Treatment of radiation injuries and establishment of the Nationwide Radiation Emergency Medical Network System in Japan.

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1. Introduction

The JCO criticality accident greatly shocked all persons concerned with nuclear energy development, nuclear regulation and most of all the Japanese public as well. We had insisted on the necessity of providing effective medical countermeasures for nuclear disasters before the JCO criticality accident occurred. Therefore, the National Institute of Radiological Sciences (NIRS) had established the Medical Network Forum of NIRS before the JCO criticality accident, which demonstrated the effectiveness in the treatment of three severely exposed workers.

In this paper, I will describe the outline of the JCO criticality accident, treatment of radiation injured patients, and the present state of establishment of the Nationwide Radiation Emergency Medical Network System in Japan.

2. The JCO criticality accident

2.1 Outline of the criticality accident

On the 30th of September 1999, at 10:35 am, a criticality accident occurred in the uranium processing plant operated by JCO company Ltd. (JCO), which resulted in the first nuclear accident involving fatalities in Japan.

The criticality event occurred when a worker was pouring a solution of enriched uranium-235 into a precipitation tank directly, bypassing a dissolution tank and buffer column which are supposed to be used in order to avoid criticality. An amount of uranium-235 was several times more than the specified mass limit.

At the accident, three workers were severely exposed mainly to neutron irradiation, mixed with gamma ray. Despite of all medical efforts including peripheral stem cell transplantation to

worker A, and umbilical cord cell transplantation to worker B , the most severely exposed worker A died 83 days after the accident and worker B died 211 days after the accident.

2.2 Treatment of severely exposed workers

Worker A, B, and C mentioned that they saw blue-white light at the accident. This means that the criticality has occurred and the blue-white light is criticality-induced luminescence named Cherenkoff phenomenon. Worker A lost consciousness for 10-20 seconds, and he vomited, and complained of a headache. Worker A was transferred to the next room attached to the uranium processing room with the help of worker B and C.

JCO called Tokaimura village ambulance at 10:43 am, and three minutes later, ambulance car arrived at the site. However, worker A was not accepted in the ambulance car until 11:27 am, because in the Japanese law of the day, ambulance car could not accept contaminated patients. And at that time, it was not clear if worker A was contaminated or not. JCO did not inform if he was contaminated or not to the ambulance staffs. After several discussions, the chief of ambulance decided to accept him in the car. And then, another difficult problem to be solved happened. This is a big matter. Tokai Fire Department was very much embarrassed to decide to which appropriate hospital he could be transferred. At that time, in Japanese Emergency Countermeasures, there had not been prepared such a countermeasure that a contaminated employee of private company could be admitted to an appropriate hospital without delay. The reflection of JCO criticality accident made Japanese Government legislate a new law, such as Special Law of Emergency Countermeasures for Nuclear Disasters.

After several discussions, the ambulance car departed for the National Mito Hospital at 11:49 am. At Mito Hospital, he received contamination check and was collected some blood to determine the degree of his exposed dose and so on. The physicians of Mito hospital decided that worker A should be transferred to the NIRS hospital in Chiba city, because they diagnosed that this patient was too much severely exposed for Mito Hospital to accept him NIRS is obligated to accept any severely exposed and highly contaminated patients at any time.

Worker A, B, and C were admitted to NIRS hospital at 3:25 pm.On their admission, physicians and researchers of NIRS began to examine if they were contaminated or not, and as for the external irradiation, by what kind of exposure, gamma ray or neutron, they were exposed. Unfortunately, NIRS hospital physicians were not informed any information about their exposure and contamination. The physicians of the Mito Hospital were neither informed any

useful information at all from JCO.

The researchers of NIRS discovered Sodium-24 peak in their excreta, vomitus, blood, and urine. The finding of sodium-24 indicates that a criticality accident had occurred and the patients had been exposed mainly to neutron and some extent of gamma ray. Sodium-24 is the activated product of stable sodium-23 in the body by fast neutron.

They analyzed radioactivity on the patients' portable phones, coins, and their hairs, induced by neutron activation.

In order to estimate the doses which were received by the three workers, NIRS physicians and researchers investigated four kinds of examinations. To analyze the sodium-24 radioactivity in blood is a very useful technique for neutron exposure. Chromosomal aberration of lymphocytes were evaluated by the plural numbers of specialists. They evaluated the same samples concurrently. Observing serially the reduction rate of peripheral lymphocyte counts is clinically very useful method in early stage to estimate the radiation dose. Evaluation of whole body sodium-24 activation by whole body counter was done to worker C who was physically tolerable to this examination.

With these four evaluation methods, converted gamma ray radiation doses which were received by three workers were estimated. Estimated dose of worker A was 16-20 GyEq, the dose of worker B was 6-10 GyEq, and dose of worker C was 1-4.5 GyEq.

The WBC counts of worker A highly elevated and lymphocyte counts decreased. This phenomenon indicates the high dose exposure to the total body. Worker B showed the slight elevation of WBC counts and decreased lymphocyte counts, which indicated rather high dose exposure to total body, as well. Worker C showed the slight elevation of WBC counts, which indicated the presence of total body exposure.

From the beginning of his admission, worker A complained of amnesia, nausea and vomiting, diarrhea, parotid swelling with pain, and skin lesions. He also complained of continuous high fever which means severe bone marrow suppression. His radiation-induced skin burns of whole body surface became worse and worse. Physicians tried skin-grafting but in vain.

The peripheral blood cell counts of worker A was evaluated during his hospitalization. His WBC counts highly elevated at the beginning of admission and showed the peak on the second day from admission. And then, his WBC counts decreased rapidly to zero. Since worker A needed a bone marrow stem cell transplant for his severe bone marrow suppression. And at the same time, intensive care medical equipment and staffs who are skilled in its use were required, he was move on the third day to the Hospital of the University of Tokyo. He received a peripheral bone marrow

stem cell transplant from his sister. In spite of the bone marrow transplant and any other conceivable treatments, he died on the 21st of December at 11:21 am and 83 days after the accident.

The V/BC counts of worker B also highly elevated and showed the peak on the second day and decreased to zero on 7th day. He received granulocyte colony stimulating factor for bone marrow suppression, but not so effective. Since stem cell transplant was necessary for him as well, he was moved to the Research Hospital of the Institute of Medical Science of the University of Tokyo. This hospital is proficient in stem cell transplant techniques. He received an umbilical cord stem cell transplant on the 9th day from accident. His stem cell transplantation was successful, and white blood cell counts recovered gradually to normal level. He received many kinds of newly developed drugs and massive intensive care, however, he died 211 days after the accident.

Worker C, who had been exposed to the lowest dose among the three workers, was treated in an aseptic room of NIRS Hospital during the bone marrow suppression period. He continued to receive medical care in a regular hospital room after recovery of bone marrow function was confirmed. He had been a leader of the team, so he complained of a severe mental shock. During his admission, he was continuously consulted with a psychiatrist of the Chiba University Hospital to relieve his psychiatric depression. He discharged 82 days after exposure.

Worker A and B showed serious radiation skin lesions during their clinical course. They received several kinds of skin graft transplantation. These skin grafting was partially successful. However, they died from radiation-induced failures in all organs.

3. Radiation emergency countermeasures of Japan at the time of JCO criticality accident

3.1 Roles of NIRS

In 1954, USA made an experimental thermonuclear test in Bikiniatoll in the Pacific Ocean. Japanese fishermen were heavily contaminated with nuclear fission products. A ship captain died from acute radiation injury. And the other crewmen have been suffered from late radiation effects even now.

Japanese government thought it was very much important and urgent matter to promote the researches of radiation effects. So, in order to carry out the researches of radiation effects and so on, NIRS was founded in 1957.

NIRS has been assigned the responsibility of treating all the victims severely exposed to radiation and/or highly contaminated,

wherever a nuclear power plant accident occurs.

3.2 Network of the Council for Radiation Exposures in Medical Emergency of NIRS

The treatment of three workers was carried out through the Medical Network Forum of NIRS, which had been established in August of 1998. In respect of medical treatment in this criticality accident, the Medical Network Forum of NIRS fully demonstrated its effective functions.

This forum consists of more than ten major hospitals and institutes including the Univ. of Tokyo and the Research Hospital of the Institute of Medical Science of the Univ. of Tokyo and so on. NIRS made a contract with these hospitals and institutes, in which they should cooperate to carry out the emergency medical treatment, especially treatment of radiation burn, severe bone marrow injuries, bone marrow transplantation and so on. The chairman of this NIRS Medical Network Forum was Professor Maekawa of the Univ. of Tokyo, who took the command of treatment of these three workers in JCO criticality accident.

4. Treatment of radiation injuries

4.1 Diagnosis and treatment of acute radiation syndrome(ARS)

Diagnosis of ARS is based on clinical and laboratory data. After external exposure, the prodromal phase may occur with nausea, vomiting and anorexia within hours. In this phase, laboratory findings can indicate hematopoietic damages (lymphocytepenia, thrombocytepenia etc) after an exposure of about 0.5 Gy or more. At the beginning of accident, highly elevated WBC counts may demonstrate that the patients will be exposed with high dose of exposure. There is usually a remission in the symptomes, which is called asymptomatic latent phase. The latent phase is followed by critical phase.

The critical phase can be divided to three types, the first of which is the phase of hematopoietic injuries, the second one is the one of gastrointesinal injuries, and the third one is the one of central nervous system injuries.

Among the assays for biological dosimetry, clinical patterns of WBC counts, especially patterns of lymphocytes counts is very useful to diagnose the exposure dose. The chromosomal aberration analysis is the most widely accepted biological dosimetry. The lower limit of detection of a dose using the chromosomal aberration

method is approximately 0.2 Gy of gamma rays or X rays.

Patients who have received external doses of less than 1 Gy may be carefully followed up as outpatients. Patients exposed to more than 1 Gy should be treated as exposed ones, the treatment schedule of them is depend upon the exposed doses. In order to prevent complications arising from bone marrow depression, prophylactic antibiotics and transfusing blood products (platelets, erythrocytes and WBC) should be administered. Use of hematopoietic growth factors(G-CSF and GM-CSF) will increase the rate of hematopoietic recovery in patients after whole body exposure.

Bone marrow transplantation (BMT) is supposed to be limitedly useful treatment for the patients whose bone marrow recovery is impossible. Information from the Chernobyl accident etc suggests that BMT should be administered to the patients who are receiving exposure dose in the range of 8 - 10 Gy, uniformly distributed, without skin burns, and in the absence of severe internal contamination.

4.2 Treatment of contaminated patients

In the case of external contamination, the radionuclide should be removed by wiping off with wet tissue and washing with warm water. The treatment rule is to avoid abrasion of the skin in order not to make radionuclides pass through the intact skin.

The purpose of the treatment of patients with internally deposited radionuclides is intended to reduce the absorbed radiation dose and hence the risk of possible future health effects. Application of stomach lavage, mild emetics, and purgatives can accelerate the removal of radionuclides from the gastrointestinal tract. Especially, prussian blue is efficiently used to reduce the gastrointestinal absorption of caesium. Specific decorporat ion drugs are used depending on the type and metabolic pathway of the contaminated radionuclides, for example, potassium iodide is widely used against deposition of I-131 to the thyroid gland. Chelating agents such as diethylene triamine pentaacetic acid (DTPA) can be administered to reduce the internal deposition of plutonium.

5. Establishing radiation emergency medical network system in Japan

In Japan, we have fifty-one commercially operating nuclear power plants, a fast breeding reactor ' Monju', many experimental reactors, and a big reprocessing plant is under construction in Rokkasho village in Aomori prefecture.

In order to construct the effective emergency medical countermeasures, it is very important to recognize that there are two kinds of victim groups in the nuclear disasters. When an accident occurs, there will be involved a large number of public people living near the nuclear power plant. However, the possibility of high dose exposure and high level contamination is considered to be very low. Sheltering evacuation and decontamination will be needed. In the JCO criticality accident, the habitants of 350 m zone were requested to evacuate and the habitants of 10 km radius were requested to stay indoors.

In nuclear disasters, it is very important countermeasure to take a long term observation of public people by their health check and psychological health consultation in order to treat or to prevent their anxieties. Regional government has much storage of stable iodine tablets, enough to administer them to public people to prevent thyroid dysfunction.

In order to construct the emergency medical countermeasures, another point of view must be considered. Near the reactors or the reprocessing facilities, there should be considered a small number of victims who are severely exposed and/or highly contaminated. High level massive emergency medical care will be needed to treat severely exposed victims like the patients in the JCO criticality accident.

We have been working hard to establish the nationwide effective emergency medical network system in Japan. The aim of Nationwide Radiation Emergency Medical Network System is to save all the victims who are injured in nuclear disaster, I think it is human being that we should save, not reactors.

I am convinced that even the highly exposed and/or heavily contaminated victims should be medically treated without delay, and without stressful feelings of physicians and nurses, whenever and wherever nuclear power plant accidents should occur in Japan.

Another purpose of establishing Nationwide Radiation Emergency Medical Network System is to provide large troops of well-trained physicians and nurses. The presence of those well-trained physicians and nurses should ease the mind of habitants living near nuclear power plant.

On the occasion of constructing Nationwide Radiation

Emergency Medical Network System, it is also very important to construct, at the same time, Regional Emergency Medical Network System in the area near nuclear power plants. And next, building up good relationship between medical network and municipal government, police and ambulance is also very important. Transmission of exact informations to medical network is indispensably important. On the occasion of the JCO criticality accident, lack of information disturbed initial treatment of patients.

To establish Nationwide Radiation Emergency Medical Network System and to maintain it, taking a budgetary measure every fiscal year is indispensable. Fortunately, from this year, a budget of every fiscal year is assured for these activities. Since several years, we have been working hard to teach physicians how to treat radiation exposed patients and how to treat contaminated patients. A larger number of well-trained physicians has been organized year and year in Japan.

In order to reinforce mutual communications and good cooperation among physicians who are expected to be engaged in treatment of radiation victims, we founded Japanese Association for Medical Management of Radiation Accident (JAMMRA) in 1997. The number of regular members has increased to more than 150. Since 1997, we have had a general assembly four times. On the 25th of August 2000, the 4th general assembly of this Association was held in Kobe, in which more than 250 members participated. In this assembly, treatment results of three workers in the JCO criticality accident were reported and discussed.

6. Establishment of collaborative relationship among Asian countries

Recently, there have augmented the number of radiation accidents involving radiation fatalities despite of decreasing tendency of nuclear power plant accidents in the world.

In Japan, we are now establishing Nationwide Radiation Emergency Medical Network System. And we think it is very important to raise the numbers of well-trained physicians and nurses for radiation accidents.

And I hope we will establish the collaboration in the field of radiation emergency medical countermeasures, for example, education of physicians and nurses, basic and clinical research, establishment of mutual communication system on the occasion of radiation accidents and so on, between and/or among Asian countries.