

# Reconstruction of the Radiation Emergency Medical System From the Acute to the Sub-acute Phases After the Fukushima Nuclear Power Plant Crisis

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## Abstract

The radiation emergency medical system in Japan ceased to function as a result of the accident at the Fukushima Daiichi Nuclear Power Plant, which has commonly become known as the “Fukushima Accident.” In this paper, we review the reconstruction processes of the radiation emergency medical system in order of events and examine the ongoing challenges to overcoming deficiencies and reinforcing the system by reviewing relevant literature, including the official documents of the investigation committees of the National Diet of Japan, the Japanese government, and the Tokyo Electric Power Company, as well as technical papers written by the doctors involved in radiation emergency medical activities in Fukushima. Our review has revealed that the reconstruction was achieved in 6 stages from March 11 to July 1, 2011: (1) Re-establishment of an off-site center (March 13), (2) Re-establishment of a secondary radiation emergency hospital (March 14), (3) Reconstruction of the initial response system for radiation emergency care (April 2), (4) Reinforcement of the off-site center and stationing of disaster medical advisors at the off-site center (April 4), (5) Reinforcement of the medical care system and an increase in the number of hospitals for non-contaminated patients (From April 2 to June 23), and (6) Enhancement of the medical care system in the Fukushima Nuclear Power Plant and the construction of a new medical care system, involving both industrial medicine and emergency medicine (July 1). Medical resources such as voluntary efforts, academic societies, a local community medical system and university hospitals involved in medical care activities on 6 stages originally had not planned. In the future, radiation emergency medical systems should be evaluated with these 6 stages as a basis, in order to reinforce and enrich both the existing and backup systems so that minimal harm will come to nuclear power plant workers or evacuees and that they will receive proper care. This will involve creating a network of medical resources becoming involved across the country.

**Key words** Fukushima Daiichi Nuclear Power Plant’s accident, Radiation emergency medical system, Reconstruction, Backup system, Emergency medicine, JMAT

## Introduction

The nuclear disaster measures in Japan have been developed by the prefectures with nuclear power plants, based on lessons learnt from nuclear power plant accidents in the past, including

Three Mile Island (1979), Chernobyl (1984), and the JCO Co., Ltd. accident (Ibaraki, Japan: 1999).<sup>1</sup> In those prefectures, the government funded the construction of an off-site center for decision-making and coordination relating to radiation emergency medical responses to be

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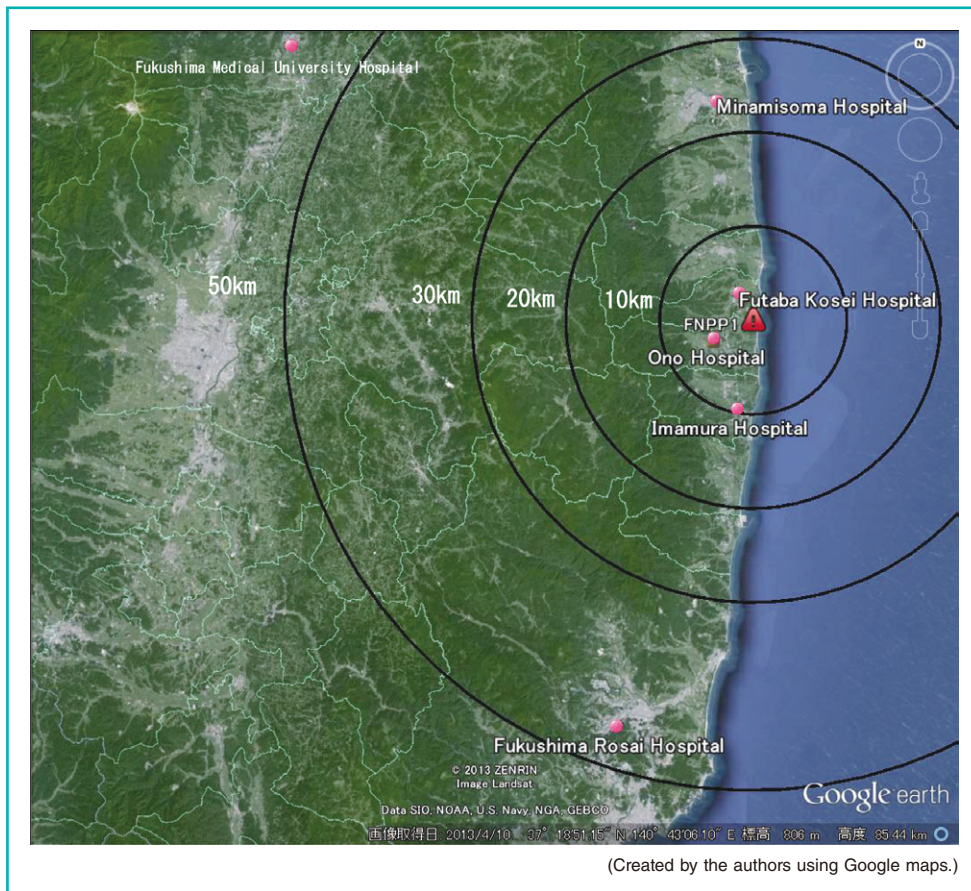


Fig. 1 Location of nuclear power plants and Radiation Emergency Hospitals in Fukushima

built around nuclear power plants. The radiation emergency medical system established by the prefectures consisted of 3 levels of hospital care: initial, secondary, and tertiary radiation emergency hospitals. The prefectures designated the initial and secondary radiation emergency hospitals, while the government designated the National Institute of Radiological Sciences (NIRS) and Hiroshima University as the tertiary radiation emergency hospitals.

In Fukushima Prefecture, the off-site center was located about 5 km from the Fukushima Daiichi Nuclear Power Plant (hereafter referred to as FNPP1). Five initial radiation emergency hospitals (Fukushima Prefectural Ono Hospital, Futaba Kosei Hospital, Imamura Hospital, Fukushima Rosai Hospital, and Minamisoma City General Hospital) and 1 secondary radiation emergency hospital (Fukushima Medical Univer-

sity Hospital) had also been designated (Fig. 1).

After the nuclear accident at FNPP1, which occurred as a result of the Great East Japan Earthquake on March 11, 2011, the off-site center and the radiation emergency hospitals in Fukushima became non-functional. The earthquake caused an emergency shutdown of the reactors and a loss of the external power supply, the tsunami caused several of the reactors to lose all AC power, and the water injection system for emergency core cooling failed. Hydrogen explosions occurred at Unit 1 on March 12 and at Unit 3 on March 14, and radioactive materials were subsequently released into the environment. This accident later became known as the “Fukushima Accident.”

Residents who lived within a 20 km radius of the power plant had to be evacuated, and residents within a 20-30 km radius had to stay

indoors on March 15. Due to the earthquake damage, limited satellite connection was the only means of communication left for FNPP1's off-site center, and information such as the plant's situation or radiation levels (e.g., SPEEDI), could not be obtained. Disappointingly, there was very little scope for assembling relevant organizations such as national and local governments and plant operators, meaning that it was extremely difficult to examine the radiation protection that was available for residents or the transportation system that was in place for radiation-contaminated patients.<sup>2</sup> At 5:44 on March 12, the off-site center had to be evacuated because everything within a 10 km radius from FNPP1 was designated an evacuation zone by government order. The facility that was previously designated as an alternate location was unsuitable because the radiation level in the area was increasing. Moreover, there was insufficient space available, as the facility was already used for disaster management for earthquakes and tsunamis.<sup>3</sup> At 18:25 on the same day, 3 out of 5 of the initial hospitals also had to be evacuated when the evacuation zone expanded to a 20 km radius from the plant, again by government order. The inpatient ward of the Minamisoma City General Hospital was also closed because the hospital was located within the designated indoor-sheltering zone.<sup>4</sup> The Fukushima Accident Hospital and the Fukushima Medical University Hospital (FMUH) are located outside the 30 km zone, but the earthquake damaged their essential utilities, leading to a marked functional decline.<sup>4</sup> The malfunctioned medical systems were reconstructed in order to respond to the much-needed medical care for the plant workers who were attempting to contain the accident, as well as about 78,000 residents and 850 inpatients.

In this paper, we have systematically classified the reconstruction of the radiation emergency medical system in Fukushima in order of events and examined the problems and the future challenges.

## Results

We have classified the reconstruction of the radiation emergency medical system in Fukushima into the following 6 stages.

Stage 1: Re-establishment of an off-site center (March 13).

Stage 2: Re-establishment of a secondary radiation emergency hospital (March 14).

Stage 3: Reconstruction of the initial response system for radiation emergency care (April 2).

Stage 4: Reinforcement of the off-site center, and stationing of disaster medical advisors at the off-site center (April 4).

Stage 5: Reinforcement of the medical care system, and an increase in the number of hospitals for non-contaminated patients (from April 2 to June 23).

Stage 6: Enhancement of medical care system at the Fukushima Nuclear Power Plant, and the construction of a new medical care system, involving both industrial medicine and emergency medicine (July 1).

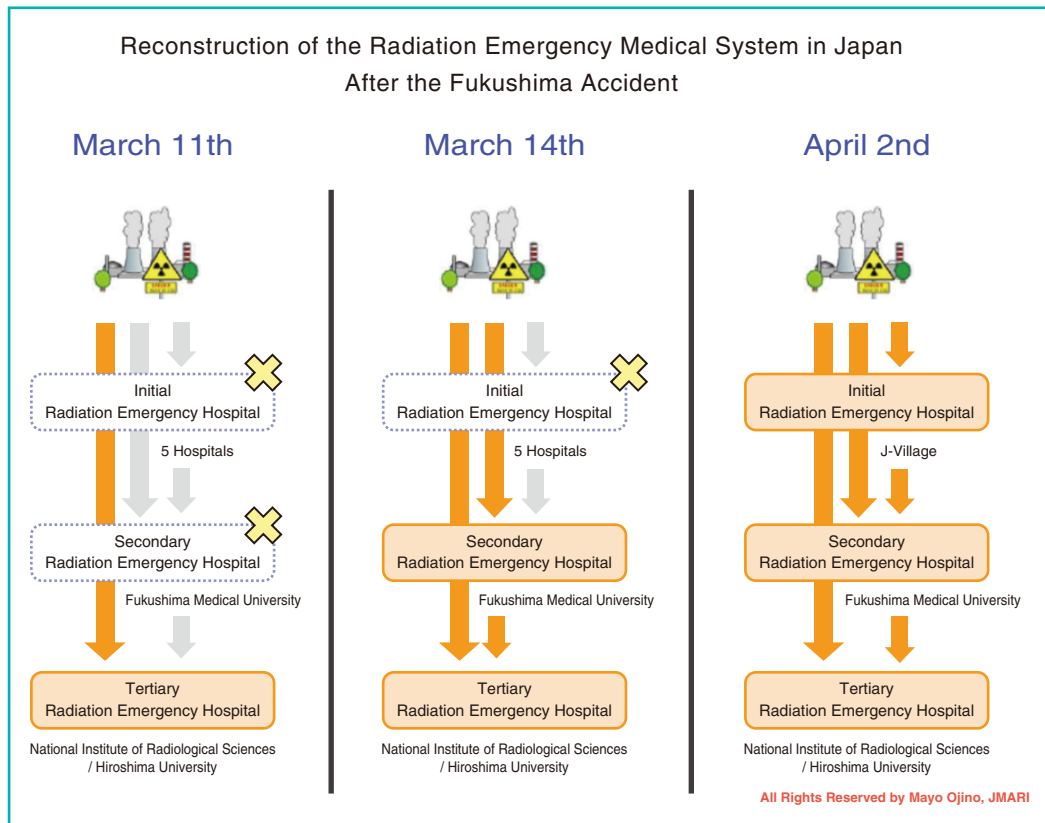
### Stage 1: Re-establishment of an off-site center (March 13)

On March 13, the Fukushima Prefecture Radiation Emergency Medical Coordination Council was established in the Fukushima Prefectural Government Building.<sup>4</sup> This council was voluntarily organized by members of NIRS team, physicians from the FMUH, and prefectural government officers to substitute the radiation emergency medical system, as the off-site center's function had failed. The members of the council had knowledge and skills relating to radiation emergency medicine, as well as personal networks through the radiation emergency medical training that had previously been conducted by the government. This council served in the decision-making regarding the radiation emergency medical system, such as transportation of contaminated patients, the screening of contamination, and decontamination work, and coordinated these tasks.

### Stage 2: Re-establishment of a secondary radiation emergency hospital (March 14)

On March 14, the FMUH, a designated secondary radiation emergency hospital located 57 km from FNPP1 (**Fig. 2**) started accepting radiation emergency patients. It takes 2.5 hours by car or 15 minutes by helicopter to travel from FNPP1 to FMUH. Although there were other hospitals nearer to FNPP1, they were not equipped to provide radiation emergency care.

At 11:00 on the same day, a hydrogen explosion occurred in Unit 3 of FNPP1, injuring 11 people,<sup>5</sup> and FMUH accepted 4 of them. While



**Fig. 2 The Radiation Emergency Medical System in Japan rebuilt after the Fukushima Accident**

1 out of these 4 patients was transported directly to FMUH, the remaining 3 patients were brought into the FMUH about 20 hours after the explosion,<sup>4</sup> because their injuries were initially thought only to be minor trauma. On March 16, a worker suspected of having trauma to the right of his chest was transported to FMUH by a Japan Self-Defense Force (SDF) helicopter.<sup>4</sup> He had more than 100,000 cpm of contamination on his head.<sup>4</sup> On March 24, 3 workers who were laying cables on the first floor and the first basement level of the turbine building of Unit 3 submerged their feet in the contaminated water, resulting in external exposure of over 170 mSv.<sup>2</sup> They also were accepted at FMUH. At this point, the initial radiation emergency care system near FNPP1, which was supposed to provide unsophisticated decontamination and first aid, was extremely weak. Medical treatment for radiation for the evacuated residents was supposed to be pro-

vided mainly by the local hospitals and clinics; however, many medical teams from various organizations across the country were providing the care. Disaster Medical Assistance Team (DMAT) members, dispatched by the national government, essentially provides medical assistance for natural disasters, and specializes in providing emergency care in affected areas<sup>6</sup>; it was not intended to address a nuclear disaster. The available information on the status of FNPP1 and radiation were sketchy, and experts disagreed in their opinions. The evacuees who had been forced to flee from their homes with nothing but the clothes they wore were concerned about their lives at shelters, and the impact of radiation exposure on their health.<sup>7</sup> The Japan Medical Association (JMA) also dispatched medical assistance teams (called JMAT) to the disaster area and supported community health with the help of local medical associations.<sup>8,9</sup>

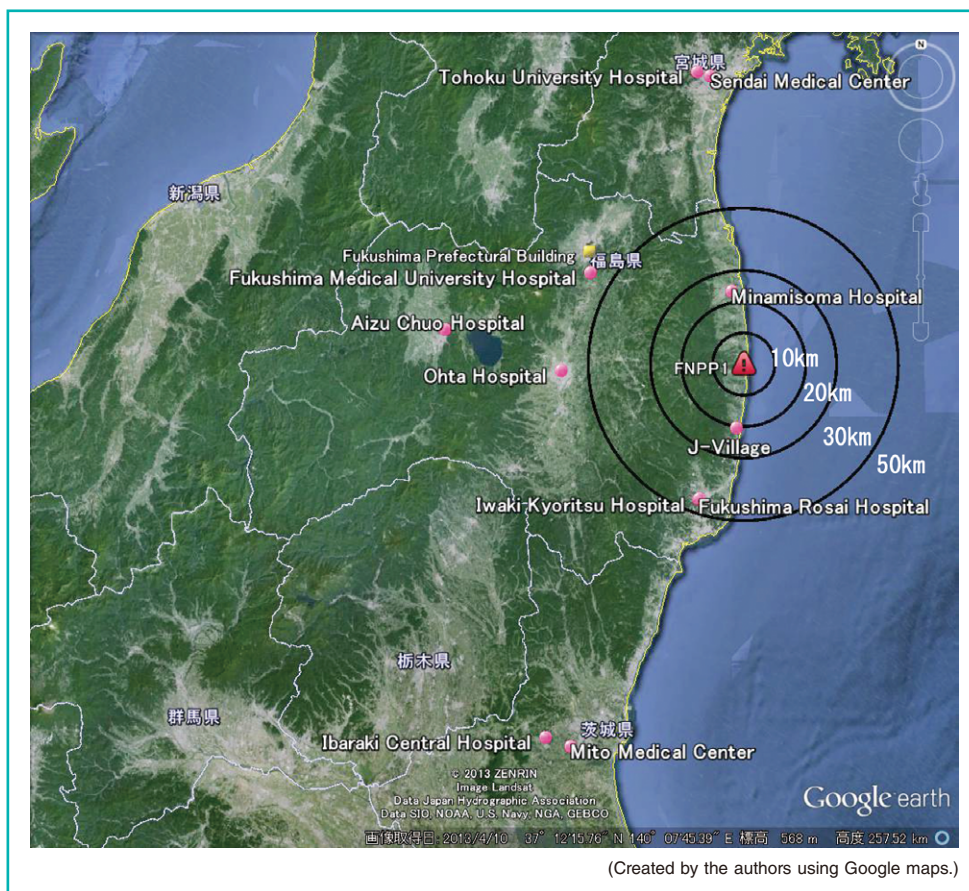


Fig. 3 Locations of the Fukushima Daiichi Nuclear Power Plant, J-Village and hospitals

### Stage 3: Reconstruction of the initial radiation emergency care system (April 2)

On April 2, a facility for initial radiation emergency medicine was established in J-Village.<sup>10</sup> J-Village is a sports training center in Naraha Town, located 20 km from FNPP1 (about 40 minutes by car) (Fig. 3). It was used by workers from Tokyo Electric Power Co. (TEPCO; the company that owns and operates FNPP1) and other companies engaged in controlling the accident as a place to assemble, put on protective clothing, and for monitoring radiation levels. The SDF and fire departments also used J-Village as a front-line base. Emergency physicians were also available here: they would accompany the emergency firefighting support team to the accident site to provide health management, medical care, and radiation protection, including the

administration of stable iodine tablets.<sup>11</sup>

On March 24, at J-Village, an emergency physician dispatched from a fire department examined the aforementioned 3 workers who had their feet submerged in the contaminated water during the cable-laying work,<sup>2</sup> and ordered them to be transported to FMUH.<sup>2,11</sup> This incident served as the turning point in the rebuilding of the area's radiation emergency medical system. The local headquarters of the Government Nuclear Emergency Response asked the Japanese Association for Acute Medicine (JAAM) to dispatch emergency physicians, and the reconstruction of the radiation emergency medicinal system for Fukushima, including J-Village, became fully operational.<sup>11</sup> This is when the initial and secondary levels of radiation emergency care system regained their function (Fig. 2).

#### Stage 4: Reinforcement of the off-site center, and the stationing of disaster medical advisors at the off-site center (April 4)

The Government Nuclear Emergency Response's local headquarters also requested that JAAM dispatch disaster medical advisors to the medical team at the FNPP1's off-site center in order to supplement its insufficient manpower: this dispatch began on April 4.<sup>11</sup> Disaster medical advisors selected by JAAM were specialists in emergency and disaster medicine with excellent coordination capabilities, the ability to cooperate, and leadership skills.<sup>11</sup> Their role included giving proper advice to the head of the medical team regarding emergency and overall disaster medicine, formulating response plans for cases where there were multiple patients with injuries and/or high-dose radiation exposure, and ensuring effectiveness in the patient response, including the status of medical facilities and patient transport.<sup>11</sup>

#### Stage 5: Reinforcement of the medical care system, and an increase in the number of hospitals for non-contaminated patients (from April 2 to June 23)

Emergency hospitals in Fukushima Prefecture could not accept trauma patients from FNPP1, because of these patients might have contamination.<sup>4</sup> From April 2 to June 23, a total of 8 hospitals were prepared to provide general medical care for non-contaminated patients. Specifically, on April 2,<sup>10</sup> Ohta General Hospital and Aizu Chuo Hospital were added to the list of hospitals able to accept patients. Fukushima Rosai Hospital, Iwaki Kyoritsu General Hospital, Mito Medical Center, and Ibaraki Prefectural Central Hospital (secondary radiation emergency hospitals in Ibaraki Prefecture) were also added to this list on April 22,<sup>12</sup> and Tohoku University Hospital and Sendai Medical Center (secondary radiation emergency hospitals in Miyagi Prefecture) were added on June 23<sup>13</sup> (**Fig. 3**).

At this point in the reconstruction process, patients with high-dose exposure or heavy contamination were transported to the designated radiation emergency hospital (FMUH, NIRS, or Hiroshima University), whereas patients in a severe condition with moderate, minor, or no

exposure were transported to other hospitals.<sup>14,\*1</sup>

#### Stage 6: Enhancement of the medical care system within the Fukushima Nuclear Power Plant, and the construction of a new medical care system, involving both industrial medicine and emergency medicine (July 1)

From May 29 onward, physicians who had been dispatched from Fukushima Rosai Hospital and the University of Occupational and Environmental Health were permanently stationed 24 hours a day at the Critical Based Isolated Building within the plant to provide initial care and health consultations for injured workers.<sup>15</sup> In addition, the medical facility "5/6ER" was established in the service building, located between Units 5 and 6,<sup>15</sup> and physicians with a good knowledge of radiation medicine were stationed around the clock in order to strengthen the emergency medical care. On July 1, TEPCO organized an in-plant emergency medical system network for FNPP1 to enhance preventive medicine, industrial medicine, and emergency medicine within the plant facility.

### Discussion

The world has experienced nuclear disasters several times, including the Three Mile Island (1979), Chernobyl (1984), and JCO (1999). Japan has learned lessons from these past nuclear crises and developed plans that incorporated international trends.<sup>1</sup> Nonetheless, a drastic review of the Emergency Preparedness Guide has not been carried out, because of the belief that a Chernobyl type nuclear accident could not occur in Japan.<sup>2</sup> Furthermore, the general disaster management training for nuclear disasters, which is annually conducted by the national government, did not take into account severe accidents or compound disaster, and in a sense existed merely as titular training.<sup>2</sup> In other words, the national preparation for a nuclear disaster never went beyond the "formulation of plans" or the "execution of plans."

We believe that the biggest problem with the radiation emergency medical system in Japan lies in the vulnerability of the backup system when the system that had been planned proved

\*1 External full-body exposure of at least 1 Gy (with prodromal symptoms such as vomiting) is considered high-dose exposure; heavy contamination is 100,000 cpm or higher.

dysfunctional. On this occasion, it took 3 weeks to compensate for the failed radiation emergency medical system (Stage 1 to 3) and almost 4 months to reinforce the system (Stage 4 to 6). None of these stages was planned ahead; they were created in accordance with the needs of the accident sites. This suggests that the 6 stages revealed here can serve as a practical and effective backup system, as they were obtained from real experience. The Fukushima Accident, as a compound disaster involving a natural disaster, a nuclear disaster, and a mass evacuation, surpassed the level of disaster that any previous plans had anticipated.

Immediately after the accident (March 13 and 14: Stage 1 and 2), the voluntary efforts of willing doctors contributed the most to the reconstruction of the radiation emergency medical system in the area. For example, the doctors who voluntarily gathered launched an organization at the Fukushima Prefecture Jichi Kaikan building to serve as a substitute off-site center with regard to medical provision in the affected areas. These doctors had knowledge of and skills in emergency radiation care and personal networks of colleagues: this allowed smooth communication and prompt responses in the decision-making process at sites.<sup>4</sup> Various medical teams across the country also gathered to assist with the care and health management of the evacuees. JMA dispatched JMAT teams to shelters and other places to provide medical care and health management with the help of local medical associations.<sup>16</sup> JMA also created a map of radiation levels in the air and posted it on the website.<sup>17,18</sup> Fulfilling this social mission required not only collaboration within JMA and its affiliated medical associations, but also collaboration with various medical organizations and different professions.<sup>9</sup> By nature, doctors are guaranteed their right to freely exercise own professional judgment.<sup>19</sup> We would suggest that the ability of doctors in the field to think for themselves created resilience in overcoming many difficulties that they faced.

In the aftermath of the Fukushima Accident, many suffered injuries as well as radiation contamination, and required emergency care. From March 11 through December 16, 2011, there were 118 cases of injuries, 44 cases of heat illnesses, 5 cases of acute coronary syndrome or arrhythmia, and 2 cases of cerebral strokes

among the plant workers alone.<sup>14</sup>

Japanese Association for Acute Medicine (JAAM) dispatched doctors to the facility for initial radiation medicine (J-Village) and the off-site center (April 2 and 4: Stage 3 and 4). In particular, disaster medical advisors enhanced the quality of medical care that was provided by making full use of the limited transportation means and selecting appropriate care facilities based on the urgency and severity of a patient's needs.<sup>14</sup> Neither the basic disaster management plan nor the nuclear emergency guidelines established by the nation stipulated the involvement of academic societies.<sup>20,21</sup> In the future, it will be essential to clearly establish the position of disaster medical advisors in response plans in advance. The involvement of academic societies will also be indispensable in establishing dispatch systems and in fostering and training advisors.

From April 2 to June 23 (Stage 5), the radiation emergency system cooperated with local community medical system. In this accident, emergency care, including decontamination management and simple decontamination, were much needed, while professional medical treatment for severe exposure that requires tertiary radiation emergency hospitals was in less demand. The designated initial and secondary radiation emergency hospitals were unable to respond to patients who required emergency radiation care. The link between initial, secondary, and tertiary care was severed, leaving only 2 tertiary hospitals a long distance away: the NIRS in Chiba Prefecture (approx. 215 km by air) and Hiroshima University Hospital in Hiroshima Prefecture (approx. 840 km by air). Tertiary radiation emergency hospitals were supposed to treat the patients in need of emergency radiation care if the initial or secondary radiation emergency hospitals were incapable of treating them.<sup>22</sup> The means of transporting patients to a tertiary radiation emergency hospital, the last safety net, were very limited. Seeking and securing means of transport took time, and so did the actual transport. Therefore, prompt treatment was not easily available for patients in need of emergency care. We submit that tertiary radiation emergency hospitals alone were insufficient as a backup for initial and secondary radiation emergency hospitals. We propose moving beyond the conventional continuity concept of initial,

secondary, and tertiary care, and encourage the establishment of a national network that involves local clinics and hospitals for emergency care, as well as the Disaster Base Hospitals.

On July 1 (Stage 6), the in-plant medical system was enriched from both the “preventative” viewpoint of industrial medicine and the “treatment” viewpoint of emergency medicine. According to the medical records of the FNPP1’s workers from March 2011 to June 2012,<sup>23</sup> the number of cases was highest in the month of the accident (March 2011), with 67 patients. The number decreased from June 2011 (45 patients). This underlines the importance of stationing both industrial physicians and emergency physicians through an organized dispatch of manpower in collaboration with university hospitals.

Various medical resources such as voluntary efforts, academic societies, a local community medical system and university hospitals provided as much support as possible under extremely limited circumstances. They originally had not planned to involving in radiation emergency medicine. The radiation emergency medical system should be reevaluated and further enriched for the future by incorporating the perspectives of these 6 stages, so that nuclear power plant workers and evacuees who require emergency radiation care may suffer minimal harm and receive proper care. In the future, radiation emergency medical systems should be evaluated with these 6 stages as a basis, in order to reinforce and enrich both the existing and backup systems so that minimal harm will come to nuclear power plant workers or evacuees and that they will receive proper care. This will involve creating a network of medical resources becoming involved across the country.

## Conclusions

The conventional radiation emergency medical system of Japan was proved insufficient after the Fukushima Accident, and the vulnerability of the backup system in the plan that existed previously became evident at a time of major disaster. In this paper, we have systematically classified the actual reconstruction process into 6 stages. These 6 stages were not the result of established procedures by planning ahead; they were born from the actual experience and have substantial significance. We conclude that the radiation

emergency medical system should be reevaluated for the future, and further enriched by incorporating the perspectives of these 6 stages, in order to minimize radiation damage and enable proper care for nuclear power plant workers and evacuees. It’s important to create a network emergency medical resources and organizations across the country.

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