Dr. Sugiura succeeded Dr. Akashi as Center Director on August 1, 2011. Dr. Sugiura is a health physicist and his major interests are: 1) dose estimation in radiation emergency medicine; and 2) biokinetics of radionuclides. He started his research career at the former JAERI in 1991 after receiving a Ph.D. from the University of Tokyo. He successively worked as a research associate at the University of Tokyo and as a professor at Kinki University before getting the present position. (*Dr. Akashi, an executive director of NIRS, served as an acting director of the Center from April 1 to July 31, 2011.)

The roles and objectives of the Center

This center has been assigned as the National Center for Radiation Emergency Medical Preparedness and Response by the Nuclear Disaster Prevention Plan of the Japanese government since 1980. The Center is responsible for, and has established a solid system for dealing with radiation emergencies from a medical viewpoint. Our required missions are as follows:

1. To receive victims exposed to radiation and/or contaminated with radioactive materials who require specialized diagnosis and treatment.
2. To dispatch a radiation emergency medical team to local emergency medical headquarters.
3. To facilitate exchange of information, research activities, and human resources, by constructing networks in cooperation with other organizations who can deal with a radiation emergency.
4. To maintain and reinforce an efficient radiation emergency medicine system under usual conditions.
5. To promote technical development and research on radiation emergency medicine.
6. To develop skilled personnel for dealing with radiation emergencies.

As an additional objective, we are carrying out fundamental research on radiation emergency medicine.

The subjects are listed here and details are presented following the list.

1. Establishment of the system and related operations suitable for the national core center for radiation emergency medicine
2. Development of radiation emergency medicine in Asia
3. Research on the diagnosis and treatment of combined radiation hazards with injuries or burns, including dose estimation

Establishment of the system and related operations suitable for the national core center for radiation emergency medicine

In 1997, the Central Disaster Prevention Council (CDPC) in the Prime Minister’s office added a section on emergency preparedness for dealing with nuclear power station emergencies to the Basic Plan for Disaster Prevention. This plan was reinforced in 2000 following the criticality accident at Tokai-mura in the previous year. The plan was also revised in 2008 after the Niigata-Chuetsu-Oki Earthquake of 2007 caused damage to a nuclear power plant.

In June 1980, the Nuclear Safety Commission (NSC) came up with a guideline entitled “Off-site Emergency Planning and Preparedness for Nuclear Power Plants”. The radiation emergency system is organized around the NIRS Hospital and Hiroshima University Hospital, which are designated as the “local tertiary radiation emergency hospitals” for eastern and western divisions of Japan, respectively. For emergencies, local governments have selected healthcare centers near nuclear facilities as primary radiation medicine centers and local main hospitals as secondary radiation emergency hospitals. The local tertiary radiation emergency hospitals prepare their system for receiving heavily exposed patients who require advanced and specialized care and they liaise with local governments and organizations over the transport of those patients. In 2000, the NSC published guidelines for radiation emergency medical preparedness and revised them in 2008 to clarify the role of hospitals for radiation emergencies.

From January 2004 the Research Center has served as a liaison...

Since then, the Research Center has carried out a variety of activities to maintain and enhance or strengthen the emergency preparedness system required to fulfill its role as a tertiary radiation emergency hospital.

NIRS established the Radiation Emergency Medical Assistance Team (REMAT) program in January 2010. During 2010, the first activity year of the REMAT program, team members participated in not only many domestic drills but also international exercises or events such as at APEC as a comprehensive expert team dealing with radiation and nuclear accidents. Verification of the status and use of equipment and testing of a communication network between the on-site team and support team at NIRS have also been performed during REMAT activities. In March 2011, a nuclear accident occurred at TEPCO’s Fukushima Daiichi Nuclear Power Plant. Responses to the accident have become a very important mission for NIRS and NIRS has been coping with the accident and its consequences since the first day. REMAT has played a central role in these activities. Details of NIRS responses to the accident are described elsewhere.

1) Network System

The primary goal is to strengthen the institutional system to prepare for radiation emergencies by establishing three nationwide network councils, for medicine, chromosome analysis as biodosimetry, and physical dosimetry.

Radiation Emergency Medicine Network Council

A cooperative system has been developed between specialized medical institutions and specialists in various places in Japan to cope with severe injuries caused by radiation exposure including gastrointestinal disorders, hematological disorders, and skin disorders.

Chromosome Network Council

With the standardization of chromosome analysis methods and with the improvement of biological dosimetric techniques, a system of cooperation with specialists to evaluate radiation doses by analysis of chromosome aberrations has been established.

Physical Dosimetry Network Council

A network has been established to perform rapid and accurate dose estimation and evaluation of contamination in the event of a radiation accident in nuclear or radiation facilities.

Local organizational system for radiation emergency medicine

In Japan, the medical system for radiation emergencies is currently being constructed in accordance with disaster prevention plans of local governments where nuclear facilities have been established. Within the framework of each local nuclear disaster prevention plan, establishment of a separate collaborative system by each local government with NIRS is mandatory and the plan must specify the steps to be performed in the smooth transfer of patients from an accident site to the medical facility at NIRS, including radiation protection management.

2) Training

The primary goal for training is the development of radiation emergency medicine skills for medical professionals and disaster response personnel; these include doctors and nurses involved in treating victims from a nuclear disaster (NIRS Course “Radiation emergency medicine”), first responders, and nuclear establishment employees (NIRS Course “Radiation emergency medicine for first responders”). Because the numbers of applicants for both courses increased after the Fukushima accident, the number of times to hold each course has been increased.

Development of radiation emergency medicine in Asia

1) Training courses for foreign medical professionals organized by NIRS

Upon a request from the Korea Institute of Radiological & Medical Sciences (KIRAMS), the NIRS Training Course for Korean Medical Professionals on Radiation Emergency Medical Preparedness was held from September 19-21, 2012.

2) International seminars/workshops

The NIRS/IAEA workshop on medical response to nuclear accidents in Asia was held from March 21-23, 2012 and March 11-13, 2013.

Reorganization of REMAT

On March 1, 2013, REMAT was reorganized with exclusive duty staff for the purposes of supporting patients of nuclear power disasters and to carry out and maintain duties based on the modified urgent radiation exposure medical care system. And the new center will concentrate on research activities relevant to practical emergency radiation medicine.
In the area of radiation emergency medicine, we have made basic and applied studies for clinical use of chelating agents in removing radionuclides, especially alpha emitters like plutonium or uranium that are incorporated into the body.

**Experimental decontamination therapy**

To evaluate decontamination effects of chelating agents on removal of uranium, a mouse model of simulated wound contamination and a high throughput (HTS) method for bioassay of tissue contents of uranium were established (Fig. 1).

The HTS method refers to the methodology used to estimate the concentration of uranium in tissue samples. In this study (Fig. 2), the concentration of uranium in the kidney and the urine of the mouse was measured with an inductively-coupled plasma-mass spectrometer (ICP-MS, SII SPCQ700-II) after separating uranium from matrix components using the closed vessel microwave digestion system (CEM Discover SP-D). This digestion system can digest up to 0.3g (dry wt.) tissue sample in 10 minutes including cool down time and the ICP-MS can measure at least 10 samples per hour. The method which combined the digestion system and the ICP-MS made it possible to increase the amount of throughput by as much as 5 times compared to a conventional method.

Studies on the removal of uranium contamination clarified that-pamidronate and zoledronate, which are 3rd generation bisphosphonates widely used in clinical practice, were as effective as etidronate, a known positive bisphosphonate (Fig. 3). These agents were clarified to suppress uranium-induced nephrotoxicity both clinically and pathologically with reduction of uranium content in the kidneys. In addition, in order to find more effective chelating agents, we have been collaborating with researchers at home and abroad. In the past two fiscal years, some newly synthesized agents have been tested in this wound model.

**Biomarkers for uranium nephrotoxicity**

Immediate detection of uranium toxicity is important to decide how clinical therapy should be contacted for contaminated patients. To find better biomarkers to detect acute uranium nephro-
toxicity, several molecules in urine were tested using uranium-contaminated rats. Kidney Injury Molecule-1 (KIM-1), albumin and β2-microglobulin were found to be more sensitive clinical indicators in comparison to conventional clinical markers, blood urea nitrogen and serum creatinine (Fig.4). In addition to those urinary biomarkers, we have been estimating the suitability of using urinary mRNA for early detection of uranium toxicity.

![Graph showing urinary total protein and glucose levels](image1)

![Graph showing total uranium content in the right kidney](image2)

Fig.3 Pamidronate protects against acute uranium nephrotoxicity in mice

![Graphs showing BUN, CRE, albumin, β2MG, and KIM-1 levels](image3)

Fig.4 Kidney injury molecule-1 as well as albumin and β2-microglobulin are sensitive indicators in uranium-induced acute renal injury in rats.
After accidental exposure to a high dose of ionizing radiation (IR), providing proper therapeutic strategies for patients with acute radiation syndrome (ARS) remains a major problem. At relatively high doses, gastrointestinal and vascular syndromes emerge in a dose-dependent manner, which lead to multi-organ dysfunction. A recent report showed that transplantation of mesenchymal stem cells (MSCs) improved wound repair from severe radiation damage and also suppressed uncontrolled successive inflammation waves in a local severe radiation victim[1]. Although precise mechanisms have not been clarified, therapeutic effects of MSCs are believed to depend on secreted factors from MSCs rather than differentiating capacity into regenerating tissue.

We are investigating the biological function of exosomes, one of the secreted factors, for radiation injury using a human bone marrow-derived MSC line (Fig. 1A). Exosomes are bilipid membrane vesicles (30-100 nm in diameter) released into the extracellular milieu. Exosomes contain bioactive proteins and RNAs; therefore they regulate biological function in exosome-receiving cells (Fig.1). Besides effects about modulating biological functions in receiving cells by exosomes, extremely high stability of this vesicle has also been shown. The contents of exosomes (such as proteins and RNA) are protected from degradative enzymes and chemicals. Moreover, exosomes have biological activity even after storage at −20°C for 6 months[2]. Thus, biological aspects of exosomes have since emerged as not only ‘intracellular communication’ but also ‘therapeutic application.’ Indeed, it has been shown that exosomes derived from MSCs under normal culture conditions have therapeutic effects for cardiac infarction[3].

We recently found that exosomes of MSCs cultured under normal conditions have therapeutic effects against radiation injury (Figs.2 and 3); exosomes could support survival of radiation-damaged rat small intestinal epithelial cells (IEC6) (Fig.3). Surprisingly, we also found that exosomes of MSCs cultured in restricted conditions conversely enhanced radiation-induced cell death, and vice versa (Fig.3). Thus, exosome functions of MSCs strongly depend on the environmental conditions surrounding the MSCs.

**Perspective**

Comparing exosomes exhibiting contradictory effects allows us to clarify key factors for modulating cellular viability of radiation damaged cells, and these factors themselves also could be applied to ARS treatment. Moreover, it also allows us to manipulate the biological function of exosomes by clarifying the intracellular mechanism leading to key factor production. Our research could lead to effective and practical therapeutic strategies using MSC transplantation combined with proper agents.
Fig. 2  Experimental procedures. (A) Exosome derived from MSCs cultured under each restricted condition was collected by ultra-centrifuge methods. (B) IEC6 cells were treated with each exosome collected in (A) at 20 min post 4 Gy irradiation. After culturing for 24 hours, each cell was analyzed by the trypan blue dye exclusion test.

Fig. 3  Biological effects of MSC-derived exosome against radiation-damaged IEC6 cell growth. The detailed procedure was shown in Figure 2B. Statistical analysis was conducted using student-t test. *: p<0.05. **: p<0.01.

References
Summary

We conducted a rapid and sensitive fluorescence in situ hybridization method using peptide nucleic acid (PNA-FISH) to evaluate the yield of multicentric chromosomes induced in cultured human peripheral blood lymphocytes (PBLs) by high-dose gamma-irradiation. The PNA-FISH allowed us to unequivocally determine centromeres in complexly rearranged chromosomes, thus validating its usefulness in biological dosimetry.

Introduction

Radiation exposure causes DNA strand breaks that lead to chromosome aberrations. Among them, the yield of multicentric chromosomes, as represented by dicentric chromosomes (dicentrics), is considered to be a reliable, sensitive, and specific indicator of recent acute exposure to ionizing radiation. In the dicentric chromosome assay (DCA) using the conventional Giemsa-staining method, the frequency of dicentrics per PBL from a radiation-exposed individual is applied to a dose-response curve that has been established by in vitro exposure experiments, and then his/her exposure dose can be estimated.

A PNA-FISH method using centromeric and telomeric repeat sequences was proposed as an alternative methodology that detects dicentrics accurately\(^1\) (Fig.1). For conducting large-scale biodosimetric examinations, the DCA using the automated scoring of PNA signals would be greatly helpful. However, because of the complicated genomic organization of the centromere, the distribution of alphoid DNA in chromosomes has not been fully investigated. We used our modified technique to detect chromosomal sites of alphoid DNA and evaluated the yield of dicentrics induced in cultured human PBLs by high-dose gamma-irradiation.

*Peptide nucleic acid (PNA) is a nucleic acid mimic that contains a pseudo-peptide backbone composed of charge neutral and achiral N-(2-aminoethyl)glycine units to which the nucleobases are attached via a methylene carbonyl linker. PNA hybridizes with high affinity to complementary DNA sequences, forming PNA-DNA complexes.

Distribution and size variation of alphoid DNA in human chromosomes

By our protocol, centromeric regions can be detected in hybridization times as short as 1-2 h, with the detection efficiency of 100%\(^1\). The results of PNA-FISH with the centromeric probe on R-banded human chromosomes are shown in Figs.2 (a) and (b). Alphoid DNA sites were present in the centromeric regions of all chromosomes, although the hybridization signal intensity varied...
between chromosomes. In addition to the inter-chromosomal variation, we detected possible inter-individual variation in the size of alphoid DNA sites, which had been difficult to precisely analyze by conventional molecular and cytogenetic methods (Fig. 2 (c)).

**Application of PNA-FISH to biological dosimetry**

Centromeres in radiation-induced multicentric chromosomes are difficult to determine by the conventional Giemsa-staining technique, especially when complicated chromosome rearrangements are induced by high-dose irradiation. By PNA-FISH, centromeric regions of lymphocytes irradiated in vitro with $^{60}$Co gamma rays were rapidly detected in chromosomes (Fig.3). However, chromosome breakage occurring in the vicinity of alphoid sequences outside the functional centromere unit may produce additional minor signals (Fig.4). The development of sophisticated software specific for the image analysis of PNA-FISH is necessary.

Interestingly, the distribution of dicentrics per cell in the high-dose range was different from that in the low-dose range (Fig. 5). To our knowledge, this is the first report on the evaluation and characterization of the yield of multicentric chromosomes induced by high levels of irradiation, as high as 20 Gy, using PNA-FISH. It should also be noted that the dicentric yield determined by the conventional Giemsa-stain analysis did not differ from that determined by the PNA-FISH analysis, contrary to another published report.

**References**


In the nuclear fuel industry, internal contamination by alpha particle-emitting actinides is a serious health problem for workers. Since the most common pathway of actinide intake inside the body is inhalation, wearing masks is necessary to prevent it; however, compounds containing actinides that deposit on healthy skin seldom enter the body. On the other hand, wound contamination by actinides is a serious problem, because it can easily cause internal contamination and intake from wounds cannot be neglected. The evaluation of the wound contamination with actinides is, therefore, necessary. Plutonium is especially known to adversely affect the body for a long time by physiologically accumulating in lung and bone. Elemental analysis is required to determine the atomic species of contaminating compounds of the wounds and decide the therapeutic strategy.

The standard method for rapid evaluation of wound contamination by alpha particles is to measure the number of particles. Although information on atomic species can be obtained after chemical purification of the samples, which takes a few days, a rapid distinction between plutonium and other actinides is too hard to provide. We have proposed x-ray fluorescence (XRF) analysis as a new technique to give a rapid diagnosis for the presence of plutonium in a wound. X-ray fluorescence analysis provides qualitative and quantitative analyses of atoms instead of radioactivity, and therefore it should be effective for nuclei having a long half-life such as plutonium and uranium, because the number of atoms per unit radioactivity is large in those atoms.

We established a methodology to rapidly evaluate the wound contamination from heavy atoms using a portable XRF analyzer. For easy handling during development of the method, we used stable lead as heavy atoms contaminating the wound; however we expect that the established method will be easily extended to actinides in the future.

Two types of wound models, dry and bleeding wound models, were prepared to develop the methodology for evaluation of lead contamination in wounds by XRF (Fig.1). The dry wound model used several epoxy resin skin phantoms, which was made by mixing epoxy resin (crystal resin, Nissin Resin Co., Ltd., Yokohama, Japan) with several concentration of lead-containing white oil paint solution. Lead-containing white oil paint solution consisted of white oil paint (Silver White, Kusakube Co., Ltd., Saitama, Japan) containing 60.5 % lead and solvent for oil paints (Odorless

**Highlight**

**Evaluation of wound contamination with heavy atoms by x-ray fluorescent spectrometry**

Hiroshi Yoshii
E-mail: yoshii@nirs.go.jp

![Image of experimental setup](image_url)

In the nuclear fuel industry, internal contamination by alpha particle-emitting actinides is a serious health problem for workers. Since the most common pathway of actinide intake inside the body is inhalation, wearing masks is necessary to prevent it; however, compounds containing actinides that deposit on healthy skin seldom enter the body. On the other hand, wound contamination by actinides is a serious problem, because it can easily cause internal contamination and intake from wounds cannot be neglected. The evaluation of the wound contamination with actinides is, therefore, necessary. Plutonium is especially known to adversely affect the body for a long time by physiologically accumulating in lung and bone. Elemental analysis is required to determine the atomic species of contaminating compounds of the wounds and decide the therapeutic strategy.

The standard method for rapid evaluation of wound contamination by alpha particles is to measure the number of particles. Although information on atomic species can be obtained after chemical purification of the samples, which takes a few days, a rapid distinction between plutonium and other actinides is too hard to provide. We have proposed x-ray fluorescence (XRF) analysis as a new technique to give a rapid diagnosis for the presence of plutonium in a wound. X-ray fluorescence analysis provides qualitative and quantitative analyses of atoms instead of radioactivity, and therefore it should be effective for nuclei having a long half-life such as plutonium and uranium, because the number of atoms per unit radioactivity is large in those atoms.

We established a methodology to rapidly evaluate the wound contamination from heavy atoms using a portable XRF analyzer. For easy handling during development of the method, we used stable lead as heavy atoms contaminating the wound; however we expect that the established method will be easily extended to actinides in the future.

Two types of wound models, dry and bleeding wound models, were prepared to develop the methodology for evaluation of lead contamination in wounds by XRF (Fig.1). The dry wound model used several epoxy resin skin phantoms, which was made by mixing epoxy resin (crystal resin, Nissin Resin Co., Ltd., Yokohama, Japan) with several concentration of lead-containing white oil paint solution. Lead-containing white oil paint solution consisted of white oil paint (Silver White, Kusakabe Co., Ltd., Saitama, Japan) containing 60.5 % lead and solvent for oil paints (Odorless

**Fig.1** Schematic structures of epoxy resin skin phantom and blood phantom with overviews of the observations of the dry and bleeding wound models.
Petroleum, Holbein Works, Ltd., Osaka, Japan) for dilution to the desired lead concentration. The concentrations of lead in the produced phantoms were 0, 2, 5, 10, 15, 20 ppm, and both diameter and height of the epoxy resin skin phantoms were 10 mm. The density of the epoxy resin skin phantoms, 1.06 g cm$^{-3}$, is similar to that of the human skin. The bleeding wound model was constructed by putting a blood phantom containing liquid blood on each of the epoxy resin skin phantom. For production of the blood phantom, small well acrylic cases were prepared. The acrylic cases, which had a thickness of 2 mm, each had an 8-mm hole bored into them, and both sides of the hole were sealed with 7.5-μm thick kapton films. The volume of the hole was, therefore, 100 μL. Liquid blood (Mouse Blood, Kohjin bio Co., Ltd., Tokyo, Japan) was enclosed in each acrylic case to make the blood phantom.

We employed the XL3t-950S (Thermo Fisher Scientific Inc., Billerica, MA) as the XRF device. In the measurements, the x-ray tube voltage was set to 50 kV, the current was set automatically, and the main filter of the XL3t-950S was chosen. Accumulation times were set to 5 s. According to the users’ manual of this device, equivalent dose of skin is estimated as less than 16.5 mSv for a 5 s exposure time when the device is applied to the skin surface. In addition, the equivalent dose limit of human skin is recommended by the ICRP as 500 mSv per year for workers[1].

Fig. 2 shows the measured XRF spectra for the dry wound model using 0 ppm and 20 ppm lead phantoms and the bleeding wound model using the 20 ppm lead phantom in the energy range from 5 to 15 keV.

Two peaks were also clearly found for both dry and bleeding wound models using the 20 ppm lead phantom and they could be identified as for Pb Lα and Lβ, respectively. The blood-derived peak of Fe Kα appeared for the bleeding wound model.

In the present measurements, minimum detection limits (MDLs) obtained by the method similar to that of Gherase et al. [2] as concentrations corresponding to three times the uncertainty of the peak areas for the 0 ppm phantom for the dry and bleeding wound models, were 1.8 and 9.6 ppm, respectively. The presently obtained MDL for the dry wound model was comparable to reported MDLs for polyester resin skin phantoms containing arsenic and selenium amounts of 1.05 and 0.88 ppm, respectively[2]. In previous measurements[3], the detection limit in a naked bone phantom containing lead was 3.3 ppm, which was evaluated using two times the uncertainty. MDLs are usually given using three times the uncertainty, and MDL was estimated as about 5 ppm for the study[3]. The present MDL value for the dry wound model is sufficiently low; this difference is mainly caused by the difference of the densities of the phantoms.

In conclusion, we proposed the basic methodology for evaluation of lead contamination in a wound by using the portable XRF device. Low MDL and short diagnostic time were achieved. Further measurements using various thicknesses of blood phantoms are required to improve accuracy of evaluation. In the long term, we expect this methodology will be applicable to evaluation of wound contamination from actinides (uranium and plutonium).

**References**


Local organizational system for radiation emergency medicine (REM)

In Japan, the medical system for radiation emergencies has been constructed in accordance with the disaster prevention plans of local governments where nuclear facilities are located. The medical system has a three-layered arrangement of hospitals i.e., primary, secondary and tertiary level hospitals. NIRS is designated as both a regional and national tertiary level hospital under that scheme (Fig.1). Within the framework of each local nuclear disaster prevention plan, establishment of a co-operative system by each local government with NIRS is mandatory and the plan must specify the steps to be taken in the effective medical care and smooth transfer of patients from an accident site to the appropriate level of medical facilities, with appropriate radiation protection management.

One of the missions of NIRS is to enforce the radiation emergency medical system in Japan. As the tertiary level hospital of REM in Japan, NIRS continues to play an important role for increasing effectiveness of the organization through co-operative work with primary and secondary level hospitals.

The status of radiation emergency medical systems in Japan since the accident at TEPCO Fukushima Daiichi NPP

Hideo Tatsuzaki, Masaya Hasegawa
E-mail: tatsuza@nirs.go.jp

Fig.1 Organizational System of Radiation Emergency Medical in Japan
As a part of this project, NIRS has been annually holding conferences for co-operation in REM in each prefecture having nuclear power plants or related facilities in eastern Japan.

Since the accident at Tokyo Electric Power Company (TEPCO) Fukushima Daiichi NPP, the central government, the Fukushima government, and other local governments together with hospitals and NIRS have been taking tremendous actions to deal with the situation according to the systems mentioned earlier. Based on the lessons learned from the accident, however, it has become apparent that local nuclear disaster prevention plans need to be reexamined in the context of the current organizational system of REM.

In order to reflect the experiences from the TEPCO Fukushima Daiichi NPP accident to local plans, conferences were held in 8 NPP located prefectures in Eastern Japan, namely Hokkaido, Aomori, Miyagi, Fukushima, Niigata, Ibaraki, Kanagawa, and Shizukoka. Participants were medical staff from primary or secondary radiation emergency medical hospitals, fire brigade officials, Self Defense Forces officials, local governments, and NPP companies. In FY2011, the conferences focused on presenting the response of NIRS and local governments to the Fukushima accident and then the participants discussed problems recognized from the accident and considered future REM systems (Fig.2).

NIRS also organized the annual general meeting of local governments on REM in Tokyo in February 2012 (Fig.3). Medical professionals and administrative officers from 19 NPP located local governments who are responsible for dealing with radiation and nuclear accidents attended the meeting. NIRS and Fukushima Medical University made presentations on their activities in Fukushima Prefecture. After the presentations, revision of REM guidelines, and issues such as patient transfer and stock pile of internal decontamination agents such as Prussian Blue and DTPA were discussed, reflecting on experiences after the accident.

In addition to these subjects, installation of whole body counters (WBCs) was discussed i.e., where WBCs should be located at places other than secondary level hospitals based on the explanation of the new operational guideline by the Nuclear Safety Commission succeeded by the Nuclear Regulation Authority (NRA) from September 2012. Officials from the relevant ministries and agencies such as the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of Defense (MOD), the Fire and Disaster Management Agency (FDMA), Japan Coast Guard and the National Police Agency also attended this meeting as observers.

**Three Network Meeting**

NIRS organizes three experts’ networks, namely Chromosome Analysis Network, Physical Dose Assessment Network, and Radiation Emergency Medical Network.

The Chromosome Analysis Network has shared the experiences of each member in response to the TEPCO Fukushima Daiichi NPP accident, and it was recognized that the biodosimetry results well agreed with those of personal dosimeters. The network also checked cooperation among the member organizations, increased the number of members in order to geographically cover all Japan, and the number of experts that would be working in five years. The importance of training of new experts through training courses to maintain the expertise was stressed.

Physical Dose Assessment Network

In the meetings of this network, experts discussed screening levels used for the NPP accident, and calibration and maintenance of WBCs.

Experts from NIRS visited 9 hospitals with WBCs and discussed the problems in operation and maintenance and then suggested possible solutions.

A workshop entitled “Status and ideal status of WBC in radiation emergency medicine —Based on TEPCO Fukushima Daiichi NPP Acci-dent—” was held at NIRS on March 5, 2012, co-organized by NIRS and MEXT. There were 82 participants including the network members and ten lectures were presented (Fig.4). The workshop clarified the limitations of transfer phantoms, discussed the need of standardization, and discussed ways to explain results to people after WBC measurements.

Radiation Emergency Medical Network

The meetings of this network discussed reestablishment and maintenance of REM systems and proper responses for low dose exposure to residents during disaster mitigation. Furthermore, in order to facilitate smooth acceptance of contaminated patients by hospitals anywhere in Japan, the network announced its “Request
from the Radiation Emergency Medical Network to staff members in medical facilities regarding patients’ management related to TEPCO Fukushima Daiichi NPP Accident” via the NIRS home page.

**24-hour Response System**

As a third level radiation emergency medical hospital, NIRS has a function to support other facilities or professionals. As an instrument for direct support, NIRS has been operating a telephone line consultation system for professionals. This system operates 24 hours a day, 7 days a week. A staff member of the Research Center receives calls during working hours, and the system connects callers to staff members of the Research Center who are responsible at night or on holidays. In FY 2011 and FY 2012, 92 consultations were carried out (as of January 31, 2013).

**Survey of REM in Japan**

In FY 2012, to increase the effectiveness of the organizational system of REM in Japan, NIRS carried out an extended survey for investigating the current situation of REM in terms of human resources, facilities and equipment. A questionnaire was sent to the organizations where NPPs were located such as: local governments throughout Japan; primary and secondary level hospitals throughout Japan; and local firefighting head offices in eastern Japan. Answers to the questionnaire were used to clarify the status and points for improvement in each organization. This research project was supervised by specialist committees (Fig.5) consisting of disaster medical care specialists, crisis management specialists, radiation protection specialist and REM specialists.

Responses were received as follows: 19 local governments out of 19; 92 hospitals out of 123; and 177 firefighting head offices out of 202. These represented reply rates of 100%, 75% and 88%, respectively. Through this survey, various types of key information were gathered concerning all resources relevant to REM. Therefore, it will now be possible to further clarify the problems and identify solutions within the organization of REM in Japan. As one type of key information, the availability of REM equipment among hospitals was found to be as indicated in Table 1.

**Exercise**

Disaster Medical Center-NIRS Joint Exercise

The Disaster Medical Center (DMC)-NIRS Joint Exercise was conducted on August 23, 2012 (from 9:51 to 20:54) at NIRS, DMC, and on roads between them. The DMC is the national center for disaster medicine. NIRS has an agreement with the center to cooperate in case of NIRS accepting severely injured patients.

<table>
<thead>
<tr>
<th>Table 1 Availability of REM equipment in primary and secondary level hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># of deployment</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Secondary Level Hospitals</td>
</tr>
<tr>
<td>181</td>
</tr>
<tr>
<td>Primary Level Hospitals</td>
</tr>
<tr>
<td>79</td>
</tr>
<tr>
<td>TTL</td>
</tr>
<tr>
<td>260</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Median value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Level Hospitals</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>Primary Level Hospitals</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>TTL</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>
The objective of the exercise was to make staff aware of the transportation and medical management in both hospitals in case a contaminated patient must be transported to DMC after initial treatment at NIRS (Fig.6).

Two special cars for REMAT (Radiation Emergency Medical Assistance Team) were used for the exercise. Twelve players and 15 exercise controllers or observers joined the exercise from the NIRS side. Many important lessons were identified during the exercise, for example a need to improve the communication system during transportation.

Overall, this exercise was thought to be important as the first joint exercise with an agreement hospital. The cooperation between two hospitals were strengthened. Additionally, many staffs of DMC recognize the procedure and meaning of accepting patients contaminated with radioactive substances.

Hachinohe City Hospital-NIRS Joint Exercise

The Hachinohe City Hospital-NIRS Joint Exercise was conducted from September 4 to 7, 2012 at the City Hospital and NIRS. The Hachinohe City Hospital (HCH) is a secondary level radiation emergency hospital located in Aomori Prefecture, in northern Japan. The Rokkasho reprocessing plant for nuclear fuels and nuclear power plants are located near the HCH; thus this hospital is well-prepared for accepting contaminated patients.

Twelve members from NIRS joined the exercise. The exercise consisted of movement between two hospitals by a REMAT car (Fig.7), lectures and drills for the HCH staff members, calibration of a WBC at HCH, radiation protection practices in a treatment area, internal contamination dose assessment, and communication exercise using on-board systems. Forty resident doctors and 20 other medical workers participated in the lecture and drill. The lecture, “Radiation protection for REM” and the drill for using survey meters were given by 10 people from NIRS. As a part of internal contamination dose assessment, an inter-comparison between the WBC on the REMAT car and that of the HCH was performed.

Some of the HCH workers did not have enough knowledge on radiation exposure, radiation protection, or dose measurements, thus instructions from NIRS staff on survey meters and radiation protection gear, were thought to be essential. This experience confirmed that assistance by NIRS in exercises at other medical facilities is important and will play an important role in establishing the REM system.
Background

Radiation can enable the improvement and development in many fields. Radiation, however, should be used in controlled environments with strict regulations. Well trained and educated personnel who handle radioactive substances are also fundamental to safe operation. Although these principles are effective to maintain peaceful and safe use of radiation, they do not guarantee absolute safety such as in case of emergency situations. Therefore, countermeasures to mitigate and control radiation and nuclear accidents must be prepared since accidents are still a possibility. When victims are exposed to radiation or contaminated with radioactive substances, the medical workforce must treat them with proper understanding of radiation. A radiation emergency medicine (REM) team is multidisciplinary team consisting of medical staff, radiation dosimetry and radiation safety experts who provide appropriate medical response to radiation or nuclear accident victims. Trained specialists are the basis of REM. Unlike other medical fields, it is difficult for medical and related personnel to accumulate experience in REM because of the rare occurrence of such incidents. For this reason, thorough training of the REM staff is the key for ensuring the capability to handle incidents.

NIRS activities for REM

NIRS is the only comprehensive research institute in Japan for studying radiation and its effects on humans, and it has also been designated as the only national tertiary radiation emergency hospital. When the JCO criticality accident occurred in 1999 in Ibaraki Prefecture, NIRS received three victims who had experienced high radiation exposure. Aside from this case, NIRS workers have dealt with past radiation-related emergency situations and in each incident, besides provision of medical care and medical follow-up, researchers have identified the radionuclides, carried out dose assessments, and provided reporting of information to the government and general public.

As preparation for radiation and nuclear emergencies, NIRS has been providing a variety of educational opportunities such as training courses, seminars, and lectures to national medical staff and first responders to maintain and enhance the establishment of REM preparedness in Japan.

In addition to these domestic activities, NIRS has cooperated in a wide variety of activities of the IAEA and the WHO, and contributed to the establishment of a global radiation emergency medical network based on the institute’s abundant experiences. NIRS has sent medical experts to third world countries where there are patients of radiation accidents. Additionally as common practice, NIRS has sent REM experts to conduct international training courses as invited lecturers and also to participate in expert meetings for compiling universal REM guidelines. All of these dispatches were requested by the responsible international organizations.

Activities for promoting REM in Asia

Since 2001, NIRS has conducted international training courses and workshops on REM for medical personnel from various Asian countries where the use of radiation has been increasing. (Fig.1) These activities are aimed at training medical professionals directly who will be in charge of REM in their respective countries. These programs basically consist of lectures which include the experience acquired in the JCO accident and the most up-to-date information on REM obtained from NIRS’s global activities, desktop drills and practical drills. Most of these global activities were organized in cooperation with IAEA and/or WHO. For the past 12 years (to January 2013), the total number of medical specialists who joined NIRS training courses and workshops from Asian countries was 365. The participants have gone on to share the knowledge and skills which they obtained during the training courses and workshops with medical REM professionals in their home countries.
What NIRS did for REM in Asia in 2011 & 2012

Although the activities of REMAT® were intended to ensure a rapid response to radiation emergencies abroad, the preparation paid off at the time of the TEPCO (Tokyo Electric Power Company) Fukushima Daiichi Nuclear Power Station accident in March 2011. NIRS was ready to send the first REMAT® team before the government ordered the dispatch in the early hours on March 12. Besides on-site activities, other staff members at NIRS provided support to the on-site REMAT® team. The strong point of REMAT® is its ability to make an immediate response to support REM in other countries. At the request of international organizations or foreign governments, the president of NIRS can make an immediate decision to send a team. REMAT® is equipped with the most advanced portable, radiation measurement equipment, communication devices, in addition to some medicines. Since its establishment, REMAT® has maintained mobile equipment by testing its capability both in Japan and overseas and it has been kept ready to function 24-7.

*REMAT® is a registered trademark of NIRS.

Symposium on the Accident of TEPCO Fukushima Daiichi Nuclear Power Station-What was seen and not seen by others?-

NIRS organized this symposium on August 26, 2011. It was co-organized by the Radiation Emergency Assistance Center/Training Site (REAC/TS) and in co-operation with the U.S Department of Energy (DOE), National Nuclear Security Administration (NNSA), and IAEA.

Although various issues associated with the accident became widely known as time went by, there were very few opportunities for foreigners living in Japan to get correct information and explanation about the ongoing problems. The symposium focused on three topics namely “Response system for REM in Fukushima”, “Contamination of environment and foods”, and “Public communication and social problems”. Two medical doctors and two health physicists from REAC/TS and IAEA joined NIRS staff for presentations. These topics were discussed and analyzed from the viewpoint of REM experts. It was particularly notable that nine persons from seven foreign embassies in Tokyo attended the symposium (Fig. 2).

Workshop on REM in Asia 2012 and Training Course on REM for Korean Medical Professionals

These two events have been promoted as continuing activities for Asian medical workers during the past decade.

The workshop on REM in Asia 2012 was entitled “NIRS Workshop on Medical Response to Nuclear Accidents in Asia 2012” and held from March 21 to 23, 2012. It was organized by NIRS with co-operation from IAEA. A total of 17 participants from China, India, Indonesia, Korea, Malaysia, Mongolia, Pakistan, Philippines, Saudi Arabia, Sri Lanka, Thailand, and Viet Nam attended.

The training course on REM for Korean medical professionals, entitled “NIRS-KIRAMS Joint Seminar on Radiation Emergency Medicine 2012”, was held at the request of the Korea Institute of Radiological & Medical Sciences (KIRAMS) which is the core organization for REM in Korea. The 19 participants were medical professionals and administrators who are involved in REM in Korea.

Although both of these programs consisted of lectures, desktop drills, and practical drills along with discussions as in past training courses, information on several issues identified in the aftermath of the TEPCO Fukushima NPS accident were newly added.