Lessons learned from Fukushima Nuclear Power Plant Accident; Limitation of public health emergency response and recovery

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• In response to any nuclear accident or disaster, medical & health experts/responders are expected to provide *rapid countermeasures at on-site and off-site*, consistent with approved guidelines, manuals, and action plans prepared in advance.

• Action plans and their implementation should comport with *international standards of radiation protection*, especially when addressing the potentially complicated and long-term health risks that may follow.

• However, difficulties with *crisis health risk communication* became apparent just after the Fukushima NPP accident, as radiation medical & health experts encountered an anxious public with insufficient knowledge of radiation and its risk, who were furthermore subjected to the ebb and flow of dubious information and conflicting value systems.
Scientific data collection and evaluation

Research on Radiation Effects
Radiation Safety

BEIR Recommendation

RERF

WHO/IARC
ILO
OECD/NEA

IAEA
Basic Standard Safety (BSS)

ICRP Recommendation

UNSCAR Report

Radiation Safety Standard

Administration of Radiation Safety

Information of radiation protection

Radiation Protection

Regulation Guidelines

Radiation Protection Culture
Dose dependent increase of radiation-induced thyroid cancer risk after exposure at younger age but high detection rate of latent and asymptomatic thyroid cancer by US examination.

External Exposure (effective dose)
- A-bomb survivors
- Marshall Islanders (fall-out)
- Children exposed to EBT

\[ \text{ERR/Gy} \approx 7.7 \ [1.1 \text{ – } 32] \]

Internal Exposure (equivalent dose)
- Therapeutic radioiodine
- Hanford (fall-out)
- Chernobyl

OR at 1 Gy \( \approx 5.5 \text{ – } 8.4 \ [\text{ERR/Gy} \ 1.9 \text{ – } 19] \)
From Chernobyl to Fukushima at the standpoint of radiation health risk management

- **Atomic Bomb survivors’ data** and radiation risk analysis with other exposure groups have proved the dose- and age-dependent cancer risk after external irradiation for all their life with unlimited latency **but no PTSD risk approaches before 1995**.

- **Chernobyl data** suggest a dramatic increase of childhood thyroid cancers associated by short-lived radioactive iodines by its internal exposure just after the accident and also a psychosocial impact.

- **Fukushima data** suggests the necessity of public health response and of improvement of radiation risk communication beyond the model of LNT.
Difference between Chernobyl and Fukushima

Similarity between Chernobyl and Fukushima

Information Disaster and Radiation Fear

Cesium 137, KBq/m²
- more than 1,480
- 185 to 1,480
- 40 to 185
- 10 to 40
- 2 to 10

Source: Philippe Rekacewicz, UNEP/GRID-Arendal
• The most important lesson learned from Chernobyl NPP accident is how to protect the public from unnecessary exposure of internal as well as external radiation, and also especially from the fear/anxiety/mistrust/anger of any possibility of increased risk of radiation-induced thyroid cancer.

• How to overcome the difficulty of understanding of LNT model for population/group risk depends on logical thinking way at the individual level but emotional reaction cannot be avoided.

• It is essentially needed to understand a stochastic effect of radiation and uncertainty of health effects interacting various confounding factors.
We have been concentrating on supporting;
① crisis communication at first and then
② post-crisis radiation risk communication, and now
③ comprehensive health risk management based on established regulatory sciences as well as the establishment and maintenance of emergency radiation medicine through the achievement of the Japanese Radiation Emergency Medicine (REM) Expert Network.

Re-establishment of Advanced REM Supporting Centers in Japan
Crisis communication started on 18th March 2011 in Fukushima Medical University

“Accept the disaster as inevitable,” "Dig in this situation"
Estimation of the Amount of Radionuclides Released from the Damaged Nuclear Power Plant

- Estimation by NSC based on the data of environmental monitoring and air diffusion (March 11 to April 5)
  \[ ^{131}\text{I} : 1.5 \times 10^{17}\text{Bq} \]
  \[ ^{137}\text{Cs} : 1.2 \times 10^{16}\text{Bq} \]

- Estimation by NISA and JNES based on the plant data immediately after the accident
  \[ ^{131}\text{I} : 1.6 \times 10^{17}\text{Bq} \]
  \[ ^{137}\text{Cs} : 1.5 \times 10^{16}\text{Bq} \]

(NSC: Nuclear Safety Commission)
(NISA: Nuclear and Industrial Safety Agency)
(JNES: Japan Nuclear Energy Safety Organization)
Ambient dose rate estimated from aerial survey

3rd monitoring map within 80 km from NPP 1F by MEXT (presented on 8 July 2011)

(\mu Sv/h)
19.0<
9.5 – 19.0
3.8 – 9.5
1.9 – 3.8
1.0 – 1.9
0.5 – 1.0
0.2 – 0.5
0.1 – 0.5
< 0.1
## Three targets of radiation-exposed

<table>
<thead>
<tr>
<th>Object</th>
<th>Situation</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant nuclear workers</td>
<td>Increased risk in radiation exposure &amp; contamination, any accident</td>
<td>Radiation Emergency Medicine</td>
</tr>
<tr>
<td>Emergency responders</td>
<td>Increased risk in radiation exposure &amp; contamination</td>
<td>Consultation clinic for mental, physical cares (stress &amp; fear)</td>
</tr>
<tr>
<td>Residents in Fukushima</td>
<td>Chronic low dose/low dose rate exposure</td>
<td>Education/communication/information</td>
</tr>
</tbody>
</table>
Lecture and Meeting during Crisis Period in Fukushima

From March 18 to May 13, 2011, 27 times (10,240 subjects)
Number of evacuees from designated evacuation areas:

- **Restricted Area**: about 77,000
- **Deliberate Evacuation Area**: about 10,000
- **Evacuation-Prepared Area**: about 26,000

Total: about **113,000**

(Source: Cabinet Office, Feb 2012)

The Number of Peaks: 164,000 in May 2012

The Number of *Disaster-related Death*; **2,316 among 4146** in December 2020

Currently about **30,000** residents are still evacuated from their hometown.
Objectives: from June 2011

- To monitor long-term health condition of resident in Fukushima and to promote their health
- To investigate whether a long-term low-dose radiation exposure has a consequence on their health


1. Basic survey (subjects: 2 million all residents in Fukushima)
2. Detailed survey (target population)
   - Thyroid examination by ultrasonography (380,000; 0-18 y/o)
   - Comprehensive medical checkups (210,000; Evacuees)
   - Mental health and lifestyle survey (210,000; Evacuees)
   - Survey on pregnant women and nursing mothers (16,000)

The results of the survey program are valuable and useful not only for public health promotion but also for sound health risk communication between experts and the residents in Fukushima.
How to analyze external radiation dose

To help understanding of individual first 4M dose

To help understanding of radiation-related health risk

To establish database for long-term health management
Distribution of External Exposure Dose (mSv)
(Estimated Cumulative effective dose from March 11 to July 11)

- Number of responses: 386,572
  - < 1mSv 66.3%
  - < 2mSv 95.0%
  - < 5mSv 99.8%
- Maximum 25mSv

All Fukushima Prefecture
(data released at 21 Feb 2013)

Estimated from location and time course on questionnaire
How to solve uncertainty of low dose radiation health effects; Necessity of Social Medicine and Regulatory Science based on common understanding and sound policy-making

The expert group endorsed the Fukushima Health Management Survey program.

Ethics, Legal and Society
Radiation Exposure Dose: **Chernobyl and Fukushima**

<table>
<thead>
<tr>
<th>Chernobyl Accident</th>
<th># of people (x1,000)</th>
<th>Mean effective dose (mSv)</th>
<th>Mean Thyroid Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belarus</td>
<td>25</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Russia</td>
<td>0.19</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Ukraine</td>
<td>90</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

**UNSCEAR 2008 Report**

<table>
<thead>
<tr>
<th>Fukushima average doses of evacuees (First year total)</th>
<th>Adult</th>
<th>10-year-old</th>
<th>1-year-old</th>
</tr>
</thead>
<tbody>
<tr>
<td>RENGE OF EFFECTIVE DOSE (mGy)</td>
<td>0.046-5.5</td>
<td>0.10-6.5</td>
<td>0.15-7.8</td>
</tr>
<tr>
<td>RANGE OF ABSORBED DOSE TO THE THYROID (mGY)</td>
<td>0.79-15</td>
<td>1.6-22</td>
<td>2.2-30</td>
</tr>
</tbody>
</table>

*Radiation Exposure among Evacuation Groups from the Chernobyl and Fukushima Nuclear Accidents*
<table>
<thead>
<tr>
<th></th>
<th>Preliminary Baseline (1st Exam)</th>
<th>Full-Scale Survey (2nd Exam)</th>
<th>Full-Scale Survey (3rd Exam)</th>
<th>Full-Scale Survey (4th Exam)</th>
<th>Survey of Age 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of target population</td>
<td>367,637</td>
<td>381,244</td>
<td>336,670</td>
<td>294,240</td>
<td>66,637</td>
</tr>
<tr>
<td>Participation rate of primary exam</td>
<td>81.7%</td>
<td>71.0%</td>
<td>64.7%</td>
<td>61.5%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Target population of confirmatory exam</td>
<td>2,293</td>
<td>2,227</td>
<td>1,501</td>
<td>1,362</td>
<td>244</td>
</tr>
<tr>
<td>Participation rate of confirmatory exam</td>
<td>92.9%</td>
<td>84.1%</td>
<td>73.4%</td>
<td>60.1%</td>
<td>68.9%</td>
</tr>
<tr>
<td>Malignant or suspicious for malignancy(FNAC)</td>
<td>116</td>
<td>71</td>
<td>31</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>Number who received surgery</td>
<td>102</td>
<td>54</td>
<td>27</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Patho-logical diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papillary cancer</td>
<td>100</td>
<td>53</td>
<td>27</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>Undifferentiated cancer</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
The first five years’ results demonstrated a high detection rate of thyroid cancer in young individuals revealing 116 and 71 cases in the first and second rounds, respectively, in the same cohort of about 300,000 subjects, aged at the time of accident from 0 to 18.
Interpretation of Fukushima Data

How to interpret more than 270 cases of childhood/adolescent thyroid cancer detected in Fukushima in the past 10 years (2011-2021)

due to sophisticated US Mass Screening from neonates to young adolescence

Screening Bias/Harvest Effect

Latency and Dose; Fukushima < Chernobyl

Unlikely due to radiation exposure

Overdiagnosis?

unnecessary examination?
indolent tumor?
life-time asymptomatic microcarcinoma PTC?

- merits and demerits of early diagnosis by US screening-

5~10mm in tumor size;
*indication of FNA cytology
*watch and wait strategy

Basal prevalence of thyroid cancer
1. The expert group recommends against population-based thyroid screening after a nuclear accident.

2. The expert group recommends that consideration be given to offering a long-term thyroid monitoring programme for higher-risk individuals* after a nuclear accident.

*higher-risk individuals are defined as those exposed in utero or during childhood or adolescence with a thyroid dose of 100-500 mSv or more.
**Five Medical Support Centers for Advanced Radiation Emergency Medicine in JAPAN**

re-organized in August 2015 and renewal in April 2019 by the Nuclear Regulation Authority (NRA)

Just before March 11 in 2011, 35 of 54 NPP reactors were in operation. Now 10 reactors are working in April 2022

*Thyroid dose measurement*
- Nuclear facility
- Prefectures located of the nuclear facilities
- Prefectures adjacent to the nuclear facilities

Indoor sheltering
- Iodine thyroid blocking (ITB)
- Evacuation, Food restriction

Core Support Center
- QST/NIRS in Chiba

Pre-distribution of stable iodine
- in PAZ (<5km) and emergency distribution in UPZ (5<, <30Km)
(1) Although the risk of radiation-associated health consequences in Fukushima is considerably low and negligible based on the estimated radiation doses individuals received, a high prevalence of childhood and adolescent thyroid cancers detected by a population-based screening aggravates negatively radiation fear and anxiety, especially by a wrong interpretation of the Fukushima’s data and through the fear and anxiety of the second coming Chernobyl.

(2) It is, therefore, critically important for the medical experts as well as radiation protection members and administrative officers to explain the current prevalence of thyroid cancers in Fukushima to the public correctly as a screening effect but not as epidemic due to direct linkage of radiation-induced.

(3) Sound radiation risk learning and dialogue with the public is currently challenged during the recovery phase after NPP accident.