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What have we learned from a questionnaire survey of citizens and doctors both inside and outside Fukushima?: survey comparison between 2011 and 2013

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Abstract
The disaster at the Fukushima Daiichi Nuclear Power Plant (FDNPP) remains unresolved because the estimated time to decommission a nuclear reactor appears to be approximately 40 years. The number of workers exposed to radiation doses ranging from 1 to 100 mSv continues to increase. To understand the accident progression at Fukushima and to anticipate what we should do in the future for occupational and environmental health, we performed a survey of citizens and doctors who lived inside and outside Fukushima in 2011 and 2013. In a comparison of these 2 years, the citizens inside Fukushima continue to suffer anxiety, although those living outside Fukushima tended to feel less anxious. Medical students who had recently studied radiation biology showed much less ongoing anxiety compared with other groups, suggesting that learning about the effects of radiation is essential to understanding one’s own circumstances objectively and correctly. The lack of trust in the government...
and in the Tokyo Electric Power Company (TEPCO) in 2013 remains high in all groups. Therefore, long-term forthright explanations from the government, TEPCO, and radiation experts are indispensable not only to establish trust with people but also to alleviate psychological stress.

Keywords: Fukushima Daiichi Nuclear Power Plant, questionnaire survey, Tokyo Electric Power Company and Japanese Government

(Some figures may appear in colour only in the online journal)

1. Introduction

In 11 March 2011, the large Tsunami resulting from the Tohoku earthquake caused an unexpected disaster that impacted not only Japan but the entire world.

Based on the accidental scale data, the Chernobyl accident released ~14 EBq of total radioactivity into the environment in 1986. Estimations of the total radioactivity released by the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident in 2011 were between 340 and 800PBq, with 80% falling into the Pacific Ocean (Wakeford 2011a, 2011b, Steinhauser et al 2014). These estimates suggest that the scale of the FDNPP was 2.4–5.7% of the scale of the Chernobyl accident. In the FDNPP, two control room operators received the highest doses a calculated internal and external dose of 0.678 and 0.643 Sv. Approximately 100 workers had received doses of greater than 0.1 Sv until end of March 2011 (INPO 2011). On the other hand, in Chernobyl accident, the recorded worker doses varied from less than 10 mSv to more than 1000 mSv, although about 85% of the recorded doses were in the range 20–500 mSv. Moreover, 0.1% (219 workers) of recovery operation workers having recorded average dose was 7.5 Gy (UNSCEAR 2008, Annex D). Note that the Chernobyl accident report used Gy for convenient and it is assumed that the recorded dose in Gy is numerically equal to the effective dose in Sv. Based on these results, the biological effects of the FDNPP accident seem unlikely to be similar to those of the Chernobyl accident. Nonetheless, differing information from government announcements, the mass media, the internet, and radiation experts have confused the citizens inside Fukushima and resulted in distrust of these sources of information (Sakai 2012). This distrust may cause unnecessary anxiety about the biological effects of radiation. Well-trained doctors who specialise in radiation biology can provide psychological support for citizens at their hospitals. Despite this situation, the number of Radiation Biology education laboratories at medical universities in Japan is declining, and there are now only 8 laboratories at 80 medical universities. In the present study, we surveyed citizens and doctors inside and outside Fukushima in 2011 and 2013 to elucidate the precise situation in Fukushima and to determine what we should do in the future for the needs of both citizens and doctors inside Fukushima.

2. Materials and methods

A survey was conducted using a de-identified document for privacy reasons. In 2013, we received permission through a local medical association in advance to conduct this survey consequent to a radiation related lecture for medical doctors outside Fukushima (23% from Ehime on 1 September 2013; 63% from Fukuoka on 28 August 2013; and 13% from other places, mainly from Tokyo on 4 August 2013). For citizens outside Fukushima (28% from the Kanto area around Tokyo on 4 August 2013 and 72% from Fukuoka on 28 August 2013), surveys were conducted using a de-identified document consequent to radiation-related lectures in Tokyo and the Fukuoka prefectures (figure 1). For doctors and citizens in Koriyama
in Fukushima prefecture, the Fukushima paediatric association called for their participation to our survey from August to November 2013. The survey list of questions is shown in Table 1.

In 2011, surveys were conducted consequent to a radiation related lectures in Koriyama in Fukushima prefecture for doctors on 16 September 2011 and citizens on 17 September 2011, Sagamihara for citizens and doctors on 29 November 2011, Oita for doctors on 26 October 2011. For doctors in Kitakyushu, doctors and citizens in Fukushima, we asked for their participation to our survey from September to November 2011 as previously published (Okazaki et al. 2012). For medical students, we conducted the survey just after an examination of ‘Radiation Biology and Health’ on September 2011 and on September 2013. Note that the survey questions were identical in 2011 and 2013 except question #8. In question #8, there were only three choices: (a) Satisfied, (b) Slightly satisfied, and (c) Dissatisfied, for this question in 2011. On the contrary in 2013, we divided the choices into five options: (a) Satisfied, (b) Slightly satisfied, (c) Dissatisfied, (d) Strongly dissatisfied, and (e) Unknown for the better understanding of responders. Therefore, there is no parenthesis in (e) Unknown. Based on our survey results in 2013, the % of (c) Dissatisfied and (d) Strongly dissatisfied were almost equal in all categories. Hence, we decided to combine (c) Dissatisfied and (d) Strongly dissatisfied and considered them as ‘Dissatisfied’ to compare with 2011. The total numbers of responders to the surveys are shown in Table 2. This research was approved by the Ethics Committee at the Occupational and Environmental Health University (H23-098 and H25-082).
3. Results

3.1. Response rates (Q. #1–Q. #4)

The response rates of citizens and doctors outside Fukushima were 61% and 70%, respectively. The average ages of the responders are shown in Table 2. Advance notification of the
radiation-related lectures through the paediatric society in Fukushima resulted in a notable number of young female responders in Fukushima both in 2011 and 2013. These results are consistent with a previous report in 2011 (Okazaki et al 2012). The reduced number of participants in citizens inside Fukushima in 2013 compared to 2011 is remarkable. One of the reasons may be a lack of interest. Alternatively, we conducted survey consists with thirteen questions and this may be a burden to some citizens who have less concern during these 2 years.

3.2. Age and sex of responders' children (Q. #4 and Q. #5)

Regarding the sex of the responders’ children, there was no significant difference in the numbers of boys and girls, as shown previously (data not shown; Okazaki et al 2012). Many female responders with children in Fukushima were relatively young, and more than 73% of the children of the citizen responders in Fukushima were less than 12 years of age. However, only 22%, 17% and 24% of the children of the doctors inside Fukushima, of citizens outside Fukushima, and of doctors outside Fukushima, were less than 12 years of age, respectively. We obtained similar results in 2011 (Okazaki et al 2012).

3.3. Anxiety about the effects of radiation after the FDNPP accident (Q. #6)

Significant changes were observed in the response to this question in three groups following. The 1st group; (a) No anxiety and (b) slight anxiety changed from 27 to 53% in citizens inside Fukushima (figure 2(a)). The 2nd group; (a) No anxiety changed from 8 and 37% in citizens outside Fukushima (figure 2(b)). The 3rd group; (a) No anxiety changed from 21 to 40% in doctors inside Fukushima (figure 2(c)). On the contrary, there was no significant difference between 2011 and 2013 in doctors outside Fukushima (figure 2(d)). Similarly, no significant difference was observed in medical students (figure 2(e)). These results may be explained by the present relatively stable situation at the FDNPP thanks to thousands of occupationally exposed workers who are repairing and preparing the nuclear reactor for decommissioning (Tsuji et al 2013). Alternatively, some worried citizens and doctors inside Fukushima already had left Fukushima between 2011 and 2013, which consequently results in those remaining indicating less anxiety.

3.4. Anxiety factors in Q. #6 (Q. #7)

Higher anxiety ratios were observed for thyroid cancer, cancer, the next generation, food contamination, and soil contamination in all groups except in medical students, who showed lower anxiety than other groups (figure 3). In the field of radiation biology, the ‘next generation effect’ means that genetic changes, such as mutations caused by radiation exposure in the 1st generation, can carry over to the 2nd generation. No clear next generation effect of

Table 2. Distribution of responders in 2013 (2011).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizens inside Fukushima</td>
<td>38.0 ± 10.0 (35.6 ± 6.9)</td>
<td>51 (117)</td>
<td>371 (842)</td>
</tr>
<tr>
<td>Citizens outside Fukushima</td>
<td>58.0 ± 10.0 (45.9 ± 12.8)</td>
<td>82 (22)</td>
<td>33 (30)</td>
</tr>
<tr>
<td>Doctors inside Fukushima</td>
<td>60.3 ± 10.6 (55.0 ± 8.6)</td>
<td>47 (43)</td>
<td>11 (9)</td>
</tr>
<tr>
<td>Doctors outside Fukushima</td>
<td>56.8 ± 10.9 (58.4 ± 11.1)</td>
<td>198 (318)</td>
<td>29 (70)</td>
</tr>
<tr>
<td>Medical students</td>
<td>21.0 ± 1.0 (21.3 ± 1.9)</td>
<td>75 (69)</td>
<td>33 (37)</td>
</tr>
</tbody>
</table>

* Data shows mean ± standard deviation.
radiation exposure is generally expected based on the research of the Atomic Bomb epidemiological survey (Neel et al 1990, Otake et al 1991). It appears likely that there is a high degree of anxiety about the next generation in all categories except medical students, stemming from confusing the ‘next genetic effect’ with ‘anxiety for their offspring in the future including health and the environment’. We will make a clear distinction between these differences in future surveys. The data from 2013 showed reduced anxiety compared with 2011 in citizens and doctors outside Fukushima with a few exceptions, such as anxiety over food contamination in doctors outside Fukushima (figure 3(d)). It is noteworthy that the percentage of anxiety factors in citizens inside Fukushima did not decrease significantly from 2011 (figure 3(a)), and an even higher percentage for health related issues such as thyroid cancer and the field contamination was observed by doctors inside Fukushima (figures 3(a) and (c)). Approximately 60–70% of the cancer related anxiety in citizens inside Fukushima is consistent with although much higher than the ~30% in citizens outside Fukushima (figures 3(a) and (b)). In addition, doctors inside Fukushima in 2013 were more anxious about health-related issues than in 2011 (figure 3(c)). These results clearly showed that the residents of Fukushima continue to feel anxiety about health related issues and the contamination of their environment.

3.5. Government or TEPCO responses to the nuclear power plant accident (Q. #8)
Overall, the percent of those dissatisfied with the government and Tokyo Electric Power Company (TEPCO) are in the majority (figures 4 and 5). There was an increase in those dissatisfied
(63 to 74% for the government, 67 to 77% for TEPCO) and a decrease in those slightly satisfied (32 to 19% for the government) or satisfied (16 to 0% for TEPCO) observed among citizens outside Fukushima (figures 4(b) and 5(b)). These data show that citizens outside Fukushima had less opportunity to recognise the situation directly and disapproved of the delayed reconstruction news from different media outlets. Among doctors inside Fukushima, there was a decrease in those dissatisfied (96 to 81%) and an increase in those slightly satisfied (0 to 16%) with the government response to the FDNPP (figure 4(c)). However, 4% slightly satisfied was replaced by 4% dissatisfied with TEPCO (figure 5(c)). These results indicate that doctors inside Fukushima tend to rely more on the government than on TEPCO, although a majority of doctors (80–90%) remained dissatisfied. The majority of people remained dissatisfied with the FDNPP accident news and information from the government and TEPCO. This result may be based on the delay in the disclosure of information about the accident from the beginning (Akiba 2012). Hence, continued faithful and rapid disclosure of information from the government and TEPCO will be essential not only for the Japanese people but also for the rest of the world.

3.6. Evacuation candidates and reason for not evacuating

3.6.1. Candidate evacuation areas (Q. #9).
All groups except doctors outside Fukushima showed an increased tendency not to evacuate and a decrease in evacuation both inside and outside of the prefecture in 2013 when compared
A marked increase in those ‘not evacuating’ was prominent for both citizens outside Fukushima and for medical students (figures 6(b) and (e)). This result was in marked contrast with citizens of Fukushima and doctors inside and outside Fukushima, in which there were no significant changes (figures 6(a), (c) and (d)). Notably, doctors outside Fukushima consistently preferred evacuating outside of the prefecture (figure 6(d)). It seems likely that doctors may have fewer economic challenges and that it was easier to evacuate when the disaster occurred. It should be noted that our survey was conducted 6 months after the FDNPP accident and some doctors inside Fukushima may already have evacuated during this period. However citizens inside Fukushima needed to trust their family doctors about health-related issues. To meet these expectations, some doctors who have a strong sense of responsibility decided to stay in their hometown, as was observed in the response of doctors inside Fukushima (figure 6(c)).

### Figure 4.
What do you think about the information provided by the Government about the FDNPP accident in 2013 (2011)? The pie chart shows the % of opinion on the information by the responders. Note that there were only three choices: (a) satisfied, (b) slightly satisfied, and (c) dissatisfied, for this question in 2011. In 2013, we divided the choices into five options: (a) satisfied, (b) slightly satisfied, (c) dissatisfied, (d) strongly dissatisfied, (e) unknown. Therefore, there is no parenthesis in (e) unknown. Based on our survey results in 2013, the % of (c) dissatisfied and (d) strongly dissatisfied were almost equal in all categories. Hence, we decided to combine (c) dissatisfied and (d) strongly dissatisfied and to consider them as ‘dissatisfied’ to compare with 2011. Numbers in parenthesis indicate % in 2011.

3.6.2. Reason for not evacuating (Q. #10).
All categories except citizens inside Fukushima considered safety as a reason for not evacuating, indicating that the citizens inside Fukushima were continuously worried about the...
radioactive contamination around them (figure 7). Moreover, citizens inside Fukushima felt they had fewer places to evacuate to and fewer evacuation possibilities because of economic concerns, reflecting the difficulties of practical matters (figure 7(a)). On the contrary, fewer concerns about options of places to evacuate to and economic issues were observed in citizens and doctors outside Fukushima (figures 7(b) and (d)). These results suggest that well-organised and continuous evacuation support will be required in the future.

3.7 Reliability of news from mass media (Q. #11)

A majority of people in all categories except medical students thought that the news from the mass media was slightly helpful in the FDNPP, although 20–30% of students felt that it was unhelpful or unpleasant (figure 8). The percentage of all of these factors did not change significantly, suggesting that the mass media was not sufficient to alter the impression in this population over the 2 year period.
3.8. Reliability of the source of information (Q. #12)

Compared with 2011, there were no significant changes in any of the groups (figure 9; Okazaki et al. 2012). Continued distrust of (a) government announcements, (c) announcements of TEPCO, (i) diet members; members of the Japanese bicameral legislature that are directly elected, and (j) local politicians were observed, especially in the citizens inside Fukushima in 2013 (figure 9(a)). Mass media information sources such as (b) local administrative announcements, (d) national network TV, (e) local network TV, (f) radio, (g) newspapers and (h) the internet were relatively reliable for all categories except medial students (figure 9(e)). The highest reliability was observed in (k) family doctors and (l) lectures by a radiation experts in all categories, suggesting that personalised communication with specific people was a more reliable way of forging a relationship of mutual trust than mass communication to the general public. There was noticeably less trust in lectures by a radiation expert by people inside Fukushima compared with people outside Fukushima (figures 9(a) and 9(b)). Note that we simply set category ‘radiation experts’ and people inside/ outside Fukushima may consider ‘radiation experts’ as ‘radiation experts in general’ rather than ‘radiation experts in physics, biology, and so on’. This result may stem from the confusion caused by the lack of uniformity in the various opinions of the radiation experts especially for the risks associated with low doses of radiation, which is technically difficult to evaluate at present (Murayama 2012).
3.9. Future expectations and radiation dose data disclosure by area

3.9.1. Future expectation (Q. #13).
All groups showed a higher expectation of radiation dose disclosures and a lower expectation of an administrative explanation both in 2011 and 2013 (figure 10). Deeply rooted distrust of the administration may continue to exist in the population. Citizens and doctors inside Fukushima showed a higher expectation of decontamination compared with citizens and doctors outside Fukushima, although doctors inside Fukushima showed less expectation in 2013 (figures 10(a) and (b); figures 10(c) and (d)). The citizens inside Fukushima continued to expect medical examinations (figure 10(a)). Citizens and doctors outside Fukushima had high expectations of an explanation by a radiology expert that was in marked contrast with citizens and doctors inside Fukushima (figures 10(a) and (b); figures 10(c) and (d)). It is possible that the lack of information uniformity about the radiation due to differing opinions of the radiation experts could have confused people inside Fukushima.

3.9.2. Expected radiation dose data disclosure by area (Q. #14).
In the areas for which disclosure was expected, all groups had the greatest expectations for areas around housing (figure 11). Citizens inside Fukushima continued to expect the disclosure of more data on the places close to their homes (the house, around the house, the school, and the school road) than public places, such as shopping areas or downtown (figure 11(a)). Doctors inside Fukushima were similarly disposed, although with reduced expectations for the areas closest to their homes (figure 11(c)). However, citizens and doctors outside Fukushima had high expectations for disclosure of more data on public places (figures 11(b) and (d)). Moreover, there was a significant decrease in all expectations in 2013 in citizens and doctors outside Fukushima and medical students compared with 2011 expectation levels.
These results indicate that citizens inside Fukushima continued to feel anxiety about environmental contamination close to their places of residence, which was in marked contrast with citizens outside Fukushima who tended to be less concerned in 2013 when compared with their 2011 levels of concern.

4. Discussion

Based on our survey, appropriate knowledge on radiation biology significantly helped decrease anxiety in medical students who had recently been informed by a radiation biology lecture (figures 2(e), 3(e) and 7(e)). A clear difference in anxiety existed between doctors inside and outside Fukushima primarily with regard to health-related issues, suggesting that doctors inside Fukushima had become familiar with the effects of radiation after the FDNPP accident as a way of providing support to their patients (figures 3(c) and (d)). The percentage of anxiety for thyroid cancer in doctors inside Fukushima 2013 was twice as high as that of 2011 (figure 3(c)). When we consider the fact that the Chernobyl accident induced a lot of thyroid cancer among children who had internal exposure to radioiodine through dietary intake, the survey for thyroid cancer among children inside Fukushima is indispensable (UNSCEAR 2008, 2014). In line with this, International Commission on Radiological Protection (ICRP 2009a) provided several aims and they emphasised that we should prevent stochastic biological effects and decrease deterministic biological effects as much as possible for the protection of people especially in emergency exposure situations (ICRP reports, 109).
Moreover, ICRP reports 111 mentioned the importance of ‘radiation monitoring’ and ‘health surveillance’ for the protection of people after nuclear accident (ICRP 2009c). Importantly, ‘Radiation monitoring’ and ‘Health surveillance’ were one of the highest interest for citizens inside Fukushima (figure 3). In fact, Fukushima Health Management Survey, which consists of a basic survey and detailed surveys such as thyroid ultrasound examination and mental health and lifestyle, was introduced from 2011 by Fukushima prefecture and Fukushima Medical University and is ongoing at present (Taniguchi et al 2013, Fukushima Radiation and Health). The median thyroid equivalent dose is estimated to be 4.2 mSv (at most 23 mSv) and 490 mSv for children in Fukushima accident and Chernobyl accident, respectively (Tokonami et al 2012). It therefore seems unlikely that the thyroid cancer among children in Fukushima will increase to be similar to those of Chernobyl accident, although a long-term survey with careful interpretation on thyroid cancer among children in Fukushima will be necessary. In conclusion, accurate information of local residents on the radiological situation and continuous monitoring are needed for enhancing understanding of people inside Fukushima.

As indicated by the reduced expectation of an explanation by a radiation expert in citizens inside Fukushima (figure 9(a)), a concordance of information based on the scientific evidence and understanding about the effects of radiation on humans is urgently needed. In the case of a radiation-induced cancer, two major reasons make it difficult to conclude to attribute a cancer caused by low dose of radiation (1–100 mSv) at present. First, there are no biomarkers available which can clearly distinguish between a radiation-induced cancers from a cancers induced by other factors. Second, the low dose of radiation effect on cancer risk is low compared to the variability of the background cancer incidence rate and it cannot be measured with state of the art statistical methods (Pierce and Preston 2000, Brenner et
Therefore, radiation expert views on the risks associated with low dose of radiation cause different opinions and conclusions. To overcome these difficulties, organising a conference with radiation experts with different opinions may help us to form a consensus to some extent; this would be essential for the people of Fukushima to objectively understand the situation and the biological effects of radiation. Actually, the International Expert Symposium in Fukushima, which was attended by experts from relevant international intergovernmental bodies including the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the World Health Organization (WHO), the International Atomic Energy Agency (IAEA), and non-governmental organisations including the ICRP, has been held three times until now to reach conclusions and recommendations (International Expert Symposium in Fukushima 2011). In addition, ICRP/OECD organised town-hall meetings during last 2 years become social conventions such as ‘ICRP Dialogue seminar’ that was started from Nov 2011 and has been held about three times per year. For the Mid-to-Long-Term Response for Decommissioning, ‘International Symposium on Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Plant Unit 1 to 4’ has hold in cooperation with IAEA and Organization for Economic Co-operation and Development/Nuclear Energy Agency (NEA/OECD) on 14 March 2012. These meetings are essential for updated epidemiological surveys and clear communications of the state to develop successful and innovative solutions for the future.

As some citizens and doctors noted in 2013, mass-media, such as TV and the internet, tended to exaggerate the original information. These complex circumstances may propagate the anxiety of people inside Fukushima. At the same time, people generally expect to be provided with information about the contamination around them, although there is
significant distrust of information from the current administration. In fact, the random distribution of radioactive materials in the field has made radiation dose disclosure difficult, especially for individual citizens at the local level (Yasunari et al. 2011, Grubich 2012). Therefore, individual dosimeters will be needed for each citizen of Fukushima to allow them to make their own decisions on how to best protect themselves. Basically, experiences from a lot of emergency situations gave us implementation of recommendations such as Iodine thyroid blocking, sheltering, evacuation, individual decontamination for the radiological protection and we should consider these recommendations as a first-line choice after nuclear accidents (ICRP 2009b, ANNEX B). Altogether, practical information on protection from nuclear accidents is indispensable for citizens inside Fukushima and early education of such practical information will be needed for young people in the future.

The declining tendency of anxiety in citizens outside Fukushima was observed within only 2 years after the FDNPP accident through this survey, although anxiety about unresolved issues is still high in the citizens of Fukushima. Although, long-term social and psychological support will be needed for some citizens inside Fukushima, citizens outside Fukushima may tend to take the FDNPP accident less seriously because there has been no direct influence on ordinary life for citizens outside Fukushima. Some women between the ages of 36 and 41 years who have children in Fukushima had made private comments in the last comment section such as, ‘Please do not easily forget the FDNPP disaster and continue to consider the best solutions for the decontamination and decommissioning of the nuclear reactor, which is estimated to take approximately 40 years’.

Figure 11. Expectation of local radiation dose data disclosure. Bar graph shows the % of expectation for each location out of the number of responders who chose (a) radiation dose data disclosure in Q #13.
5. Conclusion

This survey suggests that ongoing reporting and support from the government, TEPCO, and radiation experts are essential. To accomplish this, rapid explanations and transparency in direct information are essential. Interim explanations, while appearing necessary, may sometimes erode trust. Ongoing faithful explanations at a personalised level are essential for forging a relationship of mutual trust between citizens and the government/TEPCO. A good example in this survey is the family doctors of the citizens of Fukushima who play an important role in personally supporting patients. Radiation biology education, not only for medical students and doctors but also for citizens, will be needed to precisely and objectively evaluate information on the effects of radiation. When people can understand correctly and decide objectively for themselves on the situation around them, they will have less unnecessary anxiety. This individual attitude may help when natural disasters such as earthquakes, the eruption of volcanos, or tsunamis occur elsewhere without warning in the future.

Conflict of interest statement

None declared.

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