In this midterm plan at NIRS, the Medical Exposure Research Project (MER-project) has the mission to investigate the frequencies and doses of domestic medical radiation uses and to summarize the current status worldwide concerning radiation protection in medicine. Based on the dose data together with basic and epidemiological data, medical radiation risk will be estimated. The results will be put into a database. By sharing the data among the involved medical staff and researchers, the MER-project will contribute to provide the scientific and practical basis for the justification and optimization of radiation protection in medicine. These data are supposed to be submitted to the UNSCEAR.

To achieve the above plan, five issues have been currently undertaken: 1. Estimations of examination frequencies and organ doses in X-ray CT, PET, PET/CT, and heavy ion particle therapy; 2. Establishment of an organization for the collection of domestic data on radiation protection in medicine; 3. Estimations of secondary cancer risk of the patients in cervical cancer treatments; 4. Study of radiobiology in radiation use in medicine; and 5. Development of the method for risk-benefit communications in medicine.

For the estimation frequencies and organ doses, the data of X-ray CT examinations for pediatric patients have been collected from DICOM data in the National Center for Child Health and Development (NCCHD) Hospital in cooperation with doctors and radiologists in that hospital by using a program specially developed for this purpose. In Chiba Children’s Hospital, the data have also been extensively collected and the data for the recent 4 years on CTDI, DLP and so on were summarized. Phantom measurements of organ doses have been continued in both two hospitals as the basic data for optimization.

For PET diagnoses, the basic physiologically-based pharmacokinetic model (PBPK model) was made to consider the physiological differences among patients.

For heavy ion therapy, dose estimations of patients due to secondary exposures were estimated based on the data of both measurements and Monte Carlo simulations.

For the secondary cancer risk estimations in radiotherapy of cervical cancer, organ dose distribution is to be estimated. Gel dosimeters were selected in order to obtain 3D distribution of dose, and the fundamental data on the characteristics of the gel were experimentally obtained. Based on the data of CT images of more than 100 patients, a physical pelvic phantom was developed. The analyses of secondary cancers of 286 cases among 4,181 patients are being performed.

On radiobiology in medical exposures, the differences of the patterns of DNA breaks and repairs were studied in a comparison between young and adult mice. It was found that the speeds of DNA repairs of bone marrow in infant mice were faster than those of adult mice.

Online and off-line data collection system were under development for establishment of the system to follow-up the medical radiation exposure histories of the patients, which is the concept of the IAEA’s “Smart Card/SmartRadTrack project”.

For the nation-wide exchange of the information on medical exposures, two general meetings of the Japan Network for Research and Information on Medical Exposure (J-RIME) were held in April 2012 and in January 2013. Four working groups (Protection for pediatric patients, Smart Card system, Nationwide survey, and Publicity) were organized in J-RIME and they have been working on various tasks. The J-RIME has published the newsletter “Lime-light” three times until the end of the FY2012.

For risk communications, the draft of a pamphlet for mothers of young children was made based on information identified as necessary by medical staff in Chiba Children’s Hospital.
Fig. 1  The 4th plenary meeting of J-RIME

Fig. 2  Newsletter of J-RIME
Investigations on frequencies and doses in X-ray CT examinations in pediatric hospitals

Keiichi Akahane
E-mail: akahane@nirs.go.jp

X-ray CT examinations are the major sources of radiation exposures in medicine for patients. Among them, more attention should be paid to pediatric patients because of their higher radiation sensitivity compared to adults. As one of the research issues of the Medical Exposure Research Project (MER-project), an investigation on frequencies and doses has been performed in two pediatric hospitals, the National Center for Child Health and Development (NCCHD) Hospital, and Chiba Children’s Hospital. In addition, dose measurements have also been done by using pediatric anthropomorphic phantoms and glass dosimeters in these hospitals.

In the NCCHD Hospital, about 4,000 X-ray CT examinations are performed every year. For this study, the data of about 40,000 examinations for 10 years were selected. Original software has been developed and applied in the NCCHD Hospital to automatically collect data on the kinds of diagnoses, and patients’ data such as gender, age, etc. from DICOM-tag information. In FY2012, the data of the period from May 1st 2002 to February 29th 2012 were extracted and put into the database. For example, the numbers of patients extracted were 163 for 214 chest examinations and 151 for 194 abdomen (pelvis) examinations in 2010. Fig. 1 shows the numbers of patients for each age less than 16. The percentage of examinations for head was about 47% of the total examinations.

Fig. 1 Numbers of patients for each age at NCCHD, 2010.
The examinations for abdomen were about 26% of the total, and about half of them were for patients less than 1 year old.

In Chiba Children’s Hospital, the number of X-ray CT examinations is about 1,600 per year. About 40,000 exams for 4 years were set for the data analyses. The number of X-ray CT examinations performed in the period from October 2008 to July 2011 was 4,801 (male, 2,767; female, 2,034), and the number of the patients was 2,546 (male, 1,443; female, 1,103) (Fig.1). The largest number of the examinations was for head CT, about 52.5% of all examinations. The second largest was CT for auditory organs, about 8.7% of the examinations. The ratios of the numbers of patients were similar to those of the examinations (Fig.2).

The organ doses in CT examinations were also planned for considering optimization in radiation protection. By using anthropomorphic pediatric phantoms and glass dosimeters, organ doses have been directly measured under the exposure conditions in daily uses in NCCHD hospital (Fig.3). These data will be referred to in establishing the diagnostic reference levels for pediatric patients in CT examinations.
Radiotherapy is one of the effective methods for cancer treatments. On the contrary, the secondary cancer incidents have come to be a problem as the survival ratio is increasing in radiotherapies. In NIRS, follow-up for cervical cancer patients has been performed and data on these patients have been stored in a database. For risk estimations of secondary cancers of the organs of not only near but also in the outer region of the cancer, the development of a pelvic phantom was planned that consisted of gel dosimeters, bone equivalent material and PMMA. The data of three-dimensional dose distributions can be obtained using the gel dosimeter.

As a first step, the basic characteristics of the gel dosimeter have been studied. The gel dosimeter was made based on the standard protocol, and put into a water phantom. The phantom was irradiated with Ir-192 gamma rays to study the linearity of dose response comparing with glass dosimeters (Fig.1). After the irradiation, the phantom was scanned by using MRI. Basically, the linearity was confirmed at dose levels of less than 10 Gy (Fig.2).

In the second step, the effects of the wall width of the phantom and permeating oxygen through the wall were observed by using several cylindrical phantoms having different wall widths, because oxygen interferes with the gel phantom measurements. As a result, the MRI artifacts were about 5mm in size, and the effects of oxygen were seen at distances less than 5mm from the wall (Fig.3). For reading of doses in the gel phantom, the volume at a distance of 5mm or less from the wall should be excluded.

Since air is present inside the intestines of patients, as the third...
step, the effects for dose distributions were measured setting CaSO4 as the pelvic bone and air as the gas inside the rectum (Fig.4). The doses of glass dosimeters were similar compared to those of the radiotherapy planning system in the region with no air. The dose maps (distribution) in Fig.5 show a comparison between the system behind (left) and forward area (right) around the air region. The doses were about 10% lower than those of the system behind the air region (Fig.5).

Fig.2 Linearity of the GEL phantom

Fig.3 Effects of the wall width of the phantom and permeating oxygen

Fig.4 Geometry of the phantom with CaSO4 and air inside

Fig.5 Dose distributions obtained by using gel dosimeter inside the phantom with CaSO4 and air inside