima Daiichi and you are still not allowed to live there. This picture was taken in front of the Tomioka station. And as you may realize that each student has a nametag and the dosimeter.

And during this time the students stayed at Fukushima. They went to Kunimi on the last day. Kunimi is the northern part of the Fukushima which is famous for peaches. So we visited the peach farmers and they told us about the hardships they have had, the difficulty of selling the peaches and so on. And we picked and enjoyed eating the beautiful peaches and then at the end we picked the peaches and went back to Fukushima High School and measured the peach and confirmed that the peach doesn't contain radioactive cesium.

Well, anyway, as you would all agree, this is measured using the same dosimeter worn by the same people over about 1 week. There is not much difference between Paris, Tokyo, and Fukushima. So as you can see, this Deshuttle is very powerful device and Fukushima High School students were motivated to use this device to better understand their environment by themselves.

So, we launched a project to measure the personal dose of high-school students and compare the doses at different parts of Fukushima, other parts of Japan, and other parts of the ward. Then we recently managed to publish a research paper together. The project actually started in the summer of 2014. We invited our collaborators, the high-school students from other parts of Japan, and then we had the first kickoff meeting at Fukushima High School.



On that day, the last day of our workshop held at Fukushima High School, this picture was taken inside of the classroom of Fukushima High School. These students were attending this workshop. This is the cover of one of the best-selling books about the Fukushima accident which I authored together with Mr. Itoi and more than 100,000 copies have been sold so far.

Anyway, we then sent the dosimeters to France, to Poland, and to Belarus and they came back to Fukushima High School end of 2014 and then the data were again analyzed by Fukushima High School students. This is what we managed to publish end of November last year. Most of these 233 coauthors are high school students from Japan, from France, Poland, and Belarus. In the 5 months since we published this paper, this paper has been downloaded more than 60,000 times. Amazing!

We compared the high-school students attending six schools in Fukushima, six schools outside of Fukushima, three regions in France, many regions in Poland, Brahin, and Gomel. Brahin actually is very close to Chernobyl Nuclear Power Plant.

And This is the result. We estimated annual exposure based on our 2-week measurement and this is the comparison of individual doses including the natural background radiation. Then actually the highest median was found in France. Bastia, on Corsica Island was higher than in Fukushima.

Since our mission was to communicate this to the world, I took one of the coauthors, Ms. Onodera to the Foreign Correspondence Club of Japan on February 2016 and we gave the press conference and that may have contributed to some extent to this large number of downloads of our paper.
Here are conclusions. Well, internal exposure is negligibly low in Fukushima. I can repeat this and Tsubokura-sensei already repeated this. External exposure, at least in the region where we live, external exposure is not higher than in other parts of the world.

It is very important to empower young people in Fukushima by having them actively involved in understanding and communicating the radiological situation of Fukushima. It is important for them to avoid unnecessary prejudice, discrimination, and so on. This is something that we have to continue doing. Thank you very much.