2017

Journal of JART

—English edition—

2017

The Japan Association of Radiological Technologists

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The Japan Association of
Radiological Technologists

CONTENTS

Note: The contents of this magazine are those that have been published in JART magazine.

Overview of the Japan Association of Radiological Technologists

The Japan Association of Radiological Technologists, a public interest incorporated association under the jurisdiction of the Ministry of Health, Labour and Welfare, was established in 1947 with the purpose of contributing to the health of citizens through raising the professional ethics of members, improving and furthering the study of medical radiology and medical radiological technology, and enhancing public health.

In light of the startling progress being made in the fields of image diagnostics and radiation therapy where radiological technologists work, it is necessary to stay constantly aware of the latest know-how and technology. JART collaborates with other certification agencies to enhance the capacity of all radiological technologists in general through providing lifelong learning seminars, short courses, academic conferences and numerous other learning opportunities. We believe that such activities constitute our obligation as medical professionals to the general public.

As the only medical profession that has "radiological" in its name, we strive to limit medical exposure, to raise the standing of our profession, and to realize a profession of specialist technologists that can be advertised. And we are committed to promoting services with you all for the provision of safe and secure medical care.

general principles

We will render our services to those in need of health care.

We will act as individual members of a health care team.

We will perform our duties in our field of specialty.

We will continue to study for the benefit of mankind.

We will respect and practice the policy of informed consent.

Publication of the English Version of Our Journal

Yasuo Nakazawa (President)

Approximately 30,000 copies of the *Journal of the Japan Association of Radiologic Technologists* are published monthly, and the journal is highly acclaimed by association members. The journal has three major roles. The first is to serve as a newsletter with information about training classes (i.e., continuing education) for association members that will equip them to use high-quality medical technology in collaboration with the public and medical personnel. The second role of the journal is to document research papers on clinical radiology that are routinely submitted by association members and papers regarding specialized technology in various fields. The third is to document manuscripts based on clinical technology that are contributed by members and non-members.

I will present a summary of the history of the Japan Association of Radiologic Technologists to inform clinical radiologists throughout the world of the work of clinical radiologists in Japan. The Japan Association of Radiologic Technologists was established in 1947 for the purpose of providing national certification for clinical radiologists. Subsequently, operations were implemented for the national certification to be recognized by the government, congress, the Japan Medical Association, and the General Headquarters of the Allied Powers. Thanks to considerable effort—truly blood, sweat, and tears—, the Clinical X-ray Technologists Act (Act No. 226) was promulgated in June 1951. Following that, the Clinical X-ray Technologist Law was revised in 1968 in response to various demands. In 1983, the Radiology Technicians Act and part of the Clinical X-ray Technologists Act were revised. The unification of professions, part of the present Radiology Technicians Act, was also accomplished. The scope of operations at this time includes routine X-ray examinations, X-ray videography, angiography, X-ray CT scans, RI examinations, and radiotherapy. In 1993, the Radiology Technicians Act was further revised, enabling the performance of MRI examinations, ultrasound examinations, and non-mydriatic fundus photography. In 2010, assistance with the reading of diagnostic images and explanations and consultations for radiology examinations became possible. Furthermore, in April 2015, administration of contrast agents into blood vessels using an automatic contrast injecting device, needle removal, hemostasis, examination of the lower alimentary tract (procedures for inserting a catheter and administering a contrast agent from the anus), and procedures for inserting a catheter and suctioning air from the anus during radiotherapy were added as duties.

The Japan Association of Radiologic Technologists will continue hereafter to expand the scope of duties of clinical radiologists based on scientific rationale. I plan to promote excellence in the *Journal of the Japan Association of Radiologic Technologists* by publishing clinical, educational, and research results of clinical radiologists on a monthly basis. I pray that the English version of the journal will be useful to clinical radiologists all over the world.

History of The Japan Association of Radiological Technologists (JART)

1947
- Establishment of JART (July 13)

1951
- Promulgation of the Act on Medical Radiographers (June 11)
- Authorization for Establishment of the Japan Association of Radiographers (June 13)

1954
- First national examination for Medical Radiographers (May 30)

1956
- Event to commemorate the 10th anniversary of founding, attended by Her Imperial Highness Princess Chichibunomiya

1962
- Event to commemorate the 15th anniversary of founding and 10th anniversary of enactment of the Act on Medical Radiographers, attended by Her Imperial Highness Princess Chichibunomiya

1968
- Promulgation of the Act to Partially Revise the Act on Medical Radiographers (establishment of two professions) (May 23)
- First national examination for radiological technologists

1969
- Renaming as the JART
- Staging of the 4th International Society of Radiographers & Radiological Technologist (ISRRT) World Congress at Tokyo Palace Hotel, attended by Her Imperial Highness Princess Chichibunomiya

1975
- Event to commemorate the 80th anniversary of the discovery of X-rays, attended by Her Imperial Highness Princess Chichibunomiya

1979
- Completion of the Education Center for JART

1983
- Partial revision of the Act on Medical Radiographers and the Act on Radiological Technologists (unification of the professions)

1985
- Event to commemorate the 90th anniversary of the discovery of X-rays, attended by Her Imperial Highness Princess Chichibunomiya
- Staging of the 1st Japan Conference of Radiological Technologists

1987
- General assembly resolution for establishment of the New Education Center and a four-year university

1989
- Completion of the New Education Center (Suzuka City)

1991
- Opening of Suzuka University of Medical Science

1993
- The Act to Partially Revise the Act on Radiological Technologists, and Ministerial Ordinance to Partially Revise the Enforcement Orders (April 28)

1994
- Appointment of the President of JART as the 11th President of ISRRT

1995
- Event to commemorate the 100th anniversary of the discovery of X-ray, attended by Her Imperial Highness Prince Akishinomiya

1996
- Start of the Medical Imaging and Radiologic Systems Manager certification system

1998
- Staging of the 11th ISRRT World Congress at Makuhari

1999
- Start of the Radiation Safety Manager certification system

2000
- "Presentation of the Medical Exposure Guidelines (Reduction Targets)" for patients

2001
- Start of the Radiological Technologists Liability Insurance System

2003
- Enactment of X-Ray Week

2004
- Relocation of offices to the World Trade Center Building in Tokyo

2005
- Start of the Medical Imaging Information Administrator certification system

2006
- Staging of a joint academic conference between Japan, South Korea, and Taiwan
- Revision of the Medical Exposure Guidelines

2008
- Establishment of the committee on Autopsy imaging (Ai)

2009
- Revision to the national examination for radiological technologists
- Launch of the Team Medicine Promotion Conference, with the President of JART as its representative
- Appointment of the President of JART as chairperson of the Central Social Insurance Medical Council specialist committee

2010
- Health Policy Bureau Director's notification concerning promotion of team medicine

2011
- Support activities following the Great East Japan Earthquake
- Staging of an extraordinary general meeting concerning transition to a public interest incorporated association

2012
- Registration of transition to a public interest incorporated association (April 1)
- Event to mark the 65th anniversary of founding and transition to a public interest incorporated association (June 2)
- Renaming as public interest incorporated association JART
- Launch of the Radiological Technologists Liability Insurance System with participation by all members

2013
- Signing of the Comprehensive Mutual Cooperation Agreement on Prevention of Radiation Exposure (September 21)

2014
- Consignment of work to measure personal exposure of residents
- Revision of the Act on Radiological Technologists, Government Ordinance to Partially Revise the Enforcement Orders, and Revision of the Enforcement Regulations (June 25)
- Launch of the radiation exposure advisor certification system

2015
- Event to commemorate the 120th anniversary of the discovery of X-rays

Special Feature

The Role of Aso Medical Center During and After the Kumamoto Earthquake

Takafumi Iwamoto,
Aso Medical Center Radiology Department

A Report on the Support Provided After the Kumamoto Earthquake

The 32nd Japan Conference of Radiological Technologists

President's speech

Three Policies and Issues Facing the Japan Association of Radiological Technologists

Yasuo Nakazawa,
President, The Japan Association of Radiological Technologists

The 32nd Japan Conference of Radiological Technologists

Invited lecture

The Challenge of Teaching MRI in the Future

Dr. Grey Michael Lee,
Illinois State University, Associate Professor

Hospital Introduction and Current Status of Regional Healthcare with Progressing Depopulation

Kensuke Ehara,
Hokkaido Association of Radiological Technologists Wakkanai Branch / Esashi Hospital

The 32nd Japan Conference of Radiological Technologists

Keynote lecture

Introduction of Diagnostic Reference Levels to Japan

Makoto Hosono,
Institute of Advanced Clinical Medicine, Kindai University

The Role of Aso Medical Center During and After the Kumamoto Earthquake

Takafumi Iwamoto
Aso Medical Center Radiology Department

Introduction

Our condolences to all of those who were affected by the Kumamoto Earthquake. We also extend our most sincere gratitude to those who are involved in the rebuilding efforts and to all the volunteers.

Upon a request from the Japan Association of Radiological Technologists, I present here the activities of our center during the Kumamoto Earthquake, entitled: "The role of Aso Medical Center during and after the Kumamoto Earthquake."

Overview of Aso Medical Center

Aso Medical Center (previously Aso Chuo Hospital) opened in the old Kurokawa Village in 1950. However, 60 years after its opening, it could no longer respond to new medical demands as it had become too old. To meet the needs of cooperating with local medical institutions and enhancing the emergency medical system, in 2006, we established the "Aso Chuo Hospital Management Reform Committee," consisting of experts from Aso Medical Association and associated organizations, and discussions on the direction the hospital should take began.

In 2010, funding from the "Regional Medical Revitalization Plan (Aso)," which was devised by Kumamoto Prefecture, was applied as part of the allocated resources, and the plan to build the new hospital was put into place. In January 2013, the construction began. The main building was completed in June 2014, and the hospital opened in August after the changeover was complete.

The newly built Aso Medical Center, which opened in August 2014.

Overview of the hospital facilities

- Structure: reinforced concrete (4 stories)
- Hospital buildings: outpatient (seismic resistant structure), central clinic (seismic isolation structure)
- Number of beds: 124 (general: 120, acute: 4)
- Departments: internal medicine, neurology, cardiology, pediatrics, surgery, or-

thopedics, neurosurgery, rehabilitation, dermatology, and anesthesiology
- Number of physicians: full-time: 10 (as of August 2016)
- Advanced medical equipment: MRI, CT, angiography, etc.
- Emergency response facility: emergency helipad

Overview of the Kumamoto Earthquake

On April 14 (Thursday) at 9:26 p.m., a magnitude 6.5 earthquake (foreshock), with the epicenter in Kumamoto District in Kumamoto Prefecture, occurred at a depth of 11 km. A seismic coefficient of 7 was observed in Mashiki, in Kumamoto Prefecture. Some 28 hours later, on April 16 (Saturday) at 1:25 a.m., a magnitude 7.3 main shock occurred in Kumamoto District at a depth of 12 km, and a seismic coefficient of 7 was observed in Nishiharamura and Mashiki. Magnitude 7.3 is similar to the large-scale earthquake, the Great Hansin earthquake, which occurred in 1995. Initially, the magnitude 6.5 quake on April 14 was considered as the main shock, and any subsequent quakes were expected to be aftershocks whose intensities were never expected to be greater than the initial one. However, following the above-mentioned earthquake that occurred in the early morning of the 16th with a magnitude of 7.3, the Japan Meteorological Agency reported on the same day that it was the main shock and the earlier quake (on the 14th) had been the foreshock. During the 2011 Great East Japan Earthquake, which was a subduction earthquake, an original report was revised, switching the order of the main shock and the aftershock. However, this was the first case of an intra-plate (active fault) earthquake where a larger quake occurred following a quake with a magnitude of 6.5 or higher since the observation of earthquakes began in Japan in 1885. It was also the first time that two seismic coefficients of 7 were observed in one series of seismic activities. The earthquake on the 14th was due to activities on the northern edge of the Hinagu fault zone, while the earthquake on the 16th was due to activities on the Futagawa fault zone. These are considered to be consolidated earthquakes as the two neighboring fault zones are linked. Furthermore, after the main shock on the 16th, earthquakes continued to occur in the area between Aso, Kumamoto (northeast of Kumamoto District), the western Oita Prefecture, and the central Oita Prefecture (around the Beppu-Haneyama Fault Zone): Active seismic activities were observed in the three areas, including Kumamoto District.

(from the Wikipedia article on the 2016 Kumamoto Earthquake)

Damage in the Aso area①
From the Aso City official Facebook page

Damage in the Aso area②
From the Aso City official Facebook page

Damage in the Aso area③
From the Aso City official Facebook page

Damage in the Aso area④
From the Aso City official Facebook page

Maintaining function as a disaster base hospital after the Kumamoto Earthquake

The Aso area during the April 14 earthquake (foreshock of the Kumamoto Earthquake) experienced a seismic coefficient of 5 but did not suffer severe damage. Subsequently, upon a request from Kumamoto Prefecture, the DMAT (Disaster Medical Assistance Team, including myself) was dispatched from this center and conducted fieldwork at Mashiki town office on the instructions of the Japanese Red Cross Kumamoto Hospital DMAT field headquarters.

During the April 16 earthquake (the Kumamoto Earthquake main shock), the Aso area experienced a seismic coefficient of 6 plus, and suffered severe damage, such as landslides, collapsed homes, and disruption to daily life, due to the closure of prefectural and national roads. As the disaster base hospital for Aso area medical care, our hospital building is a seismic isolation facility (partially seismic resistant) that is resistant to disasters. Since we are equipped with a generator and a water tank, during this major disaster, we were able to provide medical care while maintaining all medical functions. However, immediately after the disaster, surrounding roads were destroyed and many staff were unable to get to the center; thus, a limited number of doctors (4 out of 9 full-time doctors were able to arrive) and medical staff diagnosed and treated emergency patients. In addition, as many residents were evacuated to our center, it filled with emergency patients and evacuees. Furthermore, many medical facilities had difficulties maintaining their functions immediately after the disaster, and patients gathered at our center. The

The DMAT team, members of which arrived from across Japan.

A meeting at the DMAT field headquarters.

next day, we received support from many DMAT and rescue teams from across Japan, and we were able to maintain our role as the disaster base hospital.

DMAT field headquarters provision of medical support for the Aso area

We set up our base for the field hospital on April 17 to provide medical support to the Aso area and also to gain an understanding of the situation. Up to 33 DMAT members were in the base at times, providing medical support to evacuation shelters and hospitals in the surrounding Aso area, with our center used as the base. From April 22, the function of DMAT was transferred to public health centers and relief teams, and Kumamoto Prefecture set up an Aso Disaster Recovery Organization (ADRO). Our center continued to be the headquarters for operations.

ADRO conference.

ADRO headquarters.

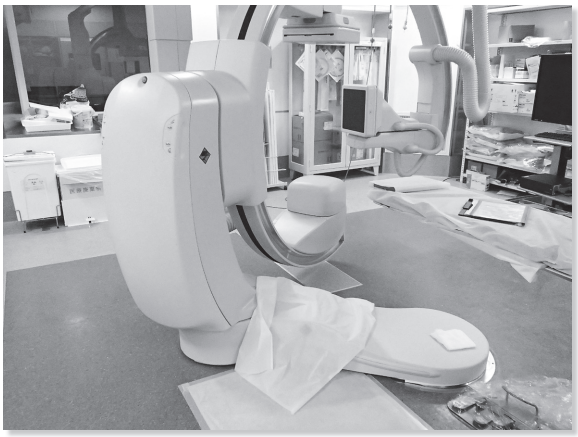
Free drinks during the disaster

Following the Kumamoto Earthquake, the Aso area suffered severe damage to its water and sewer services, and many areas were without these services for a long time; therefore, we provided free drinks for 30 days based on a cooperation agreement with a vending machine company, APEX Corporation, West Japan. The company had offered to provide free drinks for up to 30 days or up to 10,000 cups during a disaster. It was not limited to drinks such as juices, but also included water and hot water, which were used by many people to prepare milk for infants, and this was highly appreciated.

A vending machine with cups, from which free drinks were provided during the disaster.

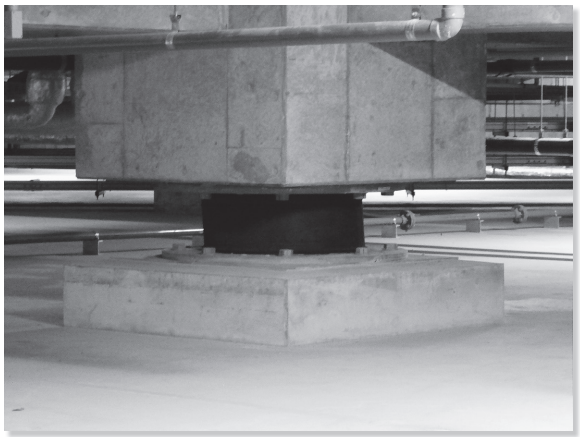
Medical device usage after the disaster (radiology-related equipment)

Following the earthquake on April 16, medical devices at our center were operated with emergency power from a generator. However, the radiology-related equipment could not be operated with emergency power, and, thus, diagnoses were based on general imaging with a portable imaging device (flat panel) and laptop computer-style console at the beginning (for about two days). On April 17, power companies around Japan provided repairmen, power supply vehicles, and aerial



The angiography room immediately after the earthquake.

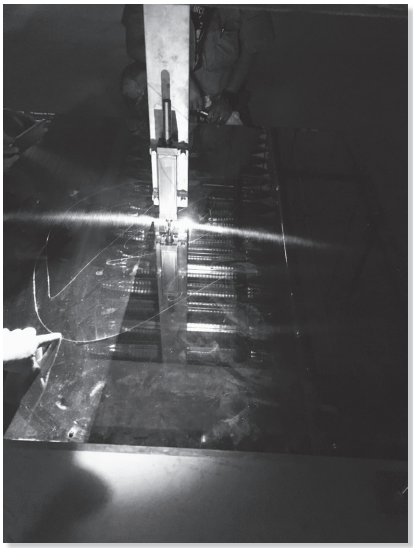
The axis of the arm shifted.



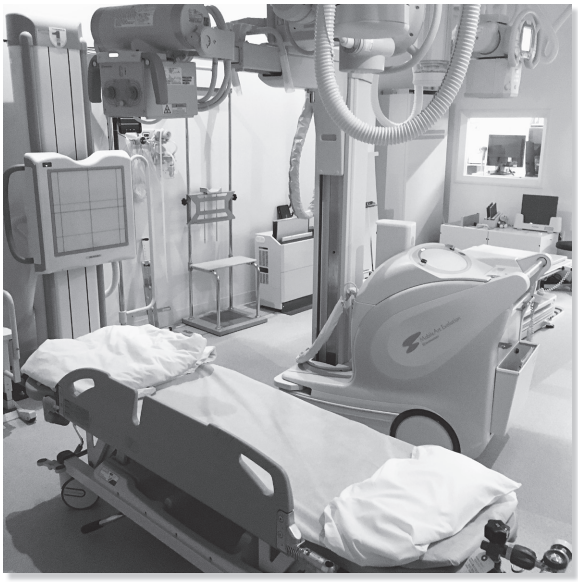
The seismic isolation structure of our center.

The radiology staff room immediately after the earthquake.

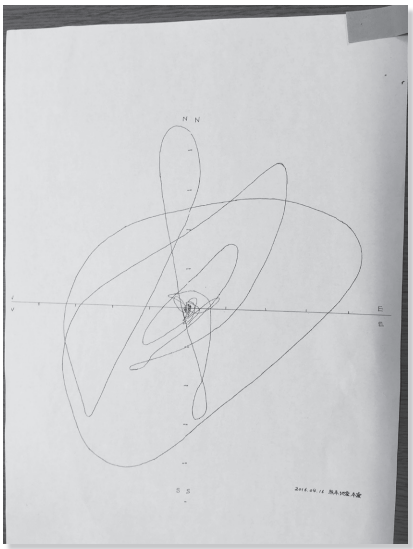
A bookshelf collapsed and the books were scattered around.



Horizontal marking panel after the earthquake.



Testing with a portable unit immediately after the earthquake (general imaging room).



Tracing on the horizontal marking panel.

The main building shifted by between 40 cm and 50 cm in all directions.

work vehicles, restoring power to our center. On April 18, the service personnel for the hospital equipment began to visit from early morning, and repaired and inspected each device. By the afternoon, all the devices were operational. Thanks to the seismic isolation facility at our center, damage to the medical devices was minimal, and tests could be re-started promptly. It made us truly appreciate the power of the seismic isolation facility.

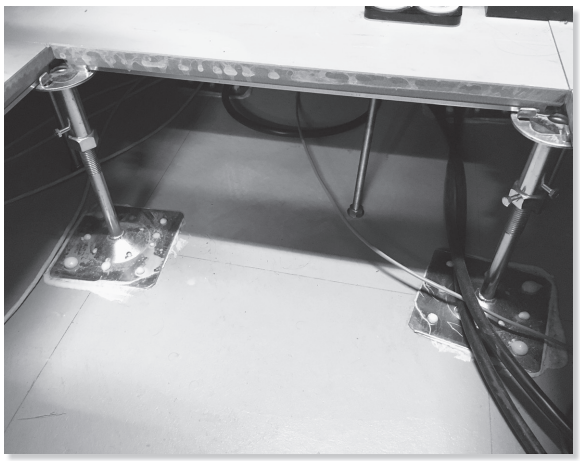
Devices used by the Radiology Department

① 1 CT (80 slices)
② 1 MRI (1.5T)
③ 1 angiography device (biplane)
④ 1 general imaging device (two sources and one room)
④ 3 FPDs (flat panels)
⑤ 2 portable imaging devices
⑥ 1 X-ray TV
⑦ 1 mammogram
⑧ 1 bone density measurement device
⑨ 2 surgical imaging devices

The medical information system functioned as normal on emergency power

The server rack in the server room (the OA floor) was fixed in place with anchors, and, thus, the rack was undamaged. Furthermore, the server room was designed to operate with emergency power in mind (including air conditioning); thus, medical care was smoothly administered following the earthquake using electronic files, PACS, and other systems. Our center is equipped with free Wi-Fi, and the Internet could be accessed even after the earthquake. Thus, the DMAT field headquarters was useful for a wide range of people in conducting various tasks, such as inputting for the Emergency Medical Information System (EMIS).

The server room of our center.



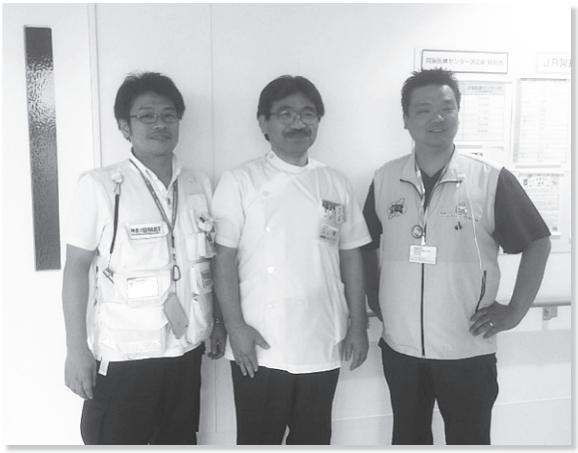
Fixed server rack.
It withstood a seismic coefficient of 6 plus.

Appreciation of compassionate medical support

With the increase in the number of patients at the emergency department following the disaster, the number of tests, such as general imaging and CT scans, increased not only during the day but even at night. Therefore, the testing department had to operate on both 24-hour shifts and on overtime during the night, at weekends, and during holidays. This center has five medical radiological technologists (two males and three females) on call for the night time, weekends, and holidays in normal

times. In addition, since I was working as a member of DMAT at the disaster headquarters, I was able to respond with a team of four technologists immediately after the disaster. As the time went on, the technologists grew increasingly fatigued, and upon consulting with the hospital director and chief technologist, it was decided that medical radiological technologists (including the nurses, pharmacists, and clinical technologists) should be dispatched to the DMAT field headquarters. Mr. Kinya Ono —a member of Kanagawa Prefecture DMAT and a former director of the Japan Association of Radiological Technologists—was at the DMAT field headquarters. Subsequently, with Mr. Ono acting as the liaison, the Japan Association of Radiological Technologists contact system allowed for rapid dispatch and support for all those involved.

The Japan Association of Radiological Technologists, the Kumamoto Association of Radiological Technologists, the Oita Association of Radiological Technologists, the Saga Association of Radiological Technologists, the Fukuoka Association of Radiological Technologist, Kumamoto City Hospital, DMAT, and the relief team sent us between one and three medical radiological technologists in turn from April 20 to May 8 (a total of 20 technologists). On April 22, Mr. Kiyoshi Ogawa, the Vice-president of the Japan Association of Radiological Technologists (at present, a supervising specialist) and Mr. Yuji Yasukawa, a specialist, visited our center, confirmed the disaster situation, and gave encouragement to the Radiology Department staff. We truly appreciate everybody who agreed to come to provide support when much of the normal communication infrastructure, such as the national and prefectural roads, were closed or destroyed due to the disaster.



From left to right: Kinya Ono, ex-Director; Kai, the Hospital Director, Hiroshi Kuwahara, the Oita Association of Radiological Technologists Vice-president.

Vice-president Kuwahara rushed to our center to provide assistance.

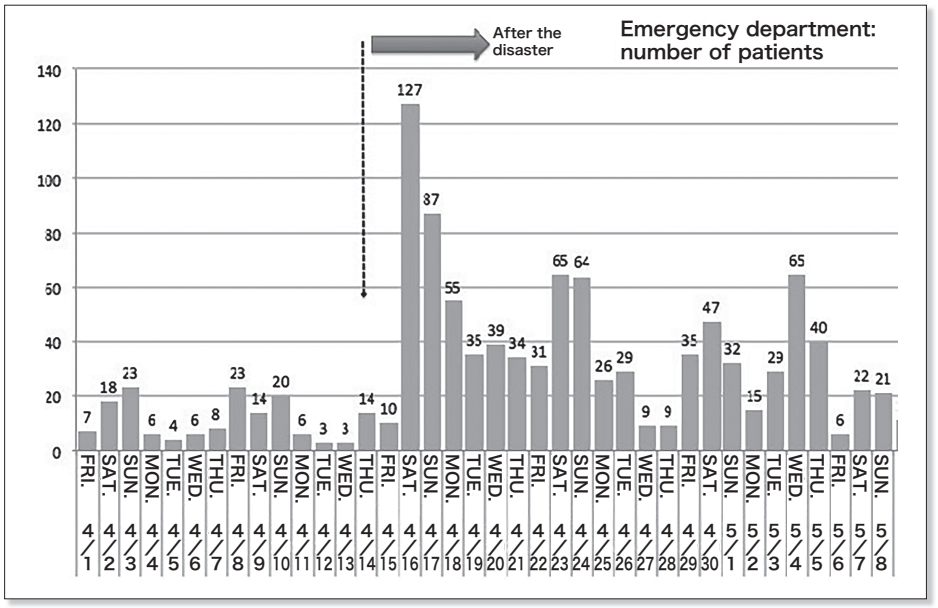
Directors of radiologist associations in Kyushu visited our center.

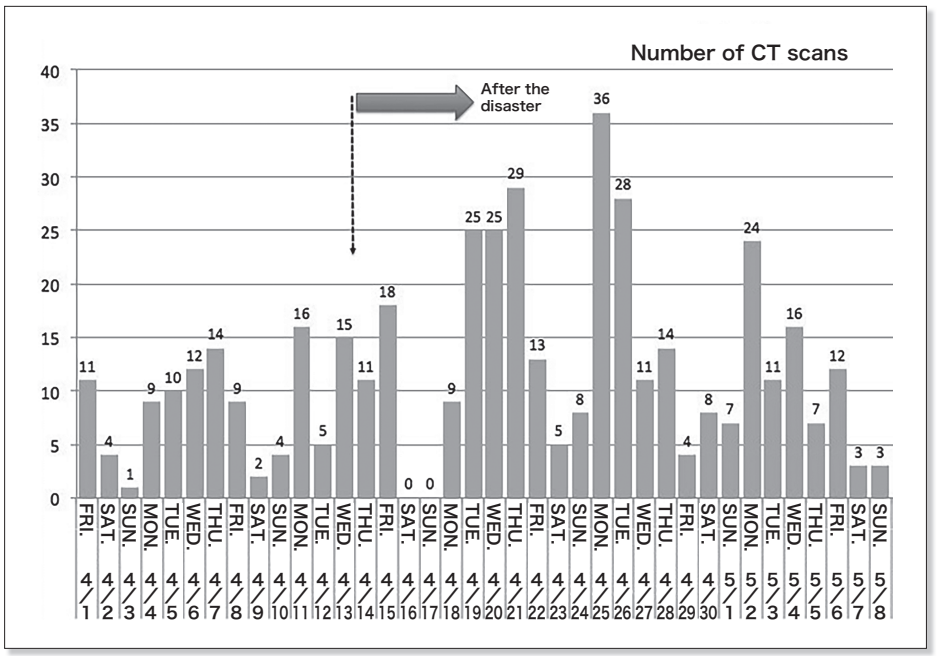
Vice-president Kiyoshi Ogawa, pictured center (the current supervising specialist), and specialist Yuji Yasukawa on the right.

Issues that arose through experiencing the earthquake

After the earthquake, an information session on the disaster was held at the center (for each department), and the most common comment made was the necessity for disaster prevention and a response manual for the center. This should be prepared immediately, and upon completion, all staff should be fully informed. There also was a request for regular disaster training.

The challenge for the Radiology Department was the need for devices that can function on emergency power. Observing the emergency outpatients immediately after the earthquake, it could be seen that the majority of the cases were head trauma ones (due to falling furniture, etc.), and there were many requests for CT scans by diagnosing doctors. Two days after the main shock, the CT was functioning again, and there were nearly double the usu-





al request for CT scans. Thus, a functioning CT during a disaster will lead to accurate diagnosis and treatment by doctors. However, since there are issues such as power capacity at this center, it must be a careful process conducted in cooperation with the hospital. We were able to overcome the acute and subacute phases of the disaster with the support of many medical radiological technologists. But there is also a future challenge to be met in that it took time to get familiar with the differences in the different makes of devices we use at our center, the operation method for the electronic files, and the operation of devices. Thus, the Radiology Department prepared a simple operation manual for each device.

Conclusion

I worked in the field as a member of DMAT from the early stage of this disaster, and following the main shock, I took part in establishing and managing the disaster response department at our center. Looking back, I regret my inexperience, but at the same time, I feel that I did the best I could with the support and cooperation of many people. I am very grateful to them. At the same time, I am happy that I met many people and was inspired by them. The Kumamoto Earthquake was unexpected, reminding me that a disaster can take place anywhere, anytime. We medical radiological technologists may be facing a time when we need to review what we can do in a disaster and to improve our skills. All of us medical radiological technologists need to think together.

Acknowledgements

We want to take this opportunity to thank the Japan Association of Radiological Technologists, the Kumamoto Association of Radiological Technologists, the Oita Association of Radiological Technologists, the Saga Association of Radiological Technologists, the Fukuoka Association of Radiological Technologists, Kumamoto City Hospital, the members of DMAT, and the relief team, who have all cooperated with and supported this center since the disaster.

DMAT members and the relief team members who worked at our center wrote messages on these boards.

A Report on the Support Provided After the Kumamoto Earthquake

On Monday August 1, 2016, the President, Mr. Nakazawa; Mr. Eto, the Kyushu Regional Director; Mr. Nakamura, Fukuoka Prefecture President; and Mr. Kato, the manager, visited Aso Medical Center, the Department of Medical Care, Medicine, and Drugs, Health, and Welfare, Kumamoto Prefectural Government, and the Kumamoto Association of Radiological Technologists. They reported on the support efforts that our association has been providing since the Kumamoto Earthquake. They passed on donations from the technologist associations of various prefectures and from members.

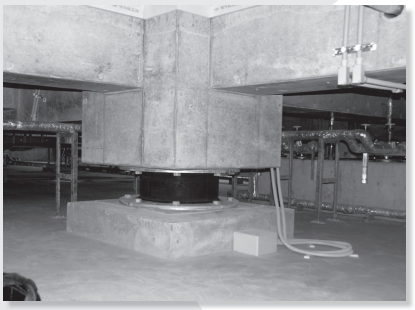
At Aso Medical Center, to which we dispatched medical radiological technologists, Hospital Director Yutaka Kai, Chief Technologist Nobuaki Anai, and all the staff acknowl-

At the Kumamoto Prefectural Office

Left to right: Mr. Nakamura, Fukuoka Prefecture President; Mr. Hiai, KART President; Mr. Anan, Assistant Director of the Department of Medical Care, Medicine, and Drugs, Health, and Welfare, Kumamoto Prefectural Government; Mr. Nakazawa, the President; Mr. Nakagawa, Councilor at the Department of Medical Care, Medicine, and Drugs, Health, and Welfare, Kumamoto Prefectural Government; and Mr. Eto, Kyushu Regional Director.

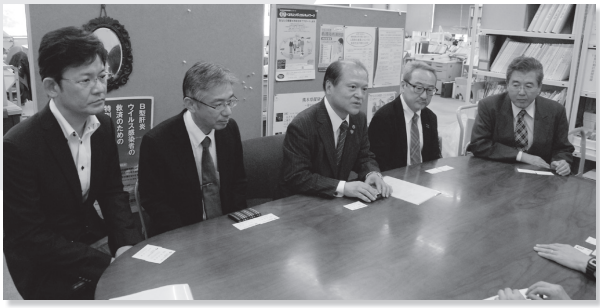
With the KART President, Yasuhiro Hiai.

With the Hospital Director, Yutaka Kai.



Seismic isolation structure at Aso Medical Center.

Presentation on the disaster response by the Hospital Director, Yutaka Kai.



Presenting a report of our support efforts at the Department of Medical Care, Medicine, and Drugs, Health, and Welfare, Kumamoto Prefectural Government.

edged the support received for the Kumamoto Earthquake disaster, and Hospital Director Kai reported on the past efforts of the hospital since its establishment, as well as the situation, response, and support system during the earthquake. In addition, we toured the seismic isolation structure that was completed in June 2014, and received an explanation on the usefulness of a seismic isolation structure during an earthquake.

At the Department of Medical Care, Medicine, and Drugs, Health, and Welfare, Kumamoto Prefectural Government, Councilor Hiroki Nakagawa and Assistant Manager Shunzo Anan, who has been the liaison with our association since the earthquake, relayed the acknowledgment of our support. We explained and reported on our efforts since the earthquake, and promised that we would actively provide support if there were any future disasters.

At the office of the Kumamoto Association of Radiological Technologists, the President, Yasuhiro Hiai, the Vice-President, Akihito Nishiono, and directors Yoshiko Nakajima, Koji Shimokawa, Toshikazu Fukushima, Yuji Yano, and Shinnosuke Tagami welcomed us and expressed their gratitude to our association and the prefectural associations of radiological technologists while passing on stories of their struggle since the earthquake until today. We reviewed our support efforts and presented a donation of 847,986 yen collected from the prefectural associations of radiological technologists and members.

At the office of the Department of Medical Care, Medicine, and Drugs, Health, and Welfare, Kumamoto Prefectural Government

From left to right: the Kumamoto Prefectural Directors, Mr. Tagami, Mr. Yano, and Mr. Fukushima; the Vice-President, Mr. Nishiono; the President, Mr. Hiai; the President, Nakazawa; the Kyushu Prefectural Director, Mr. Eto; the Fukuoka Prefectural President, Mr. Nakamura; and the Kumamoto Prefectural Directors, Mr. Shimokawa and Ms. Nakajima.

The 32nd Japan Conference of Radiological Technologists

President's speech

Three Policies and Issues Facing the Japan Association of Radiological Technologists

Yasuo Nakazawa
President, The Japan Association of Radiological Technologists

Conference Chairman Eisuke Yasuda: We will now hear from President Yasuo Nakazawa, who has served as the leader of the Japan Association of Radiological Technologists since June 2010. Today, he will share his thoughts on three policies and issues that will affect our future.

Ladies and gentlemen, President Yasuo Nakazawa.

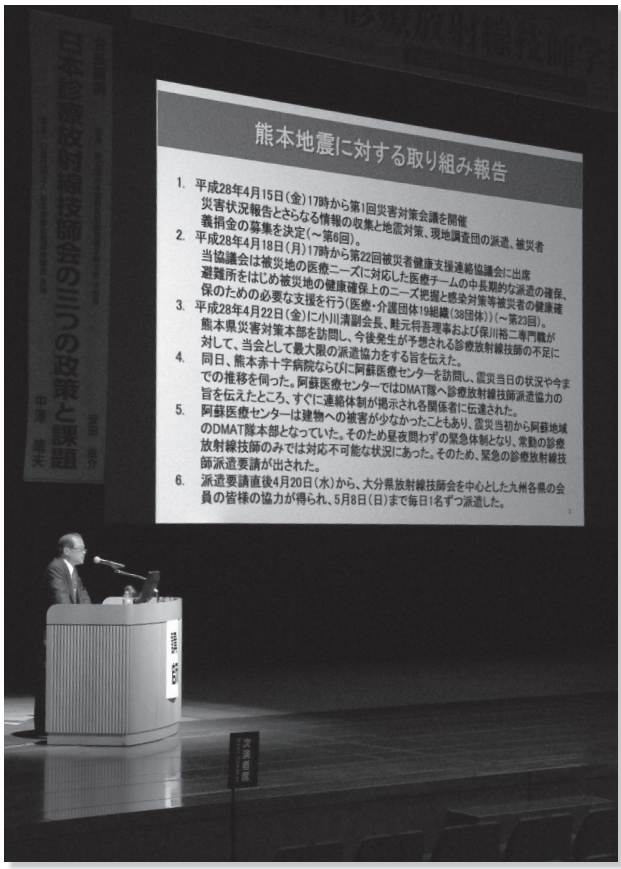
President Yasuo Nakazawa: Thank you for the introduction. My name is Yasuo Nakazawa of the Japan Association of Radiological Technologists. The theme of my speech today is "three policies and issues facing the Japan Association of Radiological Technologists." My address is divided into five sections. First, I will report on JART's initiatives after the Kumamoto earthquake. Second, I will introduce the policies that concern JART. Thirdly, I will discuss the thorough reforms of the Radiological Technologist Law, which is one of today's three policies. Fourth, I will discuss the regulations for the education of radiological technologists and the shape that clinical training should take. This is the second policy, and is an area we are struggling with right now. Fifth, I will explore the shape the educational system should take with an eye to the future, which is today's third policy.

1. Report on the association's initiatives after the Kumamoto earthquake

Before discussing our association's activities in response to the Kumamoto earthquake, I would like to express my deep sorrow over the earthquake victims, and my sincere sympathy for everyone who was affected by the disaster. The Kumamoto earthquake struck at 9:26 p.m. on April 14. Around 9:30 p.m., I received a call from JART director Naoki Kodama, who informed me of the crisis in Kumamoto Prefecture. I quickly asked our vice presidents to gather more information. The next day, April 15, the first disaster response

meeting was held. The president of the Kumamoto association, Yasuhiro Hiai, happened to be in Yokohama for the Japan Radiological Congress, so we were able to contact him quickly and ask him for information and reports. He also took part in the meeting.

At the meeting, decisions were made on various matters including our response to the disaster, information gathering, dispatching a fact-finding team, and collecting donations for disaster victims. Six more disaster response meetings were held. On April 18, I attended the 22nd meeting of the Disaster Victims Health Support Council to report on our association's disaster response. This council is composed of 19 organizations and 38 groups involved in medicine and nursing. It is chaired by Yoshitake Yokokura, head of the Japan Medical Organization. Its meetings are attended by section chief-level officials from multiple government ministries and agencies including the Ministry of Health, Labour and Welfare (MHLW) ; the Ministry of Education, Culture, Sports, Science and Technology (MEXT); the Ministry of Internal Affairs and Communications; the Cabinet Office; and the Environment Ministry. The council's first meeting was in April after the disaster struck on March 11, 2011, and have continued convening ever since. Its role is to serve as a liaison for Japanese medical professionals involved in health support. At the meeting, we asked the government to thoroughly investigate whether the earthquake had caused any radiation leaks at the Sendia nuclear power plant in Kagoshima Prefecture, the Genkai nuclear plant in Saga Prefecture, or the Ikata nuclear plant in Ehime Prefecture. If such a possibility existed, we stated that JART was ready to send surveyors. On April 22, a survey team was dispatched to the disaster response headquarters in Kumamoto Prefecture under the leadership of specialist and former JART vice president Kiyoshi Ogawa, director Shogo Azemoto, and specialist Yuji Yasukawa. We told the team that JART was prepared to provide assistance for any damages caused by the disaster. The team visited the Japanese Red Cross Kumamoto Hospital and the Aso Medical Center to inquire about the situation on the day of the disaster and what had happened since, as well as to discuss arrangements for communications and support at the Aso Medical Center. The Aso Medical Center is a seismically isolated structure, so it sustained very little damage. It was arranged so that medical activities in the Aso region were focused around the Aso Medical Center. As the large number of patients left the local radiological technologists exhausted, the association received a request to send more staff. JART regional director Akinori Hiroki, Oita association president Yoshihiro Eto, Fukuoka association president Yasuhiko Nakamura, and Kumamoto association president Yasuhiro Hiai discussed the matter and decided that support should come from the technologist associations closest to the disaster



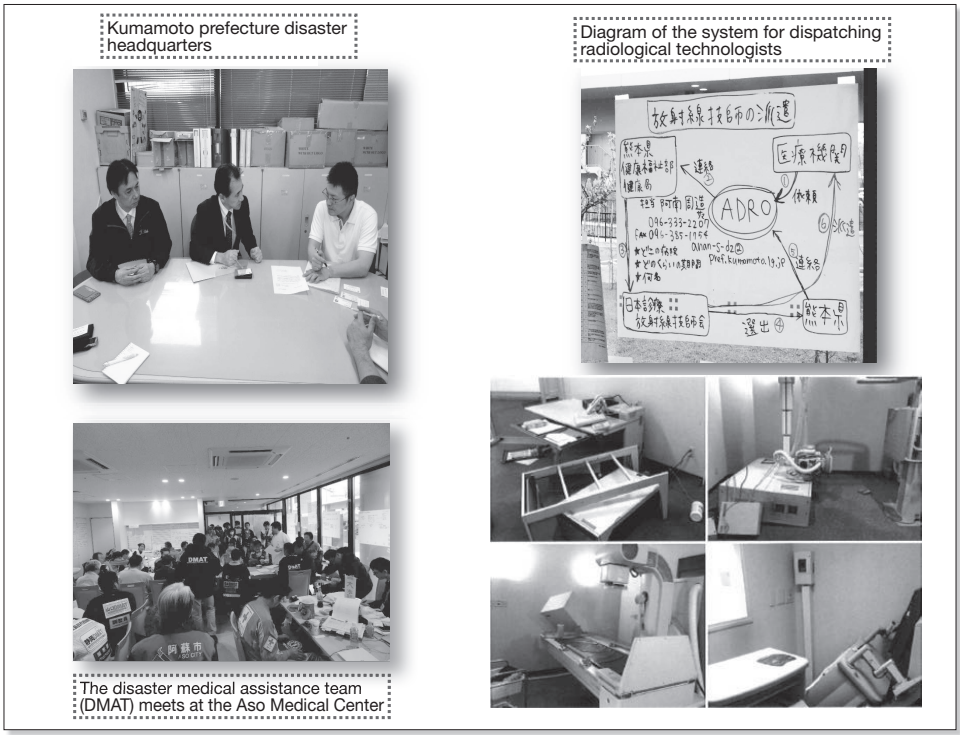


Fig.1

area. This picture shows Kumamoto disaster response headquarters assistant section chief Shuzo Anan speaking with former JART vice president Kiyoshi Ogawa (Fig.1). This picture shows some of the damage in Kumamoto that president Yasuhiro Hiai described to us. You can see that an X-ray tube has fallen down onto the bed, a control box has fallen over, and an X-ray monitor is off kilter. After hearing a report on the situation and discussing it at the Aso Medical Center, work began on a technologist dispatch system. In this system, when a request for a radiological technologist came in from a medical institution, the Aso Disaster Recovery Organization (ADRO), the northern Kumamoto Prefecture branch, and JART would decide on which staff to dispatch.

Radiological technologists from the JART team entered the area on April 22, and was preceded by Oita association vice president Hiroshi Kuwahara. Also on April 22, requests for support were sent out to Oita, Fukuoka, Saga, Kumamoto, and other prefectures, which responded by sending staff. I would like to express my sincere gratitude to the radiological technologists who provided support and to the chief radiological technologists and hospital directors at the medical institutions involved.

JART collected donations until July 31. On August 1, I visited the Kumamoto prefectural office to meet with assistant secretary Hironori Nakagawa and assistant section chief Shuzo Anan to report on our activities. The meeting was also attended by president Yoshihiro Eto, president Yasuhiro Hiai, and president Yasuhiko Nakamura (Fig.2).

In the morning before the meeting at the prefectural office, we visited the Aso Medical Center to give director Yutaka Kai a report on JART's activities. Hospital Director Yutaka Kai gave us a 45-minute explanation of the Center's initiatives. We then visited the Japanese Red Cross Kumamoto Hospital where the Kumamoto radiological technologist association office is located, and presented president Yasuhiro Hiai with approximately ¥840,000 in donations collected from around the country.

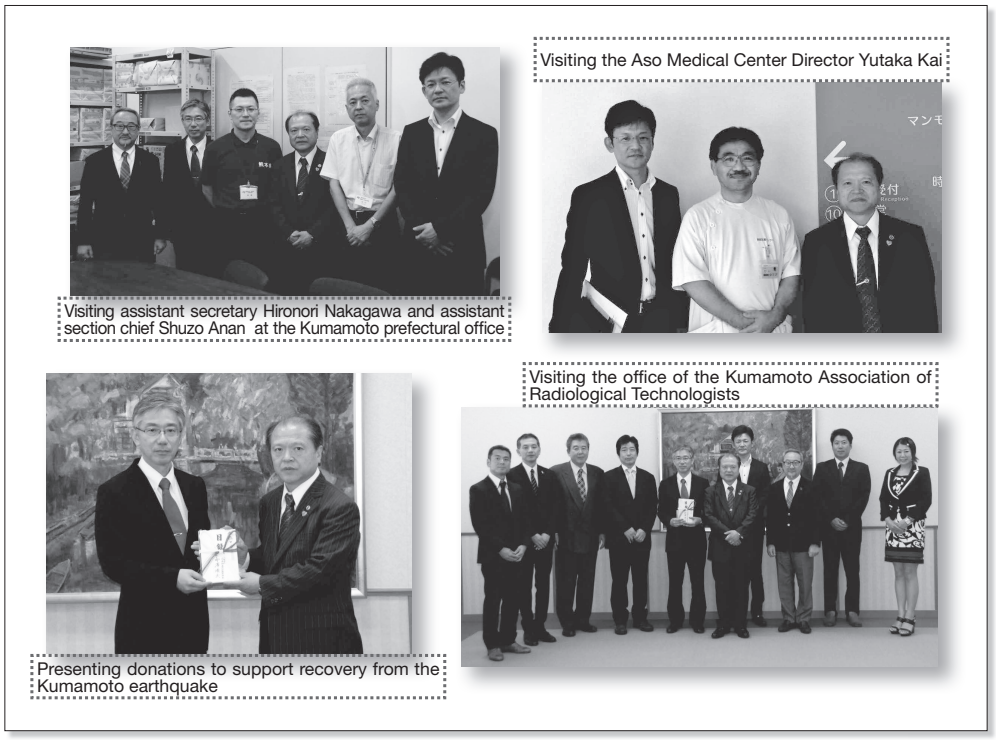


Fig.2

This picture shows the Kumamoto association board members (Fig.2). We are grateful to everyone who donated from around the country.

2. Introduction to policies that concern JART

Next, I would like to discuss policies that concern JART. Since I became president of the association in June 2010, the executive team, who worked together with the membership, has studied and drawn up various policies, particularly ones related to the government. The first involves upgrading education for radiological technologists and improving their environment based on the Basic Plan to Promote Cancer Control Programs. In 2011, a survey was conducted on cancer hub hospitals nationwide. Based on this, I have requested that three radiological technologists be assigned to each linear particle accelerator. The second involves the activities of radiological technologists in promoting team medical care. In April 2011, we formed a committee to promote team medical care in cooperation with the Ministry of Health, Labour and Welfare . Prior to this, a national survey on JART's situation was conducted from January to March 2011. Based on the survey's results, the committee discussed how to promote team medical care so that 'gray zone' duties performed by radiological technologists would be clearly within the scope of the law. After three years, we were finally able to amend the law, and are currently holding standardization lectures based on these amendments.

However, not all of our proposed job expansions were realized, so we would like to reopen discussions on promoting team medical care with the MHLW on the remaining issues.

The third involves creating a suitable work management system to ensure medical safety. Using a system to manage medical radiation exposure, we have been certifying institutions that successfully reduce radiation exposure. About 30 facilities nationwide have been certi-

fied since I became president. There are now 66 such institutions, which is an increase of 36 over the last six years. Today, I would like to urge those from other institutions to seek certification for reducing radiation exposure. I once asked Takeshi Sasaki, the former head of planning at the ministry's medical department, if certification for reducing medical radiation exposure could be reflected in compensation for medical services. His response was that the number of institutions was still too small. He told me that if there were three to five certified institutions in each prefecture, increasing the number of institutions certified for reducing medical radiation exposure could become a matter of policy. We formed a commission to look into the issue, and found that one issue is the fees needed to obtain certification. I therefore urge your institutions to budget for certification and to prepare a year and a half or two years in advance.

A management system for medical equipment was created when the revised Medical Services Law was enforced on April 1, 2007, which represented a major change to Japanese medical policy. This was centered on four pillars: medical safety, infection control, management of medical products, and management of medical equipment. Regulations for these areas were clearly laid out in the Medical Services Law. We have undertaken the task of drawing up policies for systems to manage medical equipment in radiology departments. Currently, Yasuhiko Nakamura is heading the radiology equipment supervisor section, which conducts an annual nationwide survey on medical and radiology equipment malfunctions. The yearly totals are then reported to the MHLW's economy section. We have asked that the CT, MRI, isotope, and other equipment we use be included when the scope of the "medical equipment safety management fees – 1" is expanded. People at institutions that would like to participate in these initiatives can contact Yasuhiko Nakamura at the radiology equipment supervisor section.

Next is a management system for image quality control. We have obtained data on this from the medical compensation policy planning committee, and are currently discussing the matter with the MHLW.

Fourth is the composition of the national examination committee. When I became president, it had been 60 years since the national examination system began. Over those 60 years, all the chairs and vice chairs of the na-

tional exam committee had been physicians from the Japan Radiological Society. Our opinion is that the education of radiological technologists should be carried out by radiological technologists. We believe that radiological technologists should play a leading role in the national exam to the MHLW, and asked them to allow radiological technologists to be chairs or vice chairs of the national exam committee.

However, the response we received in 2011 was harsh. The person in charge of the matter asked us, "Do you have that kind of ability?" and rejected our written request. A year later, in 2012, we tried to renegotiate with the MHLW. We asked what was needed for them to consider our request, and were told that we needed to provide evidence. We surveyed the number of radiological technologists who were professors, associate professors, lecturers, and assistant professors in universities nationwide, as well as how many of these individuals had doctorates; we then included these findings in a written request to the Ministry in 2013. However, the number of doctorates was a bit too low. Compared to 98% of doctors and 89% of scientists and technologists, only 69% of radiological technologists were doctorates. In the end, we reached a compromise to add one vice chair to the national exam committee. I urge professors and associate professors at educational institutions who do not have doctorates to pursue higher degrees. Having a large number of radiological technologists with doctorates is an extremely valuable tool we can use when dealing with the MHLW. I ask everyone working at educational institutions to cooperate with us in this.

Fifth is transitioning to four-year universities and systematizing postgraduate clinical training, which falls under the second of today's three policies. At our general meeting, we decided to move toward four-year universities, and are currently working to make this happen. Three years ago, I visited technical schools around the country to ask three-year schools to become universities, or if that was not possible, to switch to four-year programs.

Sixth is the posting of civil servants who specialize in addressing acute radiation exposure and medical radiation exposure. After the March 11 disaster, we asked that civil servants in charge of radiation management stationed within 30 kilometers of nuclear power plants to be certified radiological technologists.

Seventh is the activities of radiological technologists in education and public relations about radiation. The pioneering work being done in Oita Prefecture should serve as a model for this.

Eighth is amending the Radiological Technologist Law, which is one of today's three policies and something we have also requested from the MHLW. Ninth is the proper role of medical physicists, and tenth is work-life balance. We need the relevant stakeholders to address these areas in evidence-based ways.

3. Policy 1 – Thorough reform of the Radiological Technologist Law

The first of the three major policies is carrying out a thorough reform of the Radiological Technologist Law. Our profession was given legal standing in 1951 by the Medical X-Ray Technician Law. It has been 60 years since

our qualifications were established, and now a number of major reforms are necessary. In 2012, a committee was formed to study how the Radiological Technologist Law should be amended. The committee held discussions for one year, then submitted a report on September 21, 2013. This report was made available for public comments, and is now being used as a basis to create the necessary documents. This fiscal year, the matter is being considered once again. In particular, the report addressed article 2 of the Radiological Technologist Law, which concerns definitions.

The report stated that three articles needed thorough reform: article 20 on the qualifications for the national exam, article 24 on examinations, and article 26 on instructions from doctors and dentists.

The following points are important. First, amending the Radiological Technologist Law is necessary when the Medical Services Law is amended. Second, the Radiological Technologist Law needs to be amended to reflect the expanded scope of our duties. Third, the educational curriculum needs strengthening to further develop our radiology duties, and the Radiological Technologist Law needs to reflect this. Fourth, prescription verifications are needed to ensure medical safety, and the law needs to be amended to reflect this. And lastly, the Radiological Technologist Law needs to be amended to reflect compliance and other matters.

1) Amending the Radiological Technologist Law to align with the Medical Services Law

The first matter is amending the Radiological Technologist Law to align with the Medical Services Law. In the revised Medical Services Law implemented in 2007, formulating maintenance and inspection plans for medical equipment was one of the specific policies on safety management for medical equipment, which is one of the four pillars I mentioned previously. The law states that all medical equipment needs to have maintenance and inspection plans by 2015. Data from JIRA surveys shows this was achieved in 77.4% of cases in 2009 and in 90.1% of cases in 2015, indicating that while it has not been achieved for all medical equipment, the situation is gradually improving. It also became compulsory to appoint safety officers for medical equipment. By number of beds, this was 93.1% accomplished around 2012 and 90.1% currently, indicating that the level is hovering around 90%. I would urge everyone to make sure safety officers are appointed. The proportion of medical equipment safety officers who are radiological technologists went from 27.6% to 27.7%, then 22.7% in 2015; those who were clinical engineers went from 31.1% to 31.2%, and those who were doctors went from 30.9% to 34.3%. While the proportion of clinical engineers is around 30%, only around 20% are radiological technologists. Nationwide, only about 20% of the medical equipment safety officers appointed based on the revised Medical Services Law are radiological technologists. However, we believe that we should be responsible for the radiation we use. Therefore, we want to change article 2 of the Radiological Technologist Law by adding to the existing definition ("A person who exposes human bodies to radiation.") with the following: "A person who maintains and manages equipment and performs quality control during medical care."

2) Amending the Radiological Technologist Law to reflect the expanded scope of our duties

The next matter concerns amending the Radiological Technologist Law to reflect the expanded scope of our duties. The committee for promoting team medical care worked for three years, and we are now holding standardization lectures. Everyone is well aware of the content of these lectures: intravascular administration of contrast agents and additional duties concerning the lower digestive tract

and image-guided radiotherapy.

In addition, we have submitted a written request concerning our duties during health screenings. This request concerns the attendance of doctors or dentists during screenings for gastric cancer, breast cancer, and lung cancer. Unfortunately, screenings for gastric cancer and breast cancer were excluded from the latest evaluations, so our request was not realized. We thus believe it is necessary to drastically change article 26 of the Radiological Technologist Law so the law reflects the expanded scope of our duties.

Furthermore, this law has not been changed since 1951. Since it states that doctors and dentists are to provide "specific" instructions, doctors need to be present at screenings for gastric cancer and breast cancer. Even though it is the radiological technologist who is doing the actual work, if a doctor is not present, the screening cannot be performed. Resolving this would require amending article 26 of the Radiological Technologist Law. Removing the "specific" and amending the law so it only requires comprehensive instructions would allow us to comprehensively carry out screenings for gastric cancer and breast cancer. We believe this change is necessary for the well-being of the public.

3) Strengthening the educational curriculum to develop our radiology duties, and amending the Radiological Technologist Law to reflect this

This matter involves strengthening the educational curriculum to further develop our radiology duties, as well as amending the Radiological Technologist Law to reflect this. When the Radiological Technologist Law was written in 1951, it laid out a two-year educational system. In 1968, a three-year education system was launched. Looking at our duties around 1970, they mainly involved simple X-ray imaging, as well as X-ray TV of the digestive tract and other areas, angiography, radioisotope exams, cobalt therapy, and superficial treatments. A three-year educational system was in place at this time. However, as you all know, our duties have substantially increased since then. The arrival of X-ray CT was followed by SPECT/CT and PET/CT, and then therapies that use radioisotopes internally were introduced. Our duties have also expanded to include removing needles, stopping bleeding, explaining the exams, assisting in image interpretation, ultrasonography, non-mydriatic fundus cameras, nuclear medicine diagnostic equipment, and inserting tubes for IGRT. In the years since the three-year educational system began in 1968, our duties have continued to expand, their quality and quantity has increased, the times have gone from analog to digital, and things are continuing to progress. In fact, while the law is still based around the three-year system, our survey showed that 70% of institutions are already providing university education. One junior college is going to become a university next April, which will increase this figure to 72%. When we consider the facts along with the increase and changes to our clinical duties, it is clear that we should transition to a four-year university system. At present, the foundation of the three-year system is still in article 20, which lays out the qualifications for taking the radiological technologist exam. We would like to amend article

20 by exchanging item 1 for item 2, and item 2 for item 3.

4) Prescription verifications to ensure medical safety and amending the law to reflect this

The next matter concerns prescribing verifications for ensuring medical safety and amending the law to reflect this. When radiological technologists receive an order from a doctor in a clinical department, they always confirm the order before carrying out the test. For example, confirming whether it is the right or left knee, or if it is an upper abdominal or lower abdominal CT. In order to verify the actual situation, from December 1, 2012 until February 14, 2013, surveys were conducted on 1,129 hospitals and clinics randomly selected, and responses were obtained from 647 facilities. What was found was that radiological technologists at many medical institutions were actually carrying out certifications in the form of verifications.

However, we also learned that these were not being reported. I urge all of your institutions to file incident reports when a prescription verification finds that right should have been left, left should have been right, or upper should have been lower.

The survey also received 246 responses saying that "order slips are issued disproportionately by a specific person" and 222 responses saying they are issued "disproportionately by a specific department." We conducted a survey last year at Showa University Dental Hospital where I work. Verifications are required at pharmacies based on article 24 of the Pharmacist Law, so surveys of verifications are always discussed at meetings. We similarly performed a survey of the radiation office. There were 181 verifications over one year, about 35.9% involving the pharmacy. From a medical safety standpoint, I encourage all clinical departments to do the same. I do not think verifications are just a problem for radiological technologists or pharmacists. Instead, they need to be carried out for examination and treatment requests by all medical professionals. At present, prescription verifications are not part of the law, so I would like to add an article 25 to stipulate that if a radiological technologist is unsure about an examination or treatment request, irradiation cannot be performed until the uncertainty has been resolved with the doctor or dentist who issued the request.

5) Amend the Radiological Technologist Law to reflect compliance and other matters

To understand how to amend the Radiological Technologist Law to reflect compliance, we studied how this is handled by other professions. We found that public health nurses, maternity nurses, nurses, and assistant nurses must submit a report every two years to the governor of the prefecture where they work. This provision comes with a penalty. Doctors, dentists, pharmacists, dental hygienists, and dental lab technicians must submit a report every two years to Minister of Health, Labour and Welfare via the governor of the prefecture where they work. Dentists and dental lab technicians must also submit a report to the governor. Similarly, I believe our profession needs to submit reports based on compliance. This year we launched a committee to study this information, which is also being examined by a panel that is looking at the problems with the Radiological Technologist Law.

Conditions governing the relationships between doctors and other medical professions are laid out in article 17 of the Medical Practitioners Law. Medical care cannot be carried out by anyone except a doctor. Therefore, the current Radiological Technologist Law lays out subordinate legal relationships with respect to doctors and the Medical Practitioners Law. This is also seen in the laws governing other specialized medical professions, which highlights the need for drastic reforms.

4. Policy 2 – Regulations for the education of radiological technologists and the shape that clinical training should take

The second policy concerns regulations governing the education of radiological technologists and the shape that clinical training should take. In 2014, we asked MEXT and MHLW to reexamine our regulations and clinical training. As a result, JART and six teachers from the national association for radiological technologist training studied how the Radiological Technologist Law should address clinical training regulations. Considering the achievements of team medical care and the aforementioned expansion in our duties, MHLW officials took part in reexamining the regulations to reflect our expanded duties in 2014 and 2015.

Along with pathophysiology, clinical anatomy, and clinical pharmacology, the committee to promote team medical care instructed us to include medical safety management, so we came up with 99 credits. However, due to opposition from the Japan Radiological Society, only the current 95 credits were accepted in meetings with the MHLW.

The regulations governing our profession are now 15 years old, and are in need of substantial reform. We asked the MHLW for assistance, which officials there agreed to provide. However, they asked that JART and people from radiological technologist training institutes around the country examine the regulations together, so a committee comprising six people form the national association and five people from JART spent a year examining the issue. During the discussions, we came up with a total of 105 credits: 14 credits on basic disciplines; 13 credits on the structure and functions of the human body, and the origins of disease; 15 credits on technical basics in health, medicine, and welfare, and the science and technology of radiation; 17 credits on diagnostic imaging technology; 7 credits on radioisotope examination technology; 7 credits on radiation therapy technology; 6 credits on medical image information; 4 credits on radiation safety management; 2 credits on medical safety management; 5 new credits on imaging diagnostics; and the credits for clinical training were increased from 10 to 15. The content of the joint meetings between the national association and JART were reported to the national association in June. Unfortunately, the joint report on the 105-credit proposal—which

included new credits on imaging diagnostics and 15 credits of clinical training—became a JART proposal. Keigo Endo, president of the Kyoto College of Medical Science, which was the new duty school, formed a group to re-examine the issue. This group then proposed that 97 credits are sufficient. They eliminated the 5 credits we had allotted for imaging diagnostics and replaced it with two credits of "imaging diagnostic technology." Over the last 15 years, the field of radiological technology has grown both qualitatively and quantitatively. How is it possible to look back on these 15 years and only add two credits? These 97 credits will not be changed again for another 10 or 15 years. Is keeping a low number of credits for such a long time really the best way to educate radiological technologists for the benefit of the public?

Concerning clinical practice, doctors are transitioning from a primarily observational model to a participatory model, and other medical professionals are facing the same issue. I cannot understand how just two credits is adequate for addressing the expansion and qualitative changes in our duties over the last 15 years.

I would like to discuss clinical training for other specialists, particularly physical therapists and occupational therapists. On May 30 of this year, the topic of clinical training came up before the Diet. The person who initiated the conversation was Toshiko Abe, a member of the House of Representatives and the Japanese Nursing Association. She asked about the educational objectives of clinical training for physical therapists and other professionals.

The educational objectives of clinical training are to foster students' clinical observational and analytical abilities so they can address an array of societal needs, possess the ability to create treatment plans, and gain skills in real settings. These objectives require a participatory model. Abe then asked about the specific clinical training that physical therapists and occupational therapists receive for technical items that are not very invasive. These involve using motions designed to help patients recover basic movements like sitting and standing to disease situations—things that certainly require participatory training. She also asked about the qualifications of the teachers who conduct participatory clinical training and about the instructional system. An MHLW official replied that each training institution should have a two-to-one ratio of trainees to trainers. These are the kind of specific answers that were given during questioning in the Diet this May. All medical professionals are being asked to change from observational to participatory training. Currently, we have 10 credits of observational training. Even if we change this to 10 credits of participatory training, who can say that it will be sufficient? If we are going to do this, we need to increase the training hours.

Do you know what is happening with other medical professionals? Massage therapists, acupuncturists, and moxibustion practitioners must currently take 77, 86, and 93 credits, respectively; after an MHLW study, these numbers may increase to 85, 94, and 100 credits. Even acupuncturists, moxibustion practitioners, and massage therapists take 100 credits, and these professions are even thinking about further increasing their clinical train-

ing. The same changes are happening to judo healing therapists. A newspaper article from the August 19 issue of the Yomiuri Shimbun stated that judo therapists needed 85 credits to graduate from training institutions 15 years ago. Now, 99 credits are required, which means that as the quality and quantity of a judo therapist's duties increased over the last 15 years, 14 credits were added. How is it that radiological technologists need just two additional credits in 15 years? I am always fighting for the profession, but this is something I cannot accept. Even judo therapists added 14 credits over the last 15 years. However, after reconsidering the matter, the new draft submitted to the national association only added two credits. What is this? It is unbelievable.

5. Policy 3 – The shape the educational system should take with an eye to the future

Next is the third policy: the shape the educational system should take with an eye to the future. The Radiological Technologist Law was brought before the House of Councillors in 1951. It was proposed by Yasaburo Taniguchi, the then head of the Japan Medical Association, and was brought before the Diet by six other lawmakers. At the time, it was decided to have a two-year educational curriculum consisting of 2,195 hours.

Based on this law, the two-year educational system began in 1951. In the following year, two-year programs were launched by Osaka University and Shimadzu Roentgen Technical School. A three-year system was proposed to and approved by the Diet in 1968. Three-year programs started in 1968. These were governed by both the Medical X-Ray Technician Law and Radiological Technologist Law, and required 2,985 hours of education. I have already discussed our duties back when we had a three-year system, which was mainly simple X-ray imaging, as well as X-ray TV, angiography, radioisotope exams, cobalt therapy, and superficial treatments. However, our duties have since grown. New diagnostic imaging equipment for clinical use was developed in the form of X-ray CT, and our jobs have transitioned from analog to digital with the appearance of methods such as PET, MRI, DSA, and CR. Our work has expanded so much that we eventually began considering a four-year educational system. Thanks to the hard work of our predecessors, in 1983, the laws were integrated under a single Radiological Technologist Law. Along with integrating the laws, they also thought four-year education was something that needed to be implemented. Four-year universities and graduate schools thus began to appear, starting in April 1987 when Fujita Health University launched a program to train radiological technologists. Suzuka University of Medical Science—back then, its name also included "and Technology"—established a four-year university centered on JART. As for the national universities, Osaka University launched a program in 1993. Graduate school education began in 1996 with Suzuka University's course on medical imaging information, followed by Osaka University's Division of Health Sciences in its Graduate School of Medicine. Four-year ed-

ucational systems thus spread and graduate school programs were launched in both name and reality. Looking at how our duties have continued to expand, in 1993, there was the appearance of MRI, along with ultrasonography, non-mydriatic fundus cameras, and confidentiality requirements; then in 2005, proton beams, heavy particle beams, and neutrons came into the picture; in 2010, assisting with image interpretation, providing explanations and consultations about exams were included; and in 2015, our duties involved removing needles, stopping bleeding, lower gastrointestinal exams, nuclear medicine diagnostic equipment, comprehensive instructions for chest screenings, and inserting tubes during IGRT. If things continue in this vein, our education will become too broad for the scope of a three-year education, and we will need to turn to four-year programs or even more studies.

In 2014, MEXT launched a problem-solving orientated training program for advanced medical professionals, and sought participants from educational programs around the country for research. The issue was related to doctors and dentists, in particular the lack of advanced medical specialists, the diversification of society's medical needs, and the changes to dental and medical needs due to an aging society. Our involvement has been in three areas: promoting team medical care, strengthening ties between educational and clinical settings, and promoting regional medical networks. We need to pay particular attention to developing pre-graduate and postgraduate continuing education programs and to building a faculty development system, as well as training instructors in the clinic and carrying out personnel exchanges between university teachers and instructors. Individuals who teach in universities need at least a master's degree, so to have personnel exchanges with these educators, the radiological technologists who work in the clinic and oversee clinical training must also minimally have a master's degree.

In MEXT's problem-solving orientated training program for advanced medical professionals, instructors from educational institutions and clinical settings need to be on the same level in order to exchange views. In particular, we need to improve educational programs in fields that support biological function diagnostics (i.e. radiological technologists, clinical laboratory technicians, clinical engineers). More hours are needed for education, and we need to build strong relationships between communities and universities. The people who are responsible for the clinical training for 2,500 annual graduates nationwide minimally need a master's degree, I think. I believe this will become a major requirement for education in our field. At this year's general meeting, I proposed a six-year educational system, which was adopted by the assembly. Going forward, four-year education should be seen as the minimum; we should also start looking at master's level education or six-year educational systems. Last year, the president of the Japan Pharmaceutical Association spoke about the successes and problems with six-year pharmacy programs. Our three-year programs with 95 or 97 credits are just not adequate for

the times. Globally, Britain already has a profession called radiographer practitioners who perform reporting. In the United States, the course to be a radiology practitioner assistant or radiologist assistant is 93 credits, which allows them to assist in image interpretation. In Japan, we are working with a system that is about 15 years behind. I believe this is preventing development in our educational system and our profession. We need to look at the matter of education seriously. As the medical community develops, all specialized professions, not just radiological technologists, have a growing number of duties. It is not acceptable for just the profession to grow. The educational system that guarantees our profession is also extremely important. Looking at the history of our education, we started in 1951 with a two-year educational system, followed by three-year and four-year systems in 1968 and 1987, respectively. Furthermore, looking at what the current duties are, it seems obvious that in order to train people with advanced problem-solving skills, a six-year educational system is needed. More than anything, we need to provide medical education that meets global standards. Therefore, I believe the time has come for us to thoroughly reexamine how we conduct clinical training.

Japanese medical school graduates will switch to a participatory model of clinical training in 2023. If the current 51 weeks are not increased to 72 weeks, degrees from Japan will not be accepted around the world. The deadline for medical schools to meet global standards is 2023. Medical schools in Japan currently provide an average of 51 weeks of clinical training. If this is not increased to meet the minimal global standard of 72 weeks, as of 2023, graduates from Japanese medical schools will not be accepted at foreign study destinations (places that accept medical school graduates).

As medical professionals, we also need to

live up to global standards by switching from observational training to participatory training. On this point, we have long required 10 credits of clinical training. To take these 10 credits and move to a participatory model, it was proposed to increase to 15 credits. Unfortunately, the national association did not deem this necessary, and decided to retain the 10 credits. On top of this, we were told that the fruits of the last 15 years, quantitatively and qualitatively, mean we only need to increase our education by 2 credits. Judo therapists have added 14 credits over the last 15 years. How in the world can this difference be explained? The development of our profession is nothing if not for the development of our education. Our future depends on perfecting these educational developments. I want the national association group and professors at national universities to clearly understand this point: I believe that the report I submitted to the national association should be sent to the MHLW for consideration. The next generation of radiological technologists will serve during a time where chief radiological technologists and radiological technologist professors will play an active role. The chief radiological technologists and technical department heads

at university hospitals around the country are part of the university hospital mission to be institutes of care, education, and research. Therefore, I would like chief radiological technologists at university hospitals to at least have a doctorate. Then, when they participate in personnel exchanges with educational institutions, information from clinical settings can be quickly communicated to the educational arena. Professors as well, through exchanges between themselves and with the heads of clinical departments, need to usher in a new age of education for radiological technologists. I would urge them to play an active role. At the moment, we see a bachelor's degree as a matter of course. Please, do not be satisfied with just a bachelor's degree. Get a master's degree. Furthermore, instructors should not stop with a master's degree. Please obtain a doctorate and help generate evidence-based data to submit to the MHLW. Unfortunately, Approximately 30% of the instructors have not yet a doctorates. I hope that all instructors will obtain doctorates so students can be educated by professors with doctorates. I hope that chief radiological technologists will strive to become department chiefs and vice hospital directors, and that leaders of radiological technologist departments will play active roles within their hospitals. I hope this age will come, and to get there, I believe we need to develop a proper educational plan. I have said some harsh things in this talk, but I hope I have convinced you on this point. Let us work together. Thank you for your understanding and support. I appreciate your courteous attention during my speech.

Chairman Yasuda: Thank you very much, President Yasuo Nakazawa.

Thank you for your report on the rapid response to the Kumamoto earthquake, and the detailed description of the path our field has taken since 1951. Regarding education, thank you for your careful explanation on how we differ from other professions. President Yasuo Nakazawa has excellent teaching skills, and as the leader of Japan's 50,000 radiological technologists, I hope he continues to play an active role in our profession.

The 32nd Japan Conference of Radiological Technologists

Invited lecture

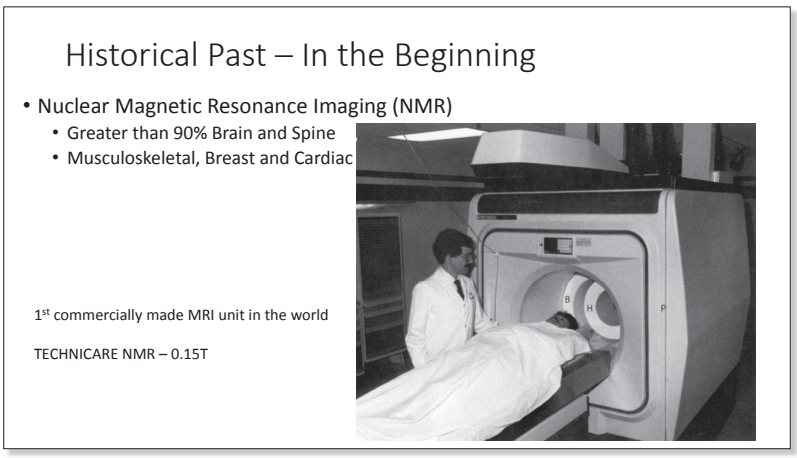
The Challenge of Teaching MRI in the Future

Dr. Grey Michael Lee
Illinois State University, Associate Professor

Michael Grey:

My presentation today is about the challenge of magnetic resonance imaging (MRI) in the United States. As you know, there are many areas of radiology, e.g., radiation therapy, ultrasound, nuclear medicine, vascular catheterization; thus, there are different areas of radiology and medical imaging as a whole. MRI is very new, whereas radiation therapy ultrasound and nuclear medicine has been in existence for many years. Thus, it was challenging to develop MRI in the United States. Any program that is developed requires funding from a university and from the government to help to start the program. In the context of this challenge, I today want to discuss program development, course development, and how to go about setting up programs in this respect.

In the beginning, MRI was not called magnetic resonance imaging. It was called nuclear magnetic resonance imaging. Thus, the abbreviation was originally NMR imaging. Therefore, when, performing any kind of literature search to prepare a paper or talk about anything historical, it will be necessary to search using the word 'nuclear magnetic resonance imaging'; not the abbreviation, but the entire

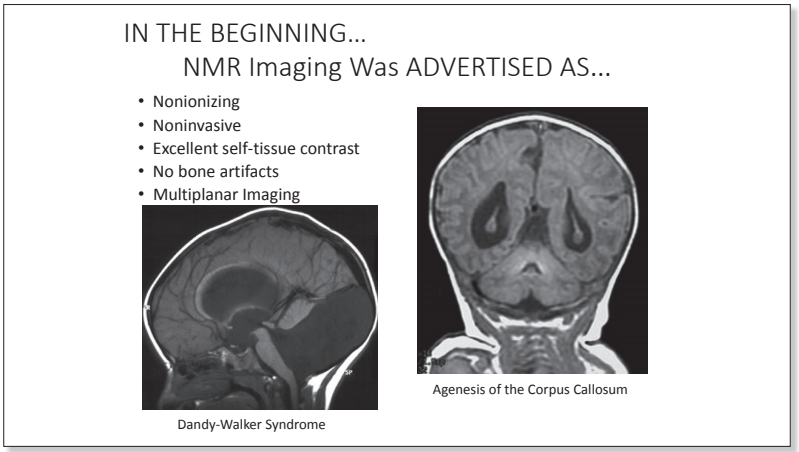


phrase. Using only "magnetic resonance imaging" will not include the very beginning of the history. This is a picture of the system that was the very first commercially made unit in the world. This is a 0.15-Tesla resistant unit and this is me, back about 1984. This was the first commercially made unit and the company was called Technicare Corporation. GE bought Technicare and thus Technicare no longer exists, it is now part of GE.

In the beginning, many of the studies that were performed focused on imaging the brain and the spine. We performed some musculoskeletal, some breast, and some cardiac, imaging, but only very little. Additionally, in the beginning, we had to introduce a brand new imaging modality to the public. We had to introduce a brand new imaging modality to the world. Our facility was at the University of Kentucky Medical Center, which has a great basketball team. Previously I have worked in CT; trauma CT, routine CT, all aspects of CT. Among the problems we had in CT at that time was that patients would get sick if we gave them IV contrast. They would have nausea and may vomit. Therefore, many people did not embrace the idea of undergoing a CT examination because they expected that they would feel sick.

When MRI became available, we educated the public and advertised the technique as involving nonionizing radiation that would not hurt the individual. We also explained that it was noninvasive, requiring no contrast agent, as gadolinium had not been approved for use at that time. It would still be a few more years until gadolinium was approved for use as an MRI contrast agent. We also advertised it as having, excellent soft-tissue contrast, and today that is still true. Of all available imaging modalities, MRI gives the best soft tissue contrast.

MRI yields no bone artifacts. Because we originally did so much brain and spine imaging, the doctors realized the benefit of MRI, especially in the posterior fossa region, which would be back in this area here, or in this area here. There is no bone artefacts due to beam hardening. Thus, the modality was very useful for looking at infratentorial-based lesions. It also multi-planar imaging. We obtained axial, sagittal, and coronal images, giving doctors a three-dimensional view of where a lesion might be located. Thus, it was very good in brain and spine imaging. So, these are – Some conditions, such as this is Dandy-Walker syndrome was very easy to diagnose on MRI. This is agenesis of the corpus callosum. There is no white matter connection here.



We initially did much work to help introduce MRI to patients, to doctors, to communities around the world on a regular basis. I can remember people coming to our facility from other hospitals and other universities. Many times they were from Japan. They would come to the USA to visit our facility to come and see what MRI was. It was an interesting and an exciting time in my history.

Shortly after MRI started, several companies began to manufacture MRI units, shown in this long list. Companies called Wang NMR and Toshiba are still here today; Technicare is gone; Siemens is still here; Shimadzu; Advanced NMR systems; Picker is no longer; around GE; Diasonics; Fonar, still produce today, (Dr. Damadian is President and CEO of Fonar;) Elscint; Philips; and Bruker. Thus, today there are fewer companies that are producing MRI machines. They have been bought out and consolidated to where we have Toshiba, Shimadzu, GE, Philips, Siemens, which are probably the main MRI machine manufacturers around the world.

Now, when I was working in MRI, I decided that I needed a new challenge. I enjoyed working with patients, I enjoyed being in the spotlight having people come by and ask questions, but pushing the buttons began to bore me. I wanted something new to do and so I went back to school and I obtained my Bachelor's degree in Health Science. There was a very strong education content to that Bachelor's degree. I then considered that both MRI and are new, but there were no education programs for either as yet. I therefore resigned as a technologist and moved to the university at which I am based now, Southern Illinois University. At that time we were transitioning from an associate degree, which was a 2-year education program on X-ray only to a 4-year baccalaureate (BS) degree. And in the fourth year, the senior year, we were going to include advanced specialization such as MRI and CT.

Now I don't know how many of you are faculty professors, but at that time, there was no MRI or CT program anywhere that I could find to look at what courses were being used, and what was being taught in class. I therefore had to consider what information should be taught in a program on MRI and CT. I was told to cover both modalities, which was a pretty tough asignment. I decided to develop four courses for dogmatic classroom instruction. There would be a CT Technology course, which would teach all aspects of CT. There would be an anatomy course teaching normal anatomy. There would be an MRI technology

course, covering all aspects of MRI, and then there would be the pathology course for CT and MRI. That was the one area for which I could not find a textbook or any information that was written for technologists that would help them to learn and develop their skills.

The first problem in the course work was finding textbooks that the students could use to read, to lecture from, and to make the program feel more like program. Remember that at this time, about 1996, nuclear medicine, radiation therapy, ultrasound, and radiology were very well, but MRI and CT were not. Thus, it was a challenge to get approval to begin a program such as this. One of the challenges was helping to produce the textbooks for the students. This is me with my very first book; it is on display with the publishing company McGraw Hill here. This was a big accomplishment. Later on the first edition of that book would be translated into Japanese. The second edition was translated into Russian. Currently, I am working on a third edition. With each edition, and the number of cases that will help the technologist to grow and be able to discern the difference between normal and abnormal structures has increased.

Now, the next challenge was in the program that I described earlier: CT technology, MRI technology, sectional anatomy, CT/MRI pathology, which was designed to provide an introduction of MRI and of CT at an entry level. However, MRI technology has advanced. We now have higher field strips, we have a better gradient system, we have a better RF coil, and we have better software. Thus, we have the ability to perform a greater variety of examinations today than in the beginning. In the beginning, over 90% of our studies were of the brain and spinal cord, but this is not the case today. Today, we see many musculoskeletal studies, we see cardiac, vascular, and breast imaging; there is a wide variety of examinations being performed today. Hence, when developing a career path or career ladder, this was something that I think professors need to think about. They need to monitor the growth and the variety of examinations that are being performed maybe in their countries. We do in our country, as I will show. This allows one to use that data to help guide programs for developing a career ladder.

MRI has advanced markedly, so that MRI can do many things today that could not be done originally. We therefore need to stay current and keep up to date with the types of examinations that are being performed. I am going to show you that in just a little while. We also need to consider what changes are occurring in MRI. In my life, there has been many changes in MRI; that has only been over the last 35 years. As professors, we need to be aware of those changes and how to integrate them into our program, or consider the need for two levels in our program a beginner level and an advanced level.

We also need to think about the new trends in imaging. Here is an example of something I found very fascinating. This fracture is termed an occult fracture. Does anyone know what an occult fracture is? You cannot see this type of fracture on a basic X-ray. Years ago, the doctor would have said, "You should undergo a nuclear medicine study." The patient would then have to be injected with a radioactive isotope, and would have to sit for a long period of time, but the image would not be nearly as good as this is. Thus, in current practice, the trend is that a patient with a normal X-ray, but with continueing problems should undergo an MRI, without contrast, gadolinium, radioactive material, or ionizing radiation. The patient simply undergoes a study and leaves. Thus, the way in which we order studies on patients has changed to improve the outcome. This is a very interesting and good example

The Challenge:

Developing the Career Path for MRI Technologists

Keeping current … and Keeping up to date…

- What changes are occurring in MRI?
- What are new trends in imaging?

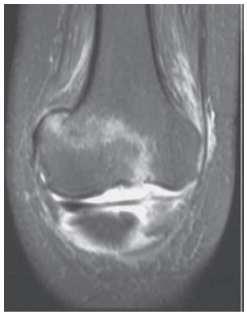


FIGURE 2. Fracture of the Medial Femoral Condyle. STIR coronal MR image of the knee (same patient as in Figure **1**) shows an oblique fracture of the medial femoral condyle as high signal.

of use as things change and why they change. This highlights the need to monitor these types of changes as they continue to occur.

Here is the challenge in teaching MRI. Today, we need to think about the career path of our students, and our technologists. We need to think about how to advance from the introductory level. In the United States, formal education about MRI or CT is not required, unfortunately. The manufacturer will teach the technologist to push various buttons, but no formal education is given. However, we are dealing with a piece of equipment that is very expensive and can have a vast impact on patient's lives. Do you know patients who have been injured during MRI in your country? Have you ever heard of a patient being injured during MRI? What about a patient who was killed during MRI, who died from MRI? Do you know?

In my country, I do medicolegal work. I review cases about people who have been hurt or killed. I do not advertise. They find me. I review cases and I consult. Two years ago, MRI death should not have occurred. However, it is very unfortunate that there is no formal education on MRI given in the US. Nevertheless, we have a program; students can choose to come or not. I am glad when they do. To go to the next level, the advanced level, we need to think about many things. We need to consider what types of skills will be required to do the new procedures, the advanced procedures. What type of education will be required? Will it be formal classroom education? How should this be done in a hospital clinic setting? We need to think about what are our goals, what are the values of accomplishing this task, where is the interest, what type of doctors, and what type of facilities will benefit from this type of education? How should we develop these courses?

There is a need for experts in education, content, and subject matter to write the objectives, to write the instructions, to write the test questions, as well as for professors who understand the content, have experience, and can teach in the correct way. Finally, we need to consider professional growth, involving the introduction, beginning, and then advanced level. We need to think about how to prove and verify the change, the trends, and how to support a proposal for advanced education. This could involve a job analysis. It is also called practice analysis or a needs assessment.

It is useful to consider and monitor what technologists do in your hospital, as this can be used to determine the type of education and training support that is needed. If a higher number of examinations are performed, it

could support the need for a program modification. If technologists perform poorly because they do not know the anatomy, and they do not know how to perform a study, other than simply how to push buttons, education and training could support that. What is the content and the scope of the education and training that needs to be done? This has two facets. Education is formal instruction in the classroom. Training occurs in the hospital environment, working with other experienced people, such as radiologists, physicians, and other technologists, gaining hands-on experience in proper sequencing. At my university, I do all the coursework first and then when the student goes into the hospital setting, they know everything about technology, pulse sequences, patients screaming, and contrast agents. They therefore merely require experience in how to position the patient and perform the studies. Thus, in their 3 week rotation, they constitute extra help, and thus, the hospitals really like the students.

Therefore, at what should be included in the program. What topics are best discussed in the classroom? What topics are best dealt with in the clinic setting. Once we know and this, we can set assignments, objectives, and questions that support this. In the United States, we are collecting much data on outcomes, where we have to do program assessment. The administration looks closely at program assessment, where we look at the students coming in, the students exiting, and 12 months later. We consider whether they are working as MRI technologists and if so, what their employer thinks about their work. We have to submit all this information to our administration on a yearly basis. In such program assessment, we determine where there is weak area, to try to improve and strengthen the program. We also need to obtain the support of management. If my management, my administration, and the hospital's management are all working together in teaching the medical students, we have a win-win situation.

It should be considered whether the hospital needs such a program, and whether the studens require such an education. This is the concept behind doing a job analysis, practice analysis, or needs assessments. For my doctorate, I used data obtained by the American Registry of Radiologic Technologists. They needed a subject matter expert, and contacted me, saying, "Here's data. We don't know what to do. Could you look at the data and help us to decide?" This is what I then did; I based my doctorate research on that data, and I wrote an article and submitted it to our professional journal in the US, Radiologic Technology, and it was published. Here is the title. It was a preliminary study, the very first one ever

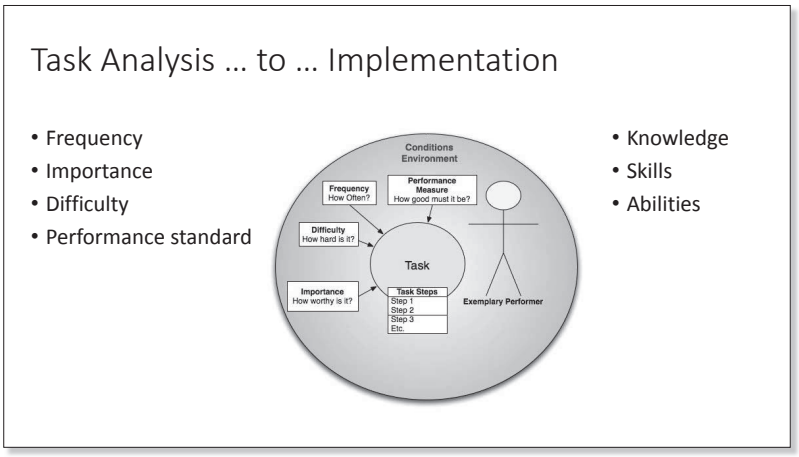
done, and this was something that I think that professors and faculties should consider.

I see many people, such as technologists doing clinical research. In our country, medical doctors do the clinical research. They have the authority to say what is good and what needs to be changed. In terms of education, I should focus on education research. This was the first study that I know of that considered advanced level MRI. We had done a survey much earlier that was published to support only the introductory level, which had been performed around 1996. From that study, I was able to identify that there were some specialty areas. We saw a large number of examinations being performed in those areas. If I were to put this together into what could be a course, I would call one course Cardiovascular; it would deal with the heart and heart coronaries. I would call another course, central nervous system imaging; this would more include doing functional MRI, MR spectroscopy, diffusion tensor imaging, and fiber tracking, in the brain. We see those areas growing. I think technologists need to be better educated in those areas. The third area would involve everything else. Thus, in body imaging, focus in greater detail on musculoskeletal imaging, include breast imaging, do more vascular imaging, and more abdominal pelvic studies. We cannot teach everything about MRI in an introductory level course; it is necessary to separate the introductory and advanced levels.

It is therefore necessary to decide what should be included in the basic introductory course and what should be included in the advanced level. In doing a task analysis, the intent is to begin a program and use a task analysis to help implement or start it. Items to consider when developing your survey is identifying the various types of examinations that are performed. Those could be the tasks that are set. In identifying these tasks, the

frequency with which, you want to look at these examinations are performed should be considered. In the US, some hospitals have an MRI unit for performing cardiac imaging only; other hospitals do no cardiac imaging, and yet other hospitals do, a little bit of cardiac imaging. Thus, while we can do cardiac imaging, not all places do cardiac imaging. In our healthcare system, the insurance companies do not reimburse for cardiac MRI although they reimburse for cardiac CT. There are therefore other issues that come into play here.

In addition to frequency, what is the importance of such a study? For example, although reimbursement is more likely for cardiac CT than for cardiac MRI, it is still necessary to record how frequently these studies are performed. Similarly, how frequently is breast imaging performed? In musculoskeletal imaging, what is the most common joint that is imaged; is it the shoulder, elbow, or wrist? It is most likely the shoulder. In the lower extremities, is it the hip, knee, or ankle? In the US, it is the knee. Besides recording frequencies, we also need to develop a scale of difficulty. How difficult is it to perform the procedure? Is it low, medium, or high difficulty? Some MRI procedures are easy to do, while some are very challenging and much more difficult to do. The more difficult procedures may require more time for teaching while those that

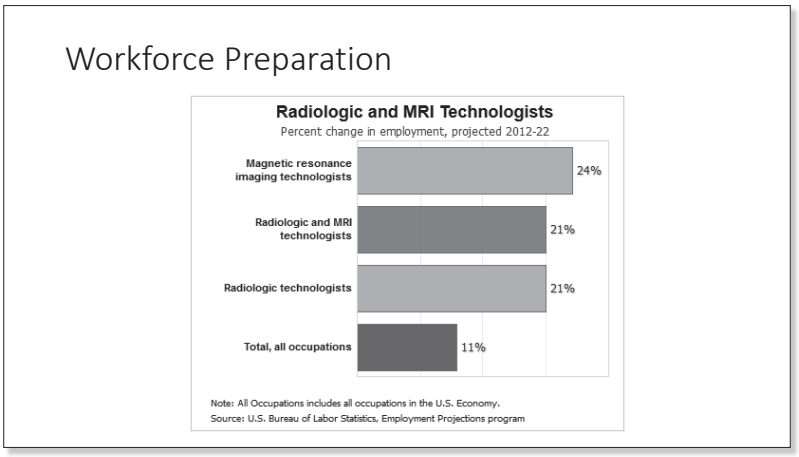


are easy may require less time. In addition, a performance standard is needed. How good should the study be? Ideally, we would want the study to be perfect. However, as this is implausible, we require a standard that determines the requirements that a study should meet in order to pass, and for the education to be good. In each type of task, it is necessary to identify the knowledge, skills, and abilities that should be acquired.

What does a technologist need to know, what do they need to know how to do, and are they able to do it? When you include these three things into the writing objectives, it allows evaluation of each student, on their knowledge, their skills, and their abilities. Thus, these items help us with our assessment program. We therefore see the beginning and we see the end, and then 12 months after graduation, what does their employer, their manager, their director think of them? It is important to monitor whether they are satisfied or not and whether there is an area in which they see the need for improvement.

Now, in the United States, a company, IMVinfo.com, track data including data on the growth in MRI sites in the US. It is very helpful to managers and administrators to have a vast amount of data to help them make decisions on trends, or even to help them in buying a brand new piece of equipment. Thus, in looking at the data in some years, in 1998, for example, there were over 4000 MRI units in the United States in 1998. In 2004, there were almost 7000, indicating a steep growth in the number of MRI units purchased. In 2007, the number dropped a little bit. Today, the most recent data for 2015, shows about 8500 MRI facilities in the US. Some hospitals have two, some have three, some have four. Not all hospitals have MRI, very small hospitals have no MRI. Nevertheless, we observe a growth in the number of MRI units from the beginning to the present day.

Likewise, we see growth in the number of MRI procedures that are performed. Starting in the same year, 1998, about 12 million examinations were performed, and this number has grown; in 2015, about 38 million procedures were performed in the US. What can one tell an educator in a university about the needs of technologists working in MRI? The technologists workforce is predicted to show a mean increase of almost 25% between 2012 and 2022. Therefore, the type of data I have been investigating and data on other trends should be put together into a proposal to submit to the administration, as something needs to be done to meet the needs of the field. If I simply go to my administration, and I sit down and talk to them, and say to my Dean, "We



need to develop our program further", they' ll say, "Why? Where is the proof? Why should we do this?" Talk alone is insufficient. You need to have the data that support what you want to do to help meet the needs of the people in your nation. Therefore, having access to that information is excellent, and when you do not have access to it, then you have to be the person that goes and gathers it.

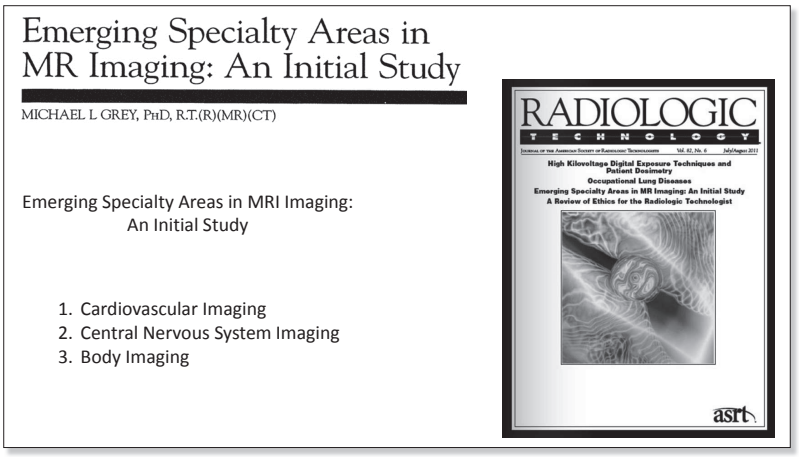
The company shown here is only for the US, but you could put together a survey and do your own study for your country. You then to write that up as a manuscript for publication in a journal, to make it a record of history. We predict the needfor an increase of almost 25% in the next few years, for MRI technologists only. We also see a need of about 20% for x-ray and MRI combined. All students that participate in my program, have already been trained and accredited in X-ray. The have already been through the basic radiology program; now they come into the advanced level, MRI and CT. By the time they have done three credentials, i.e., X-ray, MRI, and CT. They are very remarkable, and they usually have a job before they leave the program, which pleases me. It looks good on the assessment report.

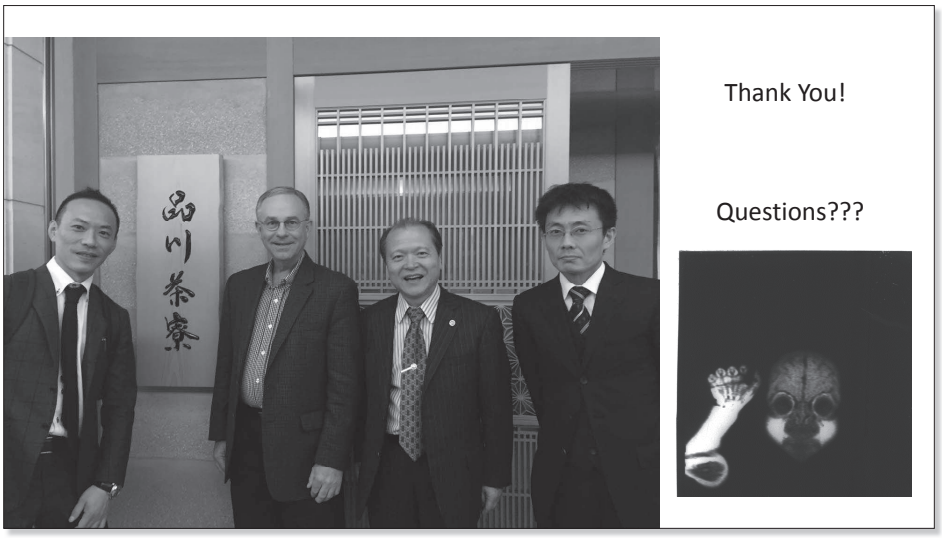
So, this comes out of a federal organization called the US Bureau of Labor Statistics and even though this is probably pointed projection, the word "projection" means they consider that there will be this type of need in future. We can use this type of data to support a change today for what is being looked at in the future, which is very helpful. Here again, when you would do a study in your country, that kind of gives an overview of what type of procedures are performed, how frequently those procedures are performed. Next, you should write that up and submit it to a journal, a professional journal, for publication.

You could be the first for your country maybe. Work with your government, work with your professional society. For me, emerging specialty areas in MRI and the initial study. If someone 10 years from now is doing a study on education trends in MRI, if they are doing a search for literature review, it will take them to the Radiologic Technology journal, and they'll see my work there. So I will encourage you to do these types of studies, write them up, and submit them for publication. Many times, professors, managers in different areas of medical imaging need to work for promotion, to climb the career ladder. This is a very good way of helping you obtain publications, to help with presentations, to share what goes on in your country. So, I have read a little bit about some of this in other countries but not very much in all the countries in the world.

So think about this and sharing what goes on in your country. It can also be beneficial in doing time course studies. Was there growth? Was there change in trends? So it can be very helpful in your nation.

And when I was here in April, I was introduced to your journal here in Japan and I was very excited that there is an English version I would be very interested in working with a professor here in Japan if he would like to collaborate and write a manuscript and submit it for publication. I think it would be good. It would be good for both nations and very good for professional status. This is from my visit in April and again Dr. Osawa and Yasu, who took care of me, getting me from the airport to the train station to my hotel to this meeting to the train station back to the airport, I cannot thank you enough. I appreciate all the help that they gave, I had a very good visit in April, and very good visit this trip here. So I am very thankful for my friends in Japan and on this trip here meeting other friends that I have not seen in a few years from other countries, Taiwan and Singapore and Macau,





I am very thankful to my friends from other countries.

Even though I am from the US, we share a common interest, medical imaging. Thus, brothers and sisters in the healthcare field would like to say thank you and if you have any questions, I would like to take those questions now. Thank you.

Chair Person:

Thank you so much Dr. Michael. Today, you delivered a very good lecture. Thank you. I'd like it for Vietnam.

Michael Grey:

Vietnam, that's right, yes.

Okay. Thank you. Thank you very much.

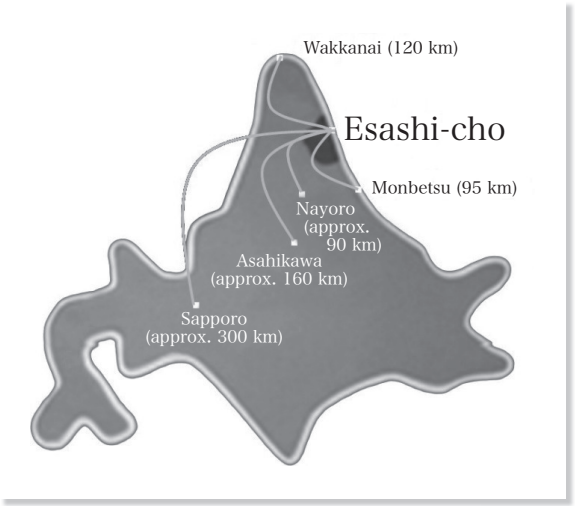
Hospital Introduction and Current Status of Regional Healthcare with Progressing Depopulation

Kensuke Ehara
Hokkaido Association of Radiological Technologists Wakkanai Branch
Esashi Hospital

Introduction

My name is Kensuke Ehara and I work in Esashi town in the Souya region of Hokkaido. Esashi Hospital where I work in a secondary emergency medical institution, which performs clinical services; it has83 beds (general beds: 46, long-term care beds: 37), and clinical departments that include the Department of Internal Medicine, Department of Cardiovascular Internal Medicine, Department of Surgery, Department of Orthopedics, Department of Pediatrics, Department of Psychiatry, Department of Neurosurgery, Department of Gynecology, Department of Ophthalmology, as well as 17 beds for artificial dialysis (including isolation). The current equipment for the Department of Radiology includes a general imaging device, x-ray TV, angiography equipment, 64-slice CT, 1.5T MRI, MMG, DEXA, US, and WS. As a local government-run hospital, we are fortunate to have a favorable environment in terms of equipment and facilities. There are currently three radiological technologists.

In 2006 Esashi was amalgamated with the neighboring Utanobori town. In the ten years since the amalgamation, the population has decreased by 1,500 people, and the current population is approximately 8,500 people. The region faces the Sea of Okhotsk and has an area of 1,115 km^2, making it the ninth largest local government region in Hokkaido. In Hokkaido there are two Esashis: there is one located in the Donan Hiyama Subprefecture, which is well-known, but our Esashi in the Dohoku Souya region is very obscure. The main industries are fishing and dairy, and the



town has a particularly large catch of hairy crab and salmon. Distances from typical cities/towns are: 300 km from Sapporo, 160 km from Asahikawa, and 90 km from Nayoro where the nearest general hospital is located. Thus we are separated by distances unthinkable anywhere else in Japan but Hokkaido. Public transport consists of intercity buses. There is one round-trip bus to Sapporo once a day (the journey takes 5 hours), and two round-trip buses to Asahikawa a day (the journey takes 3.5 hours). There is no railway line in the town (discontinued in 1985), and the nearest railway station is the JR Otoineppu Station, which is approximately 50 km away. Currently there are three direct express trains to Sapporo a day, but it is uncertain how long this will continue, which is making residents living along the train line anxious. If driving toward Sapporo or Asahikawa the Hokkaido Expressway is used, but the nearest entrance to the expressway is 110 km away at the Shibetsukenbuchi interchange. However, Esashi is not an especially remote region; I would say that all regions of Hokkaido are in a similar situation. For me, born, raised, and employed in the southern district of Saitama, Hokkaido was very desirable, and 18 years ago I made up my mind and moved here. While living for a number of years in a number of towns in Hokkaido I was astounded at the uniqueness of the local healthcare in Hokkaido; thus I started working in Esashi with the feeling that "when embarking on a great project, start with small steps." It has been 15 years since I came to Esashi. Now, I would like to give my personal account of my impressions of working in Esashi, which is so remote from an urban area, and where there is progressive depopulation.

About Esashi

Esashi has a comparatively long history within Hokkaido, and in the 1680's fishing grounds were opened under the direct control of the Matsumae clan. In 1878 with the declaration by the Hokkaido Development Commissioner there were four villages established: Esashi village, Utanobori village, Tonbetsu village, and Rebun village. After that time there was enforcement of village amalgamation, separation and reorganization, and the current conditions were subsequently reached in 2006 when the former Esashi was amalgamated with the former Utanobori (from Esashi-cho history).

The population peaked in 1960 at 18,541 people but has since continued to decline. In 2015, the population was 8,500 people, making Esashi the epitome of a depopulated area (Fig.1). The number of households has not changed very much but shows the progression of the nuclear family, with approximately 4,300 households at the peak and around 4,000 households at present. When we compare 1960 and 2015 in terms of increases and decreases by age group, there has been a 53% reduction in population while there has been a 255% increase in people aged 65 years and older; the 15–64 age group has decreased by 56% while the 0–14 age group has decreased by 85% indicating a rapidly progressing aging population combined with a low birth rate (from Esashi population vision).

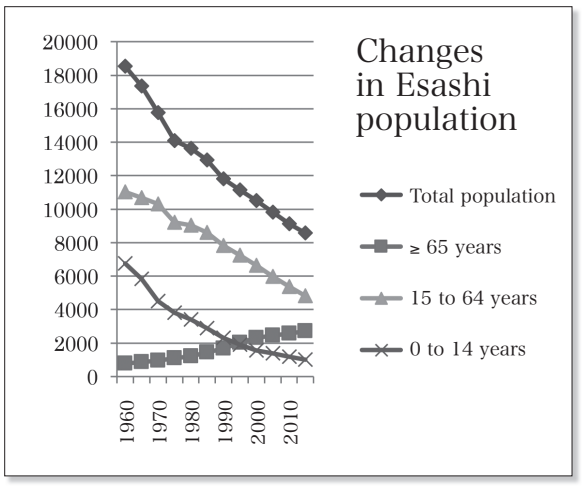


Fig.1 Changes in Esashi-cho population

There is only one hospital in the region

When I was employed by Esashi-cho, the people in the town kindly and warmly welcomed me and, needless to say, so did the hospital employees. My worries that outsiders would not be well-received were unfounded. There are many employees and residents who move here from outside the town and from outside Hokkaido, and almost all the current clinical radiological technologists, clinical laboratory technologists, and clinical engineers are originally from places other than Esashi.

The first thing that surprised me when I moved to this town was that people cannot choose their own hospital. Until a few years ago, there was a private health clinic but it was closed because the physician was very old. For me, who had been accustomed to having the option of going to hospital A for this illness, going to clinic B for that symptom, going to a duty hospital if something happened outside hours, I had never considered that people would not have a choice of different medical institutions. However, this hospital is responsible for all outpatients during the day, after-hours treatment during the night and on holidays, and emergencies. After the amalgamation of local governments Esashi ended up with only one hospital and one clinic, but this is only a transitional measure. There is the opinion that only one hospital should be enough owing to the depopulation, and there may also be some people who think that having one hospital is better than nothing, given the remoteness of the town. All the towns and villages that make up the Wakkanai Association of Radiological Technologists are in the same situation, with one hospital for one local government area. The patient flow is often to the local hospital, to the Wakkanai city medical institution if they live in northern Souya/Rumoi, or the medical institution in Nayoro if they live in southern Souya, and as decisions are made based on distance rather than on the available clinical departments, it is rare for patients to commute to a hospital in a neighboring town. Almost all the patients are local residents, and I was surprised by the high rate of encountering acquaintances. It is 90 km to Nayoro City General Hospital from Esashi, and 120 km to Wakkanai City Hospital. Half the year studless winter tires are required, and there is daily compacted snow ice burns. Frequently this region also has drifting snow which hampers visibility. For the town residents who are becoming increasingly more elderly, commuting to hospitals over long distances in their own cars is very difficult, so they must rely on their local hospital. However, for patients who need the departments of dermatology, ear, nose and throat, or ophthalmology, it is a 180 km round journey to the hospital in Nayoro and a round journey exceeding 300 km to the hospital in Asahikawa. This hospital is attempting to provide treatment to suit the needs of the local populace, but on days when there are no doctors deployed to the various clinics, and after hours, the regular doctors treat all the patients.

Shortage of doctors

When I came to Esashi there were five full-time doctors. This number decreased over the years and four years ago it became two doctors. From April of this year we gained one doctor, so now there is a three-doctor system, with two cardiologists and one surgeon. Outpatient clinics other than internal medicine, cardiology, and surgery are dispatched from Asahikawa Medical University Hospital and Nayoro City General Hospital, and we also request visiting care from hospitals in Sapporo and Asahikawa (Table 1). After-hours treatment at the weekend and emergencies are also requested of visiting doctors in the same way as the outpatient clinics. We are forever

Table 1 Number of days with visiting outpatient clinician

Pediatrics	3 days/week
Orthopedics	1 day/week
Gynecology	4 days/month
Gastroenterology	2 days/month
Neurosurgery	1 day/month
Ophthalmology	2 days/month
Psychiatry	1 day/month

grateful to these doctors, who travel vast distances to our hospital.

Esashi-cho is located within the southern district of the Hokkaido Government Souya General Subprefectural Bureau, and even in Wakkanai City Hospital in Wakkanai, which is the only city within the jurisdiction of Souya, a shortage of doctors is not unusual; there is also closure of clinical departments, and staff are beginning to find it difficult to accommodate patients from this hospital. Therefore, in terms of medical districts, secondary to tertiary treatment is requested of Nayoro City General Hospital, which belongs to the Kamikawa-hokubu district, but the acceptance system to the Nayoro City General Hospital is becoming stricter, and it is not unusual for patients to be transferred to medical institutions within Asahikawa over 160 km away from this hospital.

If there should be 200 doctors for every 100,000 people, then there should be 17 doctors for this town with a population of 8,500 people…

In Esashi-cho there was a change in the medical care system with the appointment of a cardiologist in 2005, who is the current hospital director. In 2006 MDCT and AG were introduced, which made it possible to diagnose and treat cardiovascular conditions, and then in 2009 one cardiologist was appointed to the hospital. There were originally eight beds allocated for dialysis, but the number of beds was increased to 17 to meet the needs of the local community, and the cardiologist can now deal with shunt problems with a shunt PTA. We now conduct around 100 coronary artery CT scans and cardiac catheter tests per year. In this town that has always had a high salt diet, there is a large proportion of patients with cerebrovascular disease, so we requested the introduction of an MRI machine for proper diagnosis and transport of patients to neurosurgical departments. In 2011 we were able to introduce our desired MRI machine. Since the retirement of the previous hospital director, who was a gastroenterologist, the upper gastroenterological examinations, which were previously implemented as endoscopic examinations, were almost all replaced with gastric barium examinations and 200 to 300 of these examinations are performed each year. Two years ago we managed to secure a visiting endoscopic specialist two days a month, so not only have endoscopic examinations been revived, we can now also perform ERCP, EST, and EBD using the x-ray TV equipment (updated FPD in 2015), which had been used for barium examinations.

The regional cooperation system (Northern Dohoku Medical Cooperation Network System: Polaris Network), which shares treatment information and imaging data during emergencies, has been running since June 2013, and we participate in the network centered around Nayoro City General Hospital. The hospital has also benefited greatly from this system. Not only has the overburdened emergency transport been reduced, we are also now able to seek the accurate instructions of experts. A remote radiogram interpretation system was also introduced in this hospital, and we are endeavoring to improve the accuracy of image reading for general treatment and medical checkups. Looking over the past financial year, the Esashi-cho healthcare system was overwhelmed with an average of 200 outpatient treatments per day; if emergencies came in, they were also treated, while also coping with wards running at 80% capacity. Once or twice a week the regular doctors are

Table 2　Number of patients（FY2015）

Total number of outpatients

Number of clinic days	21	18	22	22	21	17	21	19	20	18	20	22	241
Clinical department	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total
Internal medicine	1,620	1,526	1,667	1,761	1,227	1,675	1,650	1,561	1,630	1,460	1,595	1,768	19,140
Psychiatry	106	107	128	127	137	162	135	147	144	133	142	136	1,604
Cardiology	559	543	602	648	537	654	622	568	663	599	592	655	7,242
Pediatrics	243	259	290	166	144	240	327	585	596	250	255	239	3,594
Surgery	987	799	1,022	821	933	924	1,044	1,207	1,129	917	1,163	972	11,918
Orthopedics	219	178	212	256	197	242	249	237	212	214	234	248	2,698
Neurosurgery	30	34	25	38	23	32	32	37	34	29	31	37	382
Gynecology	43	49	37	51	39	31	39	62	47	38	32	45	513
Ophthalmology	50	86	146	46	81	105	112	97	98	92	103	91	1,107
	3,857	3,581	4,129	3,914	3,318	4,065	4,210	4,501	4,553	3,732	4,147	4,191	48,198

Mean number of patients per day

Number of clinic days	21	18	22	22	21	17	21	19	20	18	20	22	241
	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total
	184	199	188	178	158	239	200	237	228	207	207	191	201

on call—I think there are some doctors who are on call even more frequently—so we are only able to stay afloat with the support of doctors who travel long distances as visiting clinicians (Table 2).

Shortage of technologists

This hospital became a three-technologist system (one assistant) a number of years ago. The previous head technologist who retired because of age limits operated the system alone for approximately 20 years. After that I was employed and a two-person system was in place for ten years or so; currently, there are three technologists. Almost all Esashi-cho's neighboring towns and villages operate with only one technologist, and even if positions are advertised there are few technologists willing to relocate to the regional area (known as the backcountry). I believe there are various reasons, but the first reason to come to mind is that young people tend to be lured by big cities. Moreover, as there is no mid-sized or large hospital potential nearby, candidates are probably concerned they will be left behind by the ever-advancing medical technology. Furthermore, as this hospital is the only hospital on emergency notice (designated as secondary medical care), one of the reasons for their hesitation is probably that they would be called in to work irrespective of whether it is at night or on holidays. However, there are few tests conducted outside of normal hours (Table 3), and the current topic of the on-call system shifting to a two-shift system or a three-shift system is a problem of different dimensions.

We are on duty every day, even on weekends; we are on duty day and night, so we are basically on duty all year round. Even if there are only a few tests, the expectation that we may be called in at any time is continuous day in and day out. The best thing

Table 3　FY2015 Number of outside hours tests

Test month	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total
Outside hours (cases)	30	48	33	39	48	40	50	24	42	32	55	54	495

about having three technologists is that we are able to rotate our on-duty times. There are some regions that do not recruit a second clinical radiological technologist owing to the small number of tests and small variety of machines. I love my job as a clinical radiological technologist; I also feel comfortable with the responsibility that I (we) am the only radiological technologist in the area, and I certainly do not feel discontent at being on duty, but sometimes this degree of constraint is wearisome. In most cases, if I attend lectures or training sessions I need to stay away overnight although it does depend on the distance and the transport situation. When I need to be away from the region, I make arrangements for other technologists to be on duty. Sometimes I can ask the clinical radiological technologist, who retired in the local area to take over, but if it is not convenient then I must request the dispatch of technologists myself, and oftentimes I am unable to make these arrangements. I often need to cancel my engagements because, despite searching among my personal friends and acquaintances, I am unable to locate a replacement. I usually make requests for replacement technologists to those who live in cities where a large number of them work; however, they need to travel a long distance, and they use their own cars, so accidents while they are in transit are a constant worry—in addition to normal traffic accidents, there are frequent collision accidents with Ezo deer on Hokkaido roads. Then, even if I have the good fortune to have a technologist dispatched, in addition to taking images, my job description has recently come to include operations that are hospital-specific and machine manufacturer-specific, including HIS/RIS information system operations, image processing after taking an image, etc., which creates new problems. Therefore, I am always thinking that we should be able to build a dispatch system like that seen in other occupations—if anyone has any examples of such operations, I would love to see them.

It is not that every day is so busy that I am constantly taking images… and patients are not forced to wait for hours on end in one modality, but there are more machines than technologists, so I am often engaged in work running from one machine to the next, and sometimes I am nostalgic for the old machines where testing took time. I manage with my workload because not all clinical departments are treating patients constantly, but if there were more doctors working and orders coming in from multiple clinical departments, I would probably not be able to cope with the workload. Rather than making sure there are sufficient numbers of technologists despite a shortage of doctors… the shortage of doctors ensures that even with a shortage of technologists it is possible to work through the day's work without a backlog. As stated in the Shortage of doctors section above, there are clinical radiological technologists and testing machines even in regions where depopulation is progressing, so if preparations are made referencing courses in association with journals and allowing doctors to participate in training courses held by the Japan Association of Radiological Technologists, then it would possible to supply standard tests simply by having a doctor attend these courses.

I am often asked for advice about the test results and I often offer my opinions on these matters, so this constant interaction with doctors is also thanks to the shortage of doctors.

Appeal of the local area

I have only described the negatives of the local area, but I love this town. Half of Esashi-cho's scenery is the sea, while the other half is mountain forests, the sun and the moon rise from the horizon, the stars are bright at night, the inland temperature in the summer exceeds 30°C, while in the winter it falls below -30°C. Even along the coast, temperatures

Esashi Hospital

of -20° C are not unusual. Ice floes come close to the coast, and sea angels (Clione) also make an appearance (they can be captured and admired). Once the ice floes retreat and the sea is accessible again there is a wide range of delicious seafood on offer, ranging from hairy crabs to sea urchins, whelks, octopus, scallops, herring, flounder, salmon, trout, and mackerel. Unfortunately, I have an allergy to crustaceans and cannot eat crab. There are as many mountain vegetables and mushrooms as one can eat, and encounters with brown bears and Ezo deer, and the Steller's sea eagles and white-tailed sea eagles that fly above the mountainsides along the coast are not uncommon. There are no railway lines, expressways, or tall buildings, but there is a vast sky with clear air and no noise. For a while after I moved here the nighttime was so quiet it frightened me so I slept with the television on. There is also a cellular phone base station and internet environment. It would be a lie to say that I do not notice the inconveniences of living in Esashi, but there is more than enough appeal to offset the inconveniences. Despite saying this, there is no tourism office, and people visiting Hokkaido almost always simply pass through while traveling up the coast, but this place is appealing because it is increasingly depopulated and is retaining its natural beauty without becoming a tourist attraction. Of course, this is not limited to Esashi, or even to Hokkaido—there are many areas of beauty in all regions of Japan. If you have the qualifications and skills of a clinical radiological technologist, then you can move anywhere there is a hospital. To all the people working in regional areas of Japan let us work hard together with our local communities, and I hope that we find the ideal land that local regions are aiming for…

In conclusion

I would like to express my heartfelt gratitude to Yasuo Nakazawa, the president of the Japan Association of Radiological Technologists, for coming to Wakkanai in the northern end of the country and giving me this opportunity. I am also grateful to Shun Mori, the director of the former Tokyo Association of Radiological Technologists, who took the trouble to hold a Wakkanai special lecture for President Nakazawa.

Thank you also to Michio Bando the chair of the Hokkaido Association of Radiological Technologists, director Nobuo Tomita, director Fujihiro Akitaya, Yuichi Sekito the vice chair of the Sapporo Association of Radiological Technologists and Toshifumi Goto the chair of the Tokachi Association of Radiological Technologists, who provided their cooperation and who all traveled over 300 km to attend this lecture.

Thank you to the clinical radiological technologists at the Nayoro City General Hospital

and Shibetsu City Hospital, to whom I am indebted for their daily guidance and cooperation through the Northern Dohoku Imaging Research Group.

The technologists from the Souya region and northern Rumoi region are registered members of the Hokkaido Association of Radiological Technologists Wakkanai Branch, and there are 24 members in total (including retired technologists), which is a smaller number of technologists than that of a slightly larger hospital. I am indebted to Hajime Ohno, the vice chair of the Hokkaido Association of Radiological Technologists and the directors of the Hokkaido Association of Radiological Technologists and everyone else who provided their cooperation.

The region that makes up the branch has an area of approximately 5,000 km^2, which is about the same size as Chiba prefecture. The population in this region is small, and in towns and villages other than Wakkanai and Esashi-cho, there is probably only one technologist employed who, almost every day, is probably taken up with waiting on standby. The distance between hospitals means that apart from general meetings we are usually unable to see each other; however, we work hard every day and can take pride in our role of protecting the region in the far north of Japan. The elderly residents living in increasingly depopulated regions require even better healthcare. Under the Wakkanai City Hospital branch chief Yasuyuki Hayakawa, who is in charge of the Wakkanai Association of Radiological Technologists, we clinical radiological technologists of the Wakkanai Association of Radiological Technologists will further improve our skills and, with determination, will protect the residents living in the region, and continue to contribute to the region's healthcare.

Acknowledgments

I would like to express my heartfelt gratitude to Yasuyuki Hayakawa, Chairman of the Wakkanai Association of Radiological Technologists, Director Naomi Konta, Director Kenji Tsuda, technologists at this hospital Yoshito Takaya, Seiya Hayakawa, and all the members of the Wakkanai Association of Radiological Technologists, who provided their cooperation during the drafting of this paper.

Japan Association of Radiological Technologists Symposium 6
(Committee on Safety Controls for Medical Radiation Exposure)

Understanding Diagnostic Reference Levels (DRLs)

Chair: Rikichi Fujiwara
(Chair of the Committee on Safety Controls for Medical Radiation Exposure/Yokote Municipal Hospital)

Keynote lecture

Introduction of Diagnostic Reference Levels to Japan

Makoto Hosono (Institute of Advanced Clinical Medicine, Kindai University)

1. Introduction

In Japan, diagnostic reference levels (DRL) were initially established and published as the Diagnostic Reference Levels on June 7, 2015 (DRLs 2015). There are 11 groups associated with medical radiation, namely the Japan Association on Radiological Protection in Medicine, the Japan Society of Medical Physics, the Japan Radiological Society, the Japan Society of Nuclear Medicine, the Japan Society of Nuclear Medicine Technology, the Japan Society for Oral and Maxillofacial Radiology, the Japanese Society of Pediatric Radiology, the Japan Association of Radiological Technologists, the Japanese Radiation Research Society, the Japanese Society of Radiological Technology, and the Japan Network for Research and Information on Medical Exposure (J-RIME) (in random order). These groups, with the cooperation of the Japan Medical Imaging and Radiological Systems Industries Association and the National Institute of Radiological Sciences, built an all-Japan system, and DRLs were created on the basis of a survey of practices in Japan for computed tomography (CT), general radiography, mammography, intraoral radiographic imaging, IVR, and nuclear medicine. These DRLs have been published with the approval of each of the participating bodies.

2. What are diagnostic reference levels (DRLs)?

To put it simply, DRLs are the criteria medical organizations refer to in order to determine if a higher-than-necessary dose of radiation is being used for diagnoses in the medical field. According to international guidelines,

including various recommendations from the International Commission on Radiological Protection (ICRP) and the international basic safety standards set by the International Atomic Energy Agency (IAEA), DRL is an optimized tool for protection against medical radiation in the field of diagnostics. DRL is closely tied to the quality assurance of the equipment and methods, as well as training and education of the operators. These factors are considered to play an important role in optimization. The status of DRL overseas includes establishment of a medical radiation protection framework in Europe by the European Union (EU) Council Directive 97/43/Euratom (June 1997). Within that established framework of DRL, association with the diagnostic field is required of EU countries; therefore, based on this direction, many countries have incorporated DRLs. In the United States (US), the DRL presented by the American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), and National Council on Radiation Protection and Measurements (NCRP) have become a practical standard. Note that DRL is normally determined using the absorbed dose in the air and/or the standard phantom absorbed dose, which can be easily measured.

3. Establishing and publishing the diagnostic reference levels (DRLs 2015)

Previously in Japan a survey was conducted on the doses autonomously used for diagnosis by J-RIME affiliated bodies, as well as various academic institutions, organizations, and researchers. A standard diagnostic dose was advocated; however, a large number of affiliated personnel were not fully cooperative with the implementation of this standard. Therefore, no standard DRL existed across the entire nation and it was difficult to claim that the DRL was being implemented in medical practice in Japan.

Subsequently, in March 2010, J-RIME was established as an organization to share and link research data on medical exposure compiled by the affiliated bodies. In August 2014, as a part of these activities, a chairperson from each affiliated body was dispatched to form a DRL working group; thus, steps were taken to set the DRL. The affiliated bodies jointly set up a single platform and after investigating the definition of a dose using the DRL and detailed research methodologies, the working group implemented, organized, and analyzed the results of a large-scale, nationwide survey, while driving discussion among the members and referencing comments from both Japanese and international specialists. The dose data for setting the DRL includes newly surveyed data, as well as, data from closely scrutinized existing survey results (Fig.1).

The actual DRL is posted on the J-RIME website (http://www.radher.jp/J-RIME/) as, "Diagnostic Reference Levels Based on Latest Surveys in Japan－Japan DRLs 2015." Please reference this data.

Furthermore, Japan's DRL have been introduced via the websites of international institutions, such as IAEA, ISR, IOMP, and others.

Only the main points are presented for each modality. CT targeted volume CT dose index ($CTDI_{vol}$) and dose length product (DLP) were based on the results of two surveys on adults. One survey targeted 712 organizations with medical training of specialists, while the other targeted 307 facilities through a questionnaire that was included in the journal of the Japan Association of Radiological Technologists. Subsequently, the involved professors created the DRLs by combining the results of these two surveys. In addition, forward thinking was incorporated into the development of the DRL for dynamic liver CT scans. With a normal DRL, the dose is often based on one image or scan. However, with dynamic liver CT scans, a DLP of 1800 mGy/cm is the total exposure for the entire test. For example, for a four phase equivalent protocol, each phase

Japan Network for Research and Information on Medical Exposures (J-RIME)

- Aim of J-RIME activities: Organized and share research data on the actual situation of medical exposure and medical radiation protection and contribute to the development of medical radiation exposure research, both in Japan and overseas.
- Established in March 2010
- Office: Medical Exposure Research Project, National Institute of Radiological Sciences
- 12 Organization members:
  – Japan Association of Radiological Technologists
  – Japanese Society of Radiological Technology, others

Fig.1

would equate to 450 mGy/cm. However, the DLP-based controls are for the entire test, so the DRL can be operated for each phase irrespective of which phase protocol is being tested, even if the target resolution differs.

With general radiography, the incidence surface dose was set as the dose index and the DRL was set on the basis of the results of the latest nationwide survey (Questionnaire Results Summary from the Survey Study of Patient Doses during X-ray Diagnosis (2011) presented in Asada *et al*. (Focusing on Factors Relating to Imaging Conditions—Japanese Journal of Radiological Technology 2012; 68 (9): 1261-1268).

With mammography, the mean glandular dose was set as the dose index and was based on the survey results of 4816 radiographic equipment systems for breast scans, certified as A or B under the facility imaging certification conducted by the NPO Japan Central Organization on Quality Assurance of Breast Cancer Screening. A point to note include that in other modalities the DRL is set at the 75th percentile, but the DRL for mammography is set at the 95th due to strict accuracy controls already in place.

With intraoral radiographic imaging, the patient's incident dose is set as the dose index. The DRL is based on the results of a field survey targeting 29 university dentistry departments and dental university hospitals conducted by the Japan Society for Oral and Maxillofacial Radiology.

For IVR, the standard point dose rate is set as the dose index and is based on a field survey conducted at facilities with registered technologists certified by the Japan Professional Accreditation Board of Radiological Technologists for Angiography and Intervention. Data from the surveys obtained in 2008 and 2013 showed that the 2013 survey reported a lower dose than the 2008 survey.

With nuclear medicine, the actual dose is set as the dose index and the DRL was set based on the results of a new survey of nationwide nuclear medicine facilities. In this survey the 75th percentile value was used as a reference, but the DRL was set after investigations conducted by the Radiological Protection Commission of the Japanese Society of Nuclear Medicine and was based on considerations of the actual situation and resolution of nuclear medicine scans in Japan.

4. The future

Encouraging the widespread application of the DRLs set through this study in Japan is an urgent issue. Thus, it is important to repeatedly bring up this topic in workshops and scientific meetings to promote their application, focusing on the affiliated organizations. Fostering a culture that emphasizes quality assurance, quality control, education, and training for application of the DRLs is absolutely vital.

In December 2015, after this lecture, explanatory documents will be published by the J-RIME DRL working group (http://www.radher.jp/J-RIME/index.html), so please share and actively utilize this information.

Looking into the future, the dose index used as the basis for DRL is based on the easily measured absorbed dose in the air and/or the standard phantom absorbed dose. This is a valid method for standardization. However, there is currently an international movement towards finding a method that will enable the calculation of a dose that is closer to the actual dose required for each individual patient.

5. Summary

Setting DRLs for the first time in Japan with the cooperation of organizations involved with medical radiation is a monumental event. Now, it is our duty to strive for an improvement in the quality of medical radiation in the diagnostic field and continuous utilization through application of the DRLs.

Arts and Sciences

Proposal for the Unification Labeling Stickers for Emergency Shutdown System of MRI Equipment

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Key words: MRI, safety, emergency shutdown system

【Summary】
A magnetic resonance imaging (MRI) scanner has several buttons for safety such as an emergency stop button or an emergency operation button. In case of an emergency, the MRI operator should be able to properly operate these buttons. The locations and specifications of emergency buttons vary depending on the MR scanner manufacturer. Standardization of their designs and functions will be helpful for MR operators. However, it will be difficult to change the hardware components immediately. Thus, we designed notations in Japanese. The labeling stickers we designed were attached beside the emergency button to represent their functions, which made it easy for MR operators to comprehend them at a glance.

1. Introduction

Many medical institutions were affected by the strong tremors and tsunami generated by the Great East Japan Earthquake (magnitude 9.0, maximum JMA seismic intensity 7, JMA data) that occurred on March 11, 2011 at 2:46 PM. This included significant damage to the existing medical equipment. A survey was performed to reveal the state of damage to magnetic resonance imaging (MRI) equipment because of the earthquake for application in emergency measures during disasters as well as prevention measures (the "MRI Device Damage Questionnaire Survey" conducted from June 14 to August 31, 2012)[1), 2)].

Among the responses to this questionnaire survey, there were seven cases of problem in immobilizing the patient table, resulting in difficulty in evacuating the patient. There have also been reports that the emergency button could not be located or there was confusion as to which emergency button should be operated. It was also noted that the criteria for operating the emergency button were unclear[1)].

To safely evacuate patients during an emergency such as an earthquake, it is necessary to appropriately operate the emergency shutdown system (various emergency buttons). However, compared to other medical devices, MRI machines have a greater number of emergency-use buttons.

Looking at the multiple computed tomography (CT) devices and RI devices installed at the authors' facility, the CT devices have an emergency stop button and a scan stop button while the RI devices only have an emergency stop button.

Devices using superconducting magnets are always provided with a quench button. Other buttons include an emergency power-off button, an emergency imaging-stop button, and an emergency exhaust fan operation button. These buttons differ in shape (design) and in-

stallation location depending on the manufacturer. It is desirable that the specifications be made consistent among the various manufacturers to foster an appropriate response in times of emergency. Nevertheless, this is not currently the case.

Reports on the status of damage to MRI machines during a large-scale earthquake include the survey by Kamei and Noguchi after the Great-Hanshin Earthquake[3), 4)], the report on prompt quenching during the 2001 Geiyo earthquake[5)], and the 2004 Mid-Niigata Prefecture Earthquake[6)]. These reports focus on damage such as magnet displacement and mount damage, and do not investigate the various buttons used during the emergencies.

A rescue during the unusual situation of sustained vigorous tremors as experienced during the Great East Japan Earthquake would place the MRI operators under extreme stress. This would likely put them in a psychological state in which they would be more prone to making different errors from ordinary circumstances because they were distracted by factors other than the MRI machine itself, such as the collapse of buildings, a power outage caused by interruption of the power supply, and the occurrence of a quench[7)]. If there are multiple MRI machines from different manufacturers (in the MRI Device Damage Questionnaire Survey, 94 of the 458 respondent facilities (21%) had at least two machines installed[1), 2)]) or if a new machine has recently been installed, there is the possibility that differences in specifications among manufacturers could lead to confusion among operators under pressure. Those who do not normally specialize in MRI devices could also be forced to operate the emergency buttons in emergency situations.

Thus, this study reports on an investigation of the emergency buttons on MRI devices that are to be operated during emergencies. The primary emergency situation considered in this report is strong tremors due to an earthquake.

2. Methods

We investigated and compared the various emergency buttons (quench button, emergency power-off button, emergency exhaust fan operation button, etc.) on MRI devices made by various manufacturers. We also created proposals for unified labeling stickers to supplement the emergency buttons as an interim measure until the specifications can be unified among the various manufacturers.

3. Results

The emergency buttons on MRI machines differ in specifications and installation location depending on the manufacturer but can be categorized into the following four types.

3-1. Quench (demagnetization) button

During emergencies, such as accidents involving the sticking of a large ferromagnetic object, this button demagnetizes the strong magnetic field (Fig.1). Depending on the manufacturer, it is installed in the MRI room or in the control room. It includes battery power in case it must be operated during a power outage, and the batteries are checked and replaced during periodic inspections or at regular intervals.

3-2. Emergency power-off button / emergency imaging-stop button

These buttons are usually installed on or near the operation console, but they differ in design and position depending on the manufacturer (Fig.2). In addition, despite having the same naming among manufacturers, there are differences in the extent to which power is shut off. Furthermore, when operated, there are models that lock the patient table and those that release the patient table. These differences are shown in Tables 1 and 2.

The machines from company A release the patient table when the emergency power-off

Fig.1 Various kinds of quench buttons
The structure and colors of the buttons are different depending on the manufacturer.

Fig.2 Emergency stop button
The location of the emergency button is different depending on the manufacturer. The color and design of the buttons are similar to each other.

Table 1 Emergency power-off button
The results differ by the manufacturer. In the magnetic resonance imaging (MRI) equipment in which the bed gets locked, it is necessary to confirm the release method.

	Power shutoff status	Patient table state
Company A	All the power supplied to the MRI device is shut off. The chiller is not shut off.	Table is unlocked. However, vertical movement is not possible.
Company B	The main breaker on the power distribution panel is tripped. The power to the entire MRI system is shut off.	Patient table is locked.
	Power is not cut off to the compressor of the cooling system, the oxygen sensor, or the quench button.	
Company C	All the power to the MRI device is shut off. The magnet cooling mechanism also stops.	Patient table is unlocked.
Company D	All the power except to the chiller is shut off.	Patient table is unlocked.
Company E	Supply of the gradient magnetic field pulse to the gradient magnetic field coil is shut off. Supply of the radiofrequency (RF) pulse to the transmitting RF coil is shut off.	Patient table is locked.
	Power supply to the patient table is shut off.	

Table 2 Emergency imaging-stop button
The results differed depending on the manufacturer. In the magnetic resonance imaging (MRI) equipment in which the bed gets locked, it is necessary to confirm the release method.

	Power shutoff status	Patient table state
Company A	Power supply is shut off to the gradient amp system, radiofrequency (RF) amp system, and imaging chamber magnet device in the machine room cabinet.	Patient table is locked.
Company B	Power is not shut off. Imaging stops.	Patient table is unlocked.
Company C	Power is not shut off. Imaging stops.	Patient table is unlocked.
Company D	Power is not shut off. Imaging stops.	Patient table is unlocked.
Company E	Power is not shut off. Imaging stops.	Patient table is locked. If pressed again, it can be moved electrically.

button is used, but lock the patient table when the emergency imaging-stop button is used. Conversely, those from company B lock the patient table when the emergency power-off button is used but release the patient table when the emergency imaging-stop button is

used. Both buttons released the patient table in machines made by companies C and D. In the case of company E, both emergency buttons lock the patient table, but pressing the emergency imaging-stop button again releases the lock so that the table can be moved under electric power.

The primary application for the emergency imaging-stop button is to immediately halt imaging. However, the emergency power-off button immediately cuts off power to the entire MRI device aside from the cooling system. There are devices where this halts the cooling device without performing a forced quench.

3-3. Forced ventilation switch

This is linked to an oxygen concentration meter (oxygen monitor) so it operates automatically during a quench. It is frequently installed in the wall of the control room.

3-4. Testing table lock release button

This button releases the lock on the patient table that is imposed when there has been a power outage or the emergency power-off button or emergency imaging-stop button has been operated. It differs in installation position, shape, and manner of operation depending on the manufacturer (Fig.3).

4. Proposal for unified labeling stickers for emergency buttons

Figs.4 and 5 show the proposals for the unified labeling stickers in Japanese. An example of a sticker in actual use is shown in Fig.6, where the sticker is attached beside a quench button. The sticker includes precautions for using the quench button (Fig.7).

5. Discussion

During emergencies such as earthquakes, rescuing the patient is the initial primary concern. The emergency response for rescuing the patient during an emergency requires appropriately operating the various emergency buttons in the manner described in the operating instructions or documentation for the device to safely remove the patient. However, these emergency buttons currently do not have consistent specifications. MRI devices have many types of emergency buttons compared to other medical devices, and many of these buttons are located at a certain distance. In our survey, we found significant differences in specifications and installation locations among the emergency buttons of MRI machines. The quench buttons had entirely different forms. To ensure reliable operation under stress, it would be considered significant to standardize the specifications and create uniformity at the hardware level. While keeping this goal in mind, we believe that it would be useful as a short-term measure to add consistent supplemental indications to the various emergency buttons with inconsistent specifications.

According to the "Eleventh Survey Report on the Status of Introduction and Status of Securing Safety for Medical Imaging Systems" (issued in March, 2014) by the Japan Medical Imaging and Radiological Systems Industries Association, the replacement period for medical devices is at least 10 years. Looking at MRI devices that are at least 1.5 T (n=588), 18.9% of devices have been operating for at least 11 years, and the average number of years at replacement is 11.1 years. In addition, looking at the oldest devices at each facility (n=358), 10.3% had been installed in 1999 or earlier. Thus, it is not uncommon for MRI devices to operate for long periods after installation. In addition, we expect that suddenly changing hardware would be difficult for the various manufacturers. Thus, we believe it would be useful to decide on easy-to-understand Japanese text and to create rules for how it is displayed. Specifically, we investigated the creation of unified rules for use in Japan for the various emergency buttons to be displayed be-

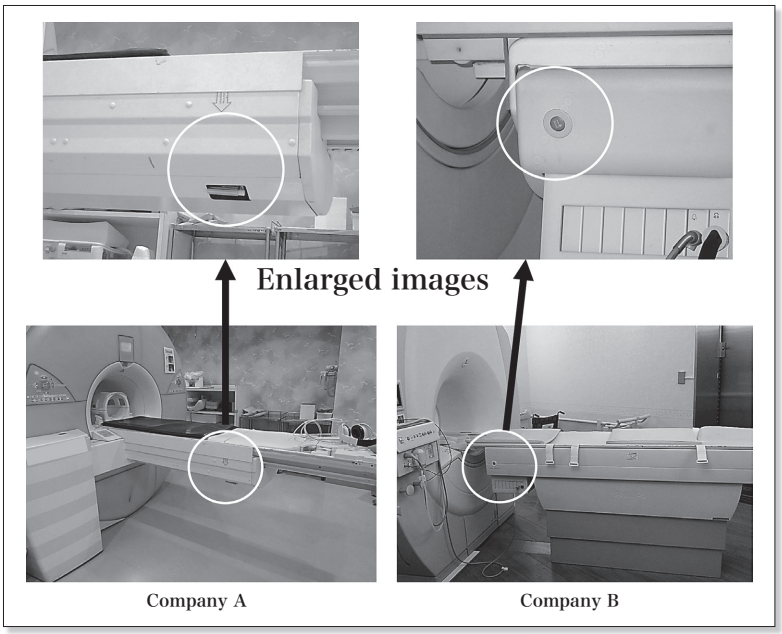

Fig.3 Lock release button (lever) of the bed
The location and design of the buttons are different depending on the manufacturer.

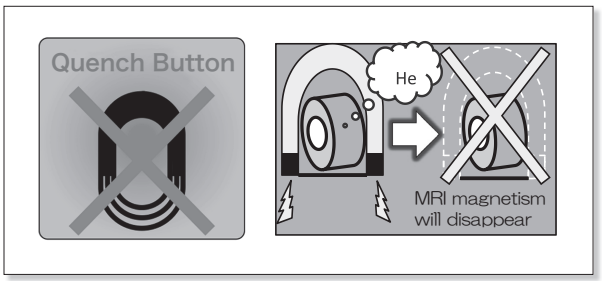

Fig.4 The design of the unified labeling sticker of a quench button (Draft)

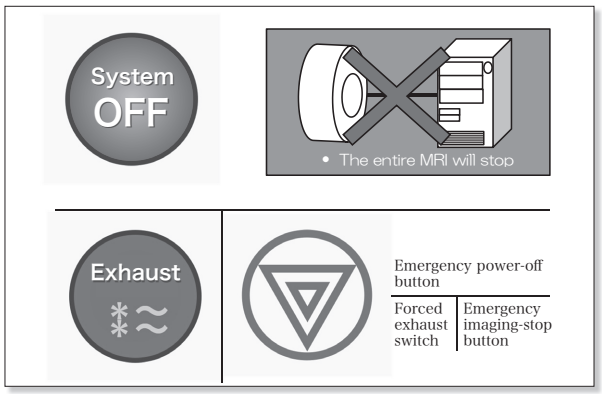

Fig.5 The design of the unified labeling sticker of an emergency power-off button and an emergency imaging-stop button (Draft)

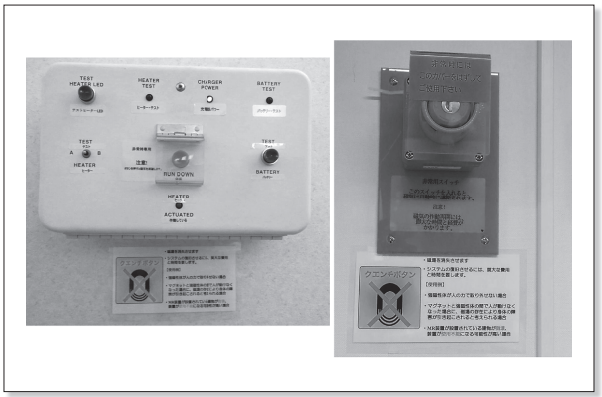

Fig.6 An example of a quench button with the unified labeling sticker.
The function of the button becomes clear with the unified labeling sticker.

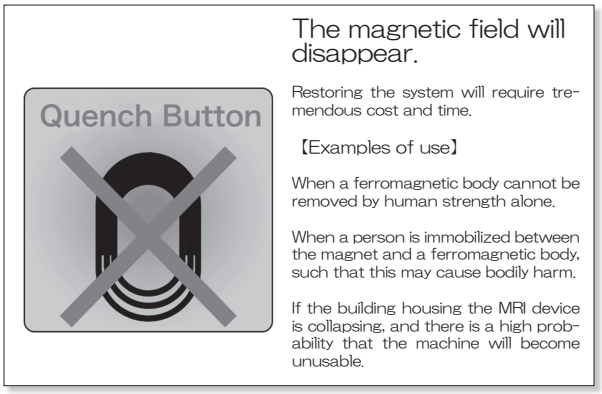

Fig.7 Criteria for use of the quench button.
By displaying the function and criteria for use of the button, it becomes useful under emergency situations.

side those buttons to be easily understood by everyone. Eventually, it will be necessary to make proposals to the industry for this to be reflected at the hardware level.

The labeling stickers should enable anyone who sees them to understand the result of pressing the associated button. However, the emergency power-off buttons and emergency imaging-stop buttons differ in the extent to which they cut off power as well as the final state of the patient table (locked or free). Thus, the unified labeling stickers must also include information unique to each device.

The emergency power-off button locks the patient table in some devices but unlocks it in others. The emergency imaging-stop button only stops imaging but leaves the power supply otherwise unchanged in some devices, while it halts imaging as well as shuts down the power supply in other devices. Furthermore, just as with the emergency power-off button, it locks the patient table in some devices but unlocks it in others (Tables 1, 2).

Thus, emergency buttons with the same name have different results upon use depending on the manufacturer, and so there is the possibility of confusion during emergencies. In particular, if the patient table becomes locked as a result of operating one of the emergency buttons, it becomes difficult to extract the patient if the location for the button for unlocking the table is not known.

Since the specifications and installation locations are not consistent between manufacturers, we believe that using the unified labeling stickers to list information for each individual machine when the emergency buttons are used is a method to reduce confusion during emergencies.

As seen in the examples of actual use (Figs.6, 7), despite differences in shape and installation location depending on manufacturer, the location of the quench button can be made clear by using the unified labeling stickers. In addition, we believe that by listing examples of situations where the quench button should be used, confusion during emergencies can be reduced.

The MRI machine disaster questionnaire survey[1), 2)] asked about whether the quench button was used immediately after an earthquake, but only one facility of the 332 respondents actually used the button. The reason given was panic caused by the strong tremors[1)]. Conversely, the reasons for not pushing the quench button included "lack of opportunity to consider it due to the emergency" and "lack of clear guidelines for making the decision." Since the unified labeling stickers that we are proposing clarify the criteria for use, we believe that they would be useful in making decisions during emergencies.

We implemented the unified labeling sticker for the quench button on a trial basis at a facility (the authors' facility) at which multiple MRI machines from different manufacturers are installed. As a result, we heard from the clinical radiologists specializing in MRIs that they paid attention to the quench buttons and became aware of their installation locations. In addition, the clinical radiologists not specializing in MRIs (rotating specialists and those who only work the night shift) stated that since the labels state the function of the quench button and the criteria for its use, they would be useful during emergencies in conjunction with regular training. However, it was also noted that the label needed to be revised to enable fast decision-making during an emergency.

It is believed to be extremely rare for the quench button to actually be pressed by an MRI operator. As stated earlier, the disaster questionnaire survey only included one such response[1), 2)]. However, there is also a case when a nurse using ankle weights become magnetically stuck to the MRI machine and unable to move, after which the quench button was pressed on the operator's judgment[8)]. Thus, there are situations in which the quench button must be used based on the MRI opera-

tor's judgment during an emergency; therefore, the unified labeling seals that we propose are useful in clearly listing the criteria for use.

Finally, the various emergency buttons used during emergencies currently differ greatly in function and installation location among the various manufacturers. At each facility, it is necessary to confirm the position of each emergency button on the machines currently in use and to reconfirm the resulting state of the machine when the buttons are operated. To this end, it is important to conduct thorough training for the MRI operators and implement full measures for occupational safety.

6. Conclusions

This study confirmed the specifications for the emergency buttons used during emergencies on the MRI devices produced by the five major manufacturers and investigated an interim plan of action until the specifications can be unified among these manufacturers.

The emergency response for patient evacuation requires appropriately operating the various emergency buttons. The specifications and form factors of these emergency buttons differ by manufacturer, and hence, their appropriate operation will require unifying the specifications and installation locations.

We expect that considerable time will be required before there is consistency in the industrial specifications. Thus, this must be preceded by efforts to tackle the current situation. Our report proposes unified labeling stickers, but we hope the efforts to tackle the current situation will continue to progress.

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Current State of the Ionization Chamber Type Survey Meter Held by Medical Facilities in the Kyoto Area: Questionnaire Survey and Calibration

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Key words: Survey meter, calibration, medical facility

【Summary】
In the medical field, radiological technologists use many types of survey meters for management of radiation facilities. However, each facility has different management practices. We performed a questionnaire survey to evaluate the present conditions of the radiation meters used in medical facilities in the Kyoto area. The results indicated that many facilities did not perform periodic calibration of the survey meters. We calibrated 53 units of ionization chamber type survey meters at the energy levels in the diagnostic areas. The average calibration was 0.996, and the standard deviation was 0.124. In addition, many ionization chamber type survey meters were old. Verification of the performance of survey meters is required during regular calibration. Kyoto Association of Radiological Technologists decided on implementing annual calibration of ionization chamber type survey meters.

1. Present conditions of survey meters in medical facilities

1-1. Introduction

Since the Fukushima Daiichi Nuclear Power Station accident caused by the Great East Japan Earthquake in March 2011, an increasing number of laypersons are purchasing radiation meters for personal use. It is unclear whether these devices are properly managed and used to measure radiation accurately. In addition, each medical facility has different management practices for survey meters, including calibration, and the actual condition of their use is unknown. The use of an unknown calibration constant when measuring scattered dose and leakage dose results in inaccurate measurements. The "Act on Prevention of Radiation Hazards due to Radioisotopes, etc." and "Medical Care Act" recommend annual calibration of survey meters that are used in medical facilities to measure leakage doses, etc[1), 2)].

To understand the present condition of survey meters used in medical facilities, we conducted a questionnaire survey in facilities within the Kyoto Prefecture. Based on the results of analyses, practical measures were proposed.

1-2. Questionnaire method

We mailed the questionnaire to the directors of all facilities who employed The Kyoto Association of Radiological Technologists member affiliates (132 facilities) and requested return mail of the anonymous response.

Responses were received from 75 facilities, with a recovery rate of 56.8%. Table 1 shows the questions and responses associated with the study.

1-3. Questionnaire results

The questionnaire results indicated the presence of 73 units of survey meters at 33 facilities; of these, about half (37 units) were ionization chamber-type survey meters. Fig.1 shows

Table 1　Questions and answers of the questionnaire related to this study

Answer and questionnaire (I have excerpted those used in the contents of this paper.)

Q1 Do you own a survey meter?			
yes	33facilities		
no	39facilities		
Rent from suppliers or related hospital	3facilities		
Q2 Answered "yes" Please tell me the number and types			
Ionization chamber type	1unit 25facilities	2units 4facilities	4units 1facility
GM tube type	1unit 13facilities	2units 4facilities	3units 1facility
Scintillation type	1unit 8facilities	2units 1facility	
Proportional counter tube type	2facilities		
Q3 Frequency of use How much is?			
Ionization chamber type	(Appendix)		
GM tube type			
Scintillation type			
Proportional counter tube type			
Q4 Who do you use?			
Radiological technologists	33facilities		
Other	2facilities		
Q5 Who will manage?			
Radiological technologists	33facilities		
Other	4facilities		
Q6 Interval of calibration How much?			
Every year	7facilities		
Every two to three years	11facilities	1)	
Irregular	11facilities		
Do not have calibration	3facilities		
Plan to calibrate future	4facilities		

1) 1facility plan to change to be calibrated every year under the guidance from the Insurance office.

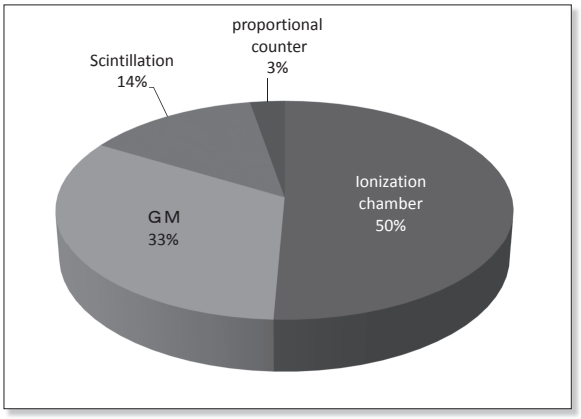


Fig.1　Type of survey meter that each facility is held

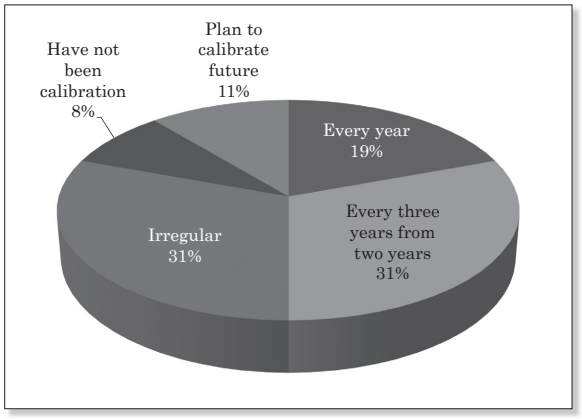


Fig.2　Calibration interval of the survey meter that each facility is held

Appendix　Usage of various survey meter that each facility is held

	Every day	Once a week	Once a month	Several times a year	rarely use
Ionization chamber type			9	20	
GM tube type		3	4	5	3
Scintillation type	1	1	3	2	2
Proportional counter tube type				1	1

the types of survey meters at surveyed facilities.

Although medical radiological technologists were involved in management and use of survey meters at all facilities, annual calibration was not conducted in more than half of these facilities. As shown in Fig.2, annual calibration was conducted in only 19% of the facilities. Three facilities did not conduct any calibration, due to the high cost involved.

As for the usage, some facilities responded that they "hardly ever use" GM - and scintilla-

tion-type survey meters; however, all facilities responded that they used the ionization chamber-type survey meters at least several times a year. The details are shown in the Appendix.

2. Toward practical measures

To understand the performance, purchase timing, and management status of the ionization chamber-type survey meters (hereafter referred to as "survey meters") that were most commonly used at all responding facilities, and to examine whether The Kyoto Association of Radiological Technologists and Kyoto College of Medical Science could lead regular calibrations, we gathered survey data from medical facilities in and around the Kyoto Prefecture.

2-1. To participate in "Attempt of Questionnaire Survey and Calibration"

We aimed to determine the characteristics of survey meters by manufacturing companies and models. In December 2012, we mailed inquiries on willingness to participate in "Attempt of Questionnaire Survey and Calibration," to the directors of 132 facilities with which members of The Kyoto Association of Radiological Technologists were affiliated and approached medical facilities and offices in neighboring prefectures as well. On principle, survey meters were to be brought to our facility for no-cost testing.

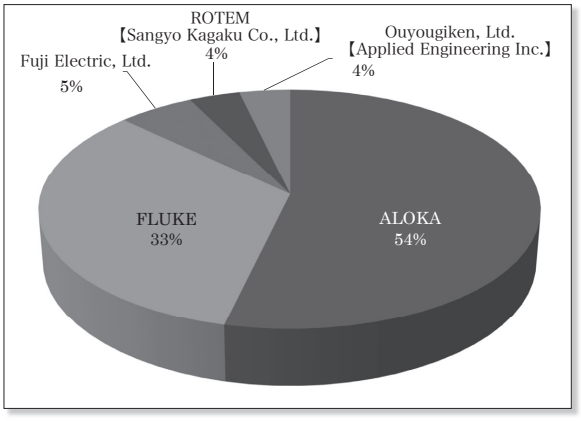


Fig.3 The ratio of Manufacturers (calibrated survey meter in this study)

2-2. Results

From the Kyoto Prefecture, 69 facilities responded including those without survey meters. Before performing calibrations, we confirmed the performance of the target survey meters using a ^{226}Ra check source. Results showed that instrument readings of several survey meters was abnormal, and these were excluded from calibrated models. Twenty-six facilities provided 38 units that were functioning normally; additionally, we received 15 units used regularly by nearby prefectures. The final tally of survey meters to be calibrated was 53.

The most common manufacturer was Hitachi Aloka Medical, Ltd. (including Aloka) at 54%, followed by FLUKE Inc. (including Victreen, INOVISION, and Cardinal Health) at 33%, and others (three Fuji Electric, Ltd. two ROTEM, Inc.【Sangyo Kagaku Co., Ltd.: Sales agent of the product】, and two Ouyougiken, Ltd.【Applied Engineering Inc.】) at 13% (Fig.3). On adjusting the schedule based on each facility, we conducted measurements within a total of four days between late February to early April 2013.

3. Attempt of Questionnaire Survey and Calibration

Highly precise and stable X-ray devices are required for calibration of survey meters. X-ray devices for calibration and measurement devices owned by Kyoto College of Medical Science had the capability to comparatively calibrate ionization chamber type survey meters with diagnostic range of energy according to the JIS standard. Hence, we used these devices for comparative calibration of survey meters.

3-1. Devices in use

X-ray device: TAITAN 225S
(GE Inspection Technologies)
X-ray tube voltage, 5–225 kV (0.1 kV step); X-ray tube current, 0.1–

Table 2 Main models of survey meter was calibrated (by manufacturers)

Manufacturer	The main models
Hitachi Aloka Medical, Ltd.	ICS301.311.315.321.331
FLUKE, Inc.	450B.450P.451B.451P
Fuji Electric, Ltd.	NDR131.NHA
ROTEM, Inc.	RAM DA 2000
Ouyougiken, Ltd.	AE-133

Table 3 The measurement accuracy of the X-ray equipment and a reference dosimeter that was used to this study

	Voltage of X-ray tube 70kV		Voltage of X-ray tube 120kV	
Number of measurements	First time	Second time	First time	Second time
1	119.1	119.2	169.8	166.9
2	119.3	119.1	170.0	167.0
3	119.4	119.1	169.9	166.9
4	119.4	119.4	170.1	166.8
5	119.4	119.3	170.0	166.9
6	119.3	119.2	169.9	166.9
7	119.3	119.2	170.2	167.0
8	118.9	119.5	170.2	167.0
9	119.4	119.3	170.0	167.1
10	119.4	119.2	169.9	166.7
Average value(mR)	119.3	119.3	170.0	166.9
Standard deviation	0.1663	0.1269	0.1333	0.1135
Coefficient of variation	0.1394%	0.1064%	0.07840%	0.0680%

45 mA (0.1 mA step); and the stability and reproducibility of tube voltage and current, within ± 0.05%.

Dosimeter: RAMTEC 1500B (Toyo Medic)

Detector: DC300 (Wellhöfer)

Ionization chamber-type survey meters to be calibrated: Hitachi Aloka Medical, Ltd., FLUKE, Inc., ROTEM, Inc., Fuji Electric, Ltd., and Ouyougiken, Ltd. The major models are shown in Table 2.

Standard dosimeter used for comparative calibration belonged to Japanese Society of Radiological Technology Diagnostic Dosimeter Standardizing Center (Kinki Region Center), and was calibrated by Japan Quality Assurance Organization (JQA).

3-2. Method to examine accuracy of standard dose measurement

To examine the measurement accuracy when X-ray device and standard dosimeter are combined, measurements were taken 10 times each

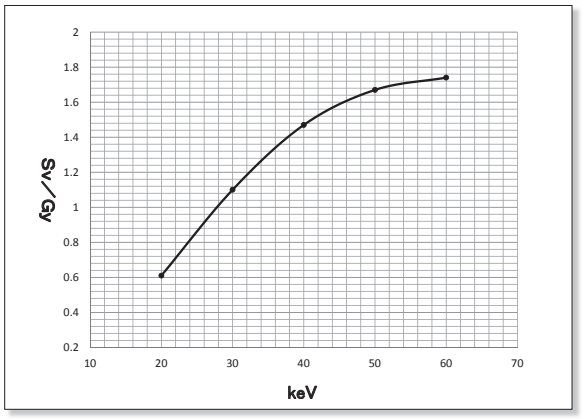


Fig.4 1cm dose equivalent conversion factor tables in 20keV to 60keV

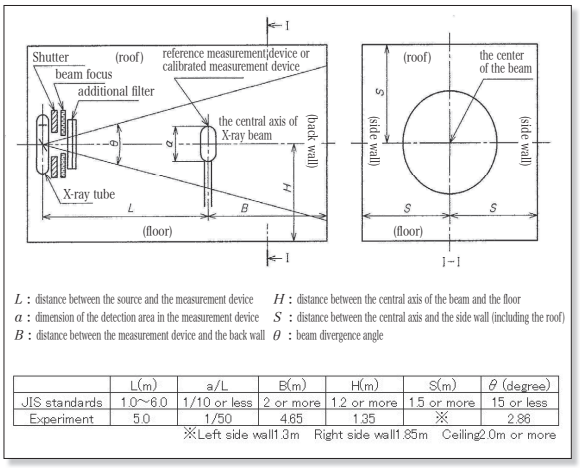
with the following settings: tube voltage, 70 kV and 120 kV; tube current, 40 mA; irradiation distance, 3.25 m and 5.0 m; and irradiation time, 5 s. Average, standard deviation and coefficient of variation (%) were obtained. Results are shown in Table 3. The measurement distance of 3.25 m is the reference point for the dose measurement for the specification of our calibration site. Actual calibration of the survey meter was performed at 5.0 m. Results showed that reproducibility of the dose measurement was favorable, and coefficient of variation was stable within 0.15%.

3-3. Calibration methods

3-3-1. To obtain 1 cm dose equivalent

Calibration of the survey meter was performed according to the JIS Z 4511 "Methods of Calibration for Exposure Meters, Air Kerma Meters, Air Absorbed Dose Meters and Dose Equivalent Meters"[3].

The standard dose for the calibration site was measured by Air Kerma (Gy) at the calibration point. To convert the obtained Air Kerma to the survey meter display of 1 cm dose equivalent (Sv), it was multiplied with the coefficient obtained from 1 cm dose equivalent conversion coefficient (1 cm dose equivalent for a site) shown in JIS Z 4511[3]. Fig.4 shows the graph of 1 cm dose equivalent conversion coefficient at 20-60 keV obtained from JIS. Since conversion coefficient changes rapidly at



L : distance between the source and the measurement device
H : distance between the central axis of the beam and the floor
a : dimension of the detection area in the measurement device
S : distance between the central axis and the side wall (including the roof)
B : distance between the measurement device and the back wall
θ : beam divergence angle

	L(m)	a/L	B(m)	H(m)	S(m)	θ (degree)
JIS standards	1.0~6.0	1/10 or less	2 or more	1.2 or more	1.5 or more	15 or less
Experiment	5.0	1/50	4.65	1.35	※	2.86

※Left side wall1.3m Right side wall1.85m Ceiling2.0m or more

Fig.5 Geometry of JIS and placement of the experiment (reprinted from JIS Z 4511: 2005)

the energy in the diagnostic range, X-ray energy used for irradiation must be measured accurately. Therefore, we used high purity (99.99%) aluminum to obtain half-value layer and in turn, equivalent energy. The value of absorption coefficient to obtain the equivalent energy was as reported by Seltzer and Hubbell[4].

Results showed that X-ray used for calibration had equivalent energy of 33.2 keV and conversion coefficient of 1.21 at the tube voltage of 70 kV, and equivalent energy of 42 keV and conversion coefficient of 1.50 at the tube voltage of 120 kV.

3-3-2. Calibration arrangements

The calibration site was arranged according to the geometry of JIS Z 4511 "A case of X-ray Irradiation"[3] shown in Fig.5. Calibration was performed with the substitution method at the reference point (5.0 m), where the reference dose was measured at the calibration site. Considering the time constant of the survey meter, measured values were obtained 40 s after starting the irradiation.

3-3-3. Calibration methods

With the present arrangement, the left wall direction was 1.3 m, which was shorter than in JIS; however, since the beam angle θ was extremely acute at 2.86 degrees, there was no scattered X-ray from the wall, and the impact from the side wall could be ignored. Scattered X-ray from the back wall could also be ignored since it was 4.65 m away from the back wall.

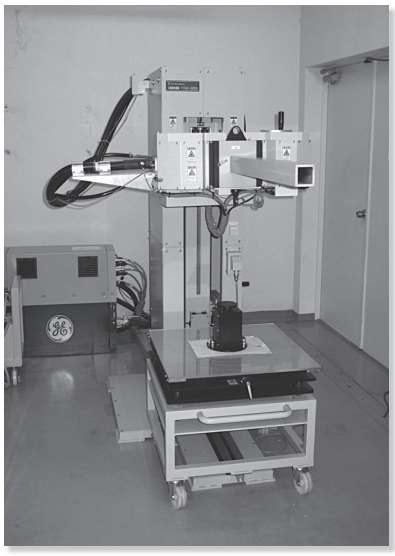


Fig.6 X-ray equipment used for calibration

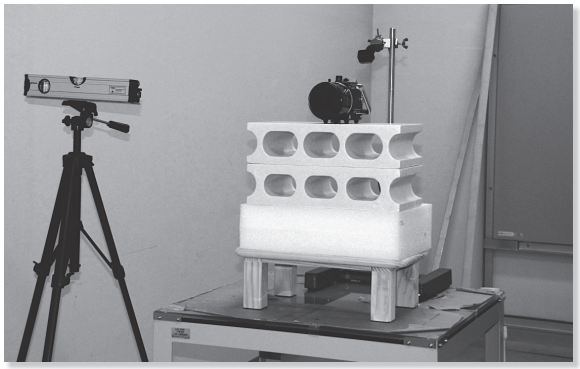


Fig.7 The placement of the survey meter at the time of calibration

Though JIS uses a circular irradiation field, in this study, we used a 5 × 5 cm focus at 1 m from the X-ray tube focus, which forms a 25 × 25 cm square at the irradiation position of 5.0 m. The photograph of the X-ray device used in the study is shown in Fig.6, while Fig.7 shows the arrangement of the survey meter.

3-4. Calibration results

Calibration results of all 53 units survey meters at 70 kV had a mean calibration constant of 0.996, with a standard deviation of 0.124. Fig.8 shows the calibration constants obtained from the experiment.

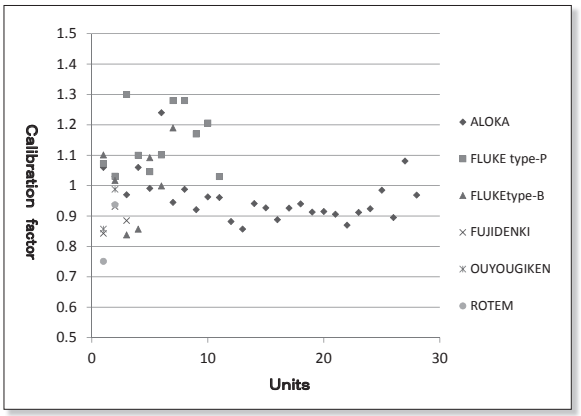


Fig.8 Calibration factor of the survey meter obtained from experiments

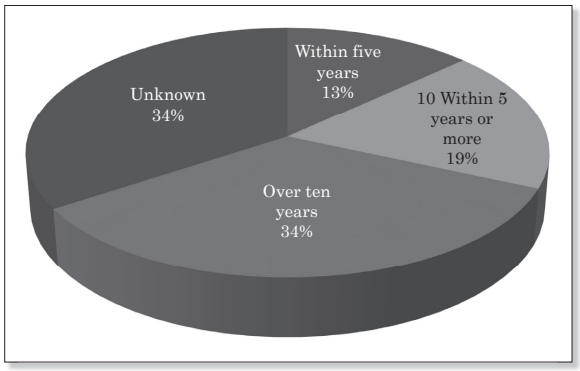


Fig.9 The time when the survey meter was purchased (Survey meter that has been provided in this study)

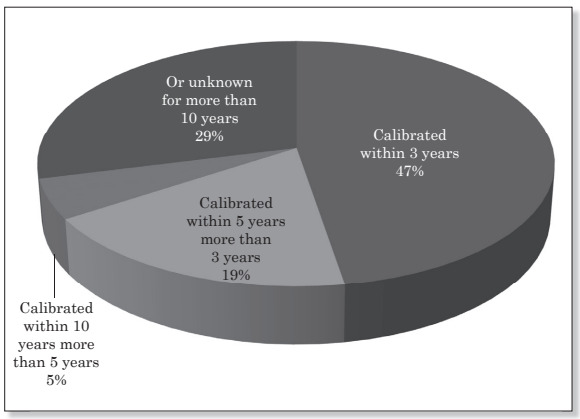


Fig.10 The time of calibrated the most recent (Survey meter that has been provided in this study)

3-4-1. Results by manufacturers

Mean calibration constants of the survey meter (Fig.8) from each manufacturer are shown below.

Twenty-eight units from Hitachi Aloka Medical, Ltd. showed little difference between each model, and the mean calibration constant was 0.957 with a standard deviation of 0.079.

Eighteen units from FLUKE Inc. had a mean calibration constant of 1.095 with a standard deviation of 0.13.

Devices from FLUKE Inc. can be divided into two groups: P-type, wherein the gas is sealed in the ionization chamber and pressurized; and B-type, wherein no pressure is applied.

Eleven FLUKE Inc. P-type (pressurized ionization chamber) had a mean calibration constant of 1.147 with a standard deviation of 0.105.

Seven FLUKE Inc. B-type (normal ionization chamber) had a mean calibration constant of 1.013 with a standard deviation of 0.129.

Overall, P-type survey meters tended to have a higher calibration constant.

3-4-2. Purchase timing

Of the 38 units survey meters belonging to medical facilities in the Kyoto Prefecture brought in for the present "attempt of calibrate", 26 units (68%) were purchased at least 10 years ago, or their purchase timing was unknown; 5 units (13%) were purchased within the last 5 years (Fig.9).

3-4-3. Calibration timing

Similarly, the final calibration of 38 units belonging to medical facilities in Kyoto Prefecture was at least 10 years ago or unknown in 11 units (29%); 18 units (47%) were calibrated within the last 3 years (Fig.10).

4. Discussion

The results from the present "Attempt of Questionnaire Survey and Calibration" confirmed that many survey meters were not regularly calibrated. Specific characteristics by manufacturers and models, as well as individual differences between each model were observed.

In the past, many survey meters (including those calibrated irregularly) were calibrated with ^{137}Cs. Hence, caution is required when using these meters to measure leakage dose and scattered dose distribution in the diagnostic range. For example, based on the manufacturer specifications[5], the relative sensitivity of FLUKE Inc. 451P-type does not show much difference in measuring ^{137}Cs between the front and sides of the survey meter, but for measurements in the diagnostic range (around the equivalent energy of 30 keV), the front and side surfaces show more than the two-fold difference and energy-dependence is significant.

More accurate values can be obtained by considering the calibration constant at the energy range that matches actual usage.

Regular confirmation of the performance is necessary, since many in-use survey meters are old. Especially, the types wherein pressure is applied to the ionization chamber may lose the gas over time, which could lead to decreased sensitivity. Among survey meters that were included in the current study, some showed a normal background range but a 50% reduction in sensitivity in actual measurement of the calibration sites was observed (excluded from the data analyses).

Performance can be maintained by calibrating every year and confirming the change. Furthermore, each facility is required to consider the characteristics its own survey meter and use the calibration constant that is suitable for the target energy, in order to maintain precision of dose measurement, which leads to appropriate measurement of environmental radiation.

5. Conclusion

Due to occupational exposure to radiation, sufficient knowledge and skills for measurements and use of survey devices based on the characteristics of dosimeters is required. Calibration of dosimeters is required for reliable measurement results.

Based on the results of the present study, comparative calibration training that has been offered irregularly in the past would be provided as an annual event of The Kyoto Association of Radiological Technologists as of 2014, to confirm performances of survey meters at facilities where annual calibration by consultants is difficult due factors such as budgets, etc.

Acknowledgements

We would like to extend our sincere gratitude to personnel from facilities that participated in the questionnaire and generously provided survey meters.

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Development and Evaluation of the Safety Grid Holder

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Key words: Safety grid holder, Anti-scatter grid, ABS, X-ray imaging, Support tool

【Summary】
X-ray imaging using an anti-scatter grid has various problems associated with it. Though devised as a support tool, the safety grid holder may also be used to improve imaging in clinical use. The safety grid holder has a structure that covers both the grid and the cassette so that the patient does not come into contact with the grid. The prototype was created using a polyvinyl chloride based resin, which demonstrated excellent durability. However, an improved version created with a strong lightweight ABS resin, resulted in improved visibility along with improved X-ray transmittance and impact resistance.

Thus, the safety grid holder both provides support for portable imaging and is an important support tool for obtaining images quickly and safely.

1. Introduction

The anti-scatter grid (hereinafter, referred to as the "grid") is a device positioned in front of the X-ray receiving surface[1)] that is used to obtain clear images while preventing degradation in the quality of the X-ray images due to scattered radiation. Grids that are used for general imaging are usually made of metal, such as aluminum or lead. In general, a higher grid weight results in a higher anti-scatter capability (the grid ratio). Various issues have occurred when using grids for emergency or hospital ward imaging. There are concerns of the grids having extremely hard and sharp corners that correspond to the shape of the cassette[2)]. The most common issue is discomfort caused by grids made of hard metal inserted with the cassette behind the subject. Less frequently, but with more impact on the subject, abrasions and even lacerations can occur from skin coming into contact with sharp metal corners. In particular, it is not easy to provide protection from the metal that pierces vulnerable skin where there is decreased resistance. Furthermore, it is not rare to see damage to the grid corner as a result of the grind being dropped, or misalignment when the grid and cassette are inserted behind the patient.

These grids are tools designed to improve image quality and are used with the assumption that the user will ensure the safety of the subject, which requires the user to pay close attention to the safe use of these grids in a clinical setting. By resolving various issues that occur during grid photography, we devised a safety grid holder to use as an auxiliary tool for clinical application that ensures the subject's safety during rapid imaging. Two types of resins were used to create the safety grid holders, which were then compared. Various modifications to the materials and shape were made in order to create these improved resin-based grid holders that have superior X-ray transmittance to previously used devices.

In this report, we present our results concerning the development, evaluation, and specifications of the modified safety grid holders.

2. Method

The specifications for the resin safety grid holders are described in the following sections: materials, structure, and performance.

2-1. Materials

Plastic was chosen as the construction material considering its high durability, the ability to maintain a clean surface, ease in processing, and various other factors. Initially, we used highly durable polyvinyl chloride type resin (PVC) to create a prototype. Later, we used a durable and lightweight ABS resin (ABS) to create an improved structure[3]. Additionally, the base color was also changed from off-white to yellow. The color change to yellow was made after consulting the evaluation team, which was comprised of five in-house medical radiology technicians and coordinators from the manufacturer. Below, we present data that compare the two materials discussed in this section.

2-2. Structure

The prototype (PVC) and the improved version (ABS) have identical structures. A structure was chosen that would cover both the cassette and the grid in order to ensure that the subject does not come into contact with the grid (Fig.1). In the clinic, the grid would be attached to the inner side of the safety grid

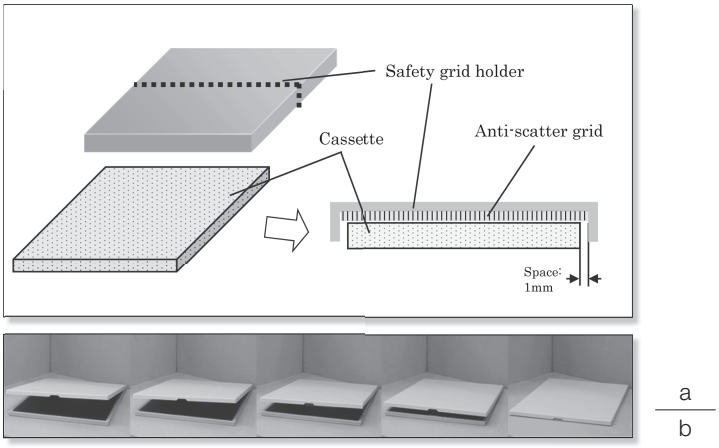


Fig.1 Structure of the safety grid holder
a) Exterior and cross section of the safety grid holder
b) Usage of the safety grid holder

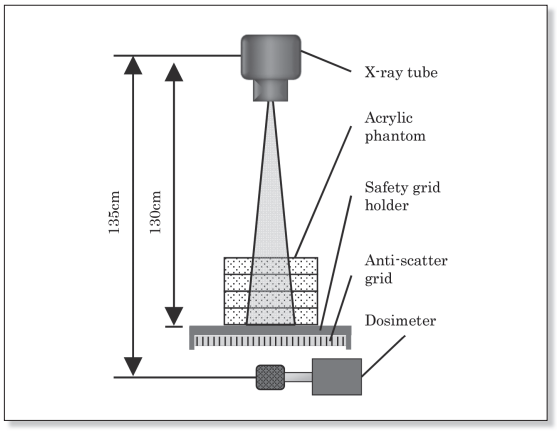


Fig.2 Alignment of experiment (X-ray transmittance)

Table 1 Parameters of the X-ray transmittance

Thickness of acrylic phantom (cm)	10	15
Voltage (kV)	80	
SID (cm)	130	
Field size (cm)	10×10	
Grid ratio	3：1	6：1
Density (lines/cm)	40	

holder using double-sided tape. A gap of 1 mm was present both vertically and horizontally between the grid and the cassette in order to make it possible to quickly detach the grid from the cassette. Moreover, small wrinkles (emboss processing) were created on the front surface in order to reduce the friction that occurs during positioning.

2-3. X-ray Transmittance

The arrangement during the test assumed that the images would be taken using portable devices (Fig.2). The subject was recreated by stacking 35 cm × 35 cm acrylic boards with a thickness of 1 cm. A grid that is proportional to the thickness of the subject is used in the clinic. Therefore, we used acrylic boards with a thickness of 10 cm for a grid having a 3:1 grid ratio (grid density of 40) when simulating the imaging of the chest area. We used acrylic boards with a thickness of 15 cm for a grid having a 6:1 grid ratio (grid density of 40) to simulate the imaging of the abdominal area (Table 1). The parameters used for imaging the 10-cm-thick acrylic boards were a tube voltage of 80 kV, radiographic exposure of 20 mAs, and SID of 135 cm. For 15-cm-thick acrylic boards, the parameters were a tube voltage of 80 kV, radiographic exposure of 50 mAs, and SID of 135 cm. The dosage measurement was performed using an ionization chamber dosimeter (6cc chamber, Radcal 9501; produced by Radcal) and three measurements were performed with a 10 cm ×10 cm irradiation field on the grid surface. The following equation (Eqn.1) was used to calculate the X-ray transmittance using the average value of the three measured values as the transmitted radiation dosage incurred by these specimens.

Equation 1

$$\textit{X-ray transmittance} = \frac{\text{Acrylic /material grid transmitted radiation dosage}}{\text{Acrylic /grid transmitted radiation dosage}} \times 100\%$$

In this evaluation, in addition to the two types of materials described previously, a calculation was also performed for the X-ray transmittance of dry carbon (Carbon Cassette: Toshiba Medical Systems Corporation), which is widely used in X-ray imaging.

2-4. Impact Resistance

In the same manner as described for the clinical practice, a grid having a grid ratio of 6:1 (grid density of 40) was adhered to the safety grid holder using double-sided tape. This grid was then dropped consecutively ten times from a height of 1 m onto plastic tiles while pointing the same corner in the downward direction.

3. Results

3-1. Materials

The weight changed from 490 g to 385 g by changing the material from PVC to ABS. Additionally, after changing the base color from off-white to yellow, it became easier to perform positioning during imaging and to recognize the tube types that are used for drainage and infusions (Fig.3).

3-2. Structure

The structure that covers the grid and the cassette prevents misalignment of the grid and the cassette during imaging and is capable of protecting the subject from coming into contact with the sharp corners while protecting the cassette and grid. This structure also prevents the grid body from being damaged and deformed, and can also be used safely with grids that have damaged corners due to extended usage (Fig.4).

3-3. X-ray Transmittance

We have provided a comparison of the X-ray transmittance for each of the materials. The X-ray transmittance for the PVC, carbon, and ABS was found to be 84.5%, 94.5%, and 96.0%,

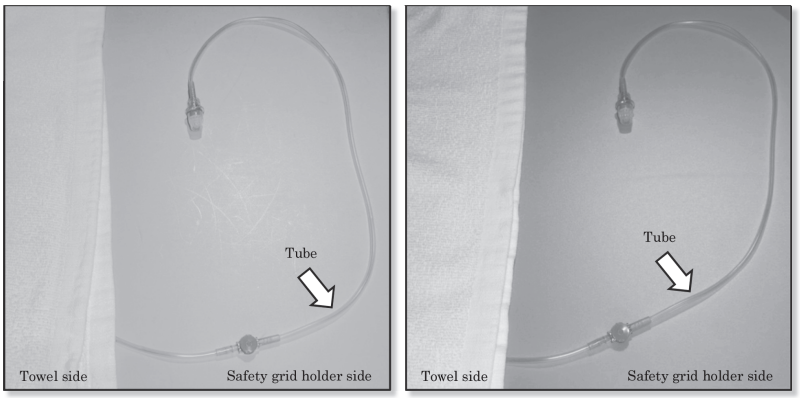


Fig.3 Effect of base color change a | b
a) Proto type (Off-white)
b) Improve type (Yellow)

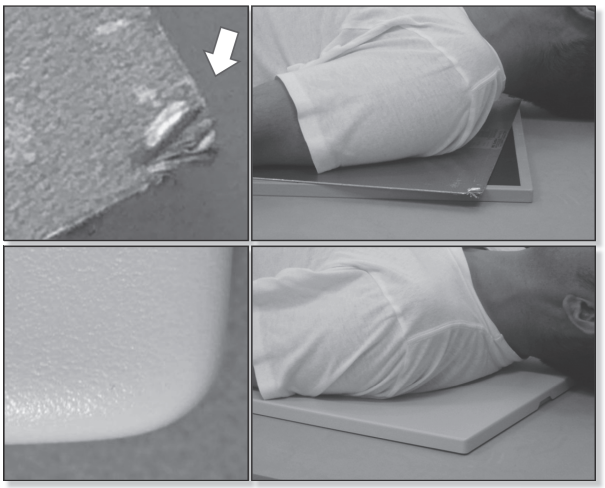


Fig.4 Effect of the safety grid holder a | b / c | d
a) Corner of the damaged grid
b) Example of use the damaged grid
c) Corner of the safety grid holder
d) Example of use the safety grid holder

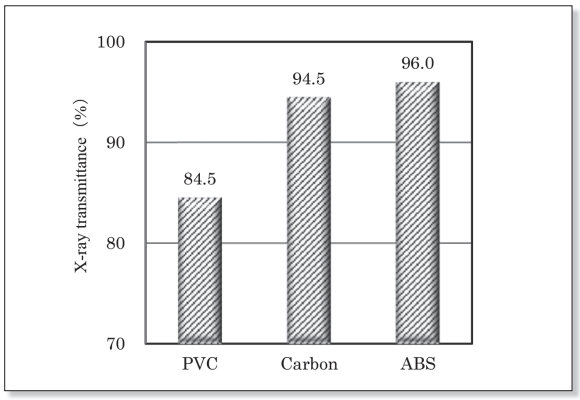


Fig.5 Comparison of X-ray transmittance
(Voltage : 80kV, Acrylic phantom : 10cm)

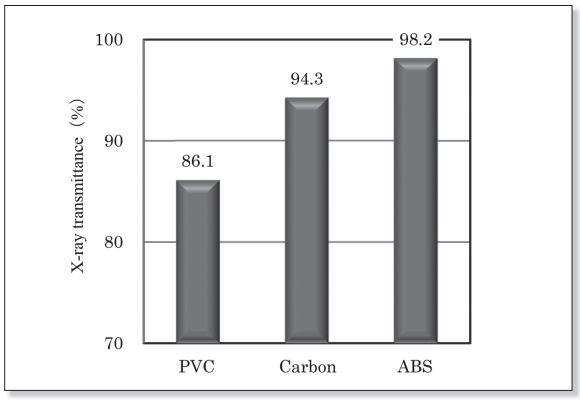
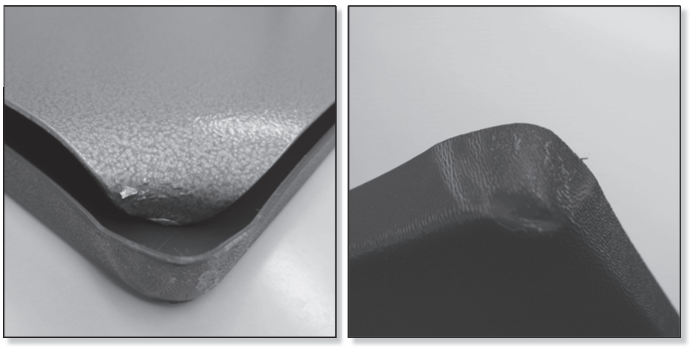


Fig.6 Comparison of X-ray transmittance
(Voltage : 80kV, Acrylic phantom : 15cm)

respectively, when the acrylic thickness was 10 cm (Fig.5), and the X-ray transmittance was found to be 86.1%, 94.3%, and 98.2%, respectively, when the acrylic thickness was 15 cm (Fig.6). With respect to both of the acrylic thicknesses (10 cm and 15 cm), the ABS exhibited a higher X-ray transmittance compared to the PVC or carbon. The X-ray transmittance increased when the materials were changed.

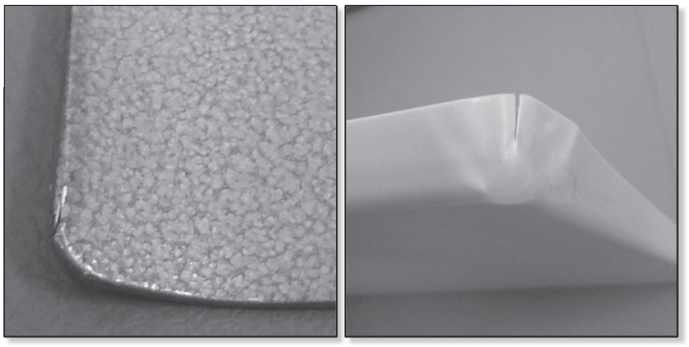
3-4. Impact Resistance

After being dropped once, the corner of the safety grid holder of the prototype (PVC) was deformed, and the grid also bent significantly (Fig.7-a, b). After being dropped ten times, there were no further signs of large deformations. Although the improved-type (ABS) in-



a | b

Fig.7 Result of impact resistance test (Proto type)
a) Distorted grid
b) Distorted the safety grid holder



a | b

Fig.8 Result of impact resistance test (Improved type)
a) Grids protected by the safety grid holder
b) Cracked safety grid holder

curred a slight bend in the grid after being dropped three times (Fig.8-a), there were no noticeable changes in the shape of the safety grid holder. After being dropped six times, a crack was found on the corner of the safety grid holder (Fig.8-b); however, there were no significant changes in the shape after ten drops.

4. Discussion

The structure of the safety grid holder is thought to provide improved protection and prevent misalignment between the grid and the cassette when used to image diverse areas and regions of the subject. In particular, with respect to the imaging of the abdominal area and pelvic region, it is easy for misalignment to occur between the grid and the cassette. Now, it will be possible to use the safety grid holder to easily insert the grid behind the subject (Fig.9-a). Additionally, safety grid holders are produced by vacuum molding one plastic sheet, which provides an easy surface to clean since there are no joints. Safety grid holders can also be applied as grid covers when stains are anticipated on the cassette front, such as in emergency imaging of traumatized areas (Fig. 9-b).

The improvement in the X-ray transmittance is thought to be attributable to the decrease in the specific weight of the material. The X-ray absorption increases as the mass number, density, and thickness increase[4]. Decreases in the specific weight, brought about by changing the material type, are thought to contribute to the improvement of the X-ray transmittance and reducing the mass of the grid holder itself[5] (Table 2).

When the acrylic thickness is increased, hardening of the radiation quality is thought to cause a small difference in the X-ray transmittance between the two thicknesses of carbon

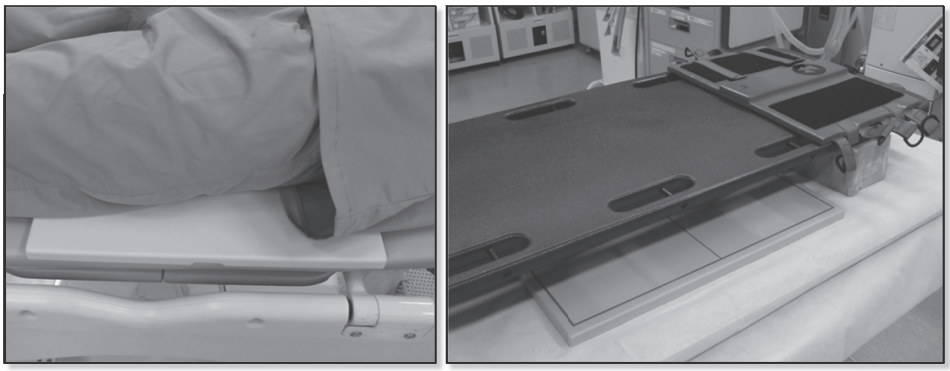


Fig.9 Examples of using the safety grid holder a | b
a) X-ray imaging on stretcher
b) Emergency X-ray imaging

Table 2 Characteristics of plastic

Material	PVC	ABS
Specific gravity (g/cm^3)	1.35-1.45	1.05-1.07
Rockwell hardness	D65-85	R108-113
Impact strength Izod, notch (+) (kg·cm/cm^2)	1.7-8.6	10-50
Stretch (%)	2-40	5-25
Acid resistance	Good	Good
Alkali resistance	Excellent	Excellent
Usage/ Characteristics	• Coating material • Toy • Card case etc.	• Light electrical equipment parts • Interior and exterior parts • Toy etc.

＊Modified from "Performance list of the major plastic", Plastic reader

compared to the ABS and PVC.

The improvement in the visibility of linen and tube types is thought to be attributable to the use of yellow, which is more easily recognized than white. The contrast is determined by three factors, namely, hue, saturation, and intensity. It is possible to obtain strong contrast with colors that are farther apart on the Munsell color scale. It became easier to observe the contrast with tubes or linen that have a high saturation and are achromatic by changing the base color to yellow, which has a higher intensity and is chromatic[6]. There is an improvement in recognizing contamination that occurs during treatment and an overall impression of cleanliness is given when either white (which is achromatic and has a high intensity) or a similar color is used, suggesting significant benefits associated with using yellow, which is easily recognized.

The grid was better protected when using the sturdy ABS. However, it was also shown that harder materials are susceptible to cracks. Although reinforcing the frame using metal is one method to improve durability, it presents new problems resulting from interference with wireless systems such as the cassette-type flat panel detectors (FPD). Metal used in the material for the grid holder is considered counterproductive since the metal will reflect and absorb the electromagnetic waves, possibly leading to problems with transmission instability or decreased throughput for data transfer[7].

The safety of the subject should increase as a result of using the safety grid holder, and we believe that it will also be easier to protect the grid owing to this. However, caution is still needed when handling this grid, as damage can result in costly expenses. Future plans focus on improving the durability of the device and refining the factors relating to imaging.

5. Conclusion

In this report, we have provided specifications for the safety grid holder and the modifications relating to its development and evaluation thereof. The safety grid holder, which is capable of resolving many of the issues associated with portable imaging, is an auxiliary tool that adequately supports the grid imaging used

in emergency settings and hospital ward imaging, enabling quick and reliable imaging while improving the safety of the subject.

6. Acknowledgments

We would like to express our deep gratitude to the staff of the Osaka City University Hospital Central Radiotherapy Dept. for guidance and encouragement that was provided for this report.

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Fundamental Study of Magic Angle in the Meniscus of the Knee Joint

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Key words: MRI, magic angle, meniscus, short-TE

【Abstract】
Physicians must be cautious about the magic angle phenomenon in MRI, especially during the imaging of the tendons and ligaments. The magic angle phenomenon occurs when a high signal is produced by a tendon or ligament at about 55 degrees relative to the static magnetic field. In addition to the tendons and ligaments, the meniscus is also an object of the magic angle phenomenon, but a clear image is rarely produced. This study examined the magic angle phenomenon of the meniscus. The magic angle phenomenon was detected in the meniscus. To rule out the magic angle phenomenon, it is necessary to image the joint using a sequence with a long echo time (TE) or change the orientation of the tissue to avoid the magic angle.

Introduction

Magic angle phenomenon is a problem observed in magnetic resonance imaging (MRI) of fibrous tissues such as the tendons and ligaments. In particular, the magic angle phenomenon is often observed during imaging of the rotator cuff of the shoulder joint and the anterior cruciate ligament of the knee joint[1)-3)]. The meniscus of the knee joint is histologically classified as fibrocartilages. T_2*-weighted sequences with short echo times (TE), proton density weighted sequences, or T_1-weighted sequences are typically used to image the meniscus of the knee[4), 5)]. Therefore, it is highly likely that the magic angle phenomenon affects the imaging of the meniscus[6)]. However, the occurrence of false image findings in clinical settings is reported to be rare because it is believed that hyperintensity on the dorsal horn of the meniscus is caused by the degeneration or tear of the meniscus, and not by the magic angle phenomenon[7)]. In this study, we examined whether the magic angle phenomenon would occur with respect to the static magnetic field at the meniscus using a phantom MRI method.

1. Magic angle phenomenon

Once the angle of a tendon or ligament reaches the magic angle during acquisition of an image with a short-TE MRI sequence, some tissues show high signal intensities that may resemble images of pathological conditions such as degeneration or bleeding[1)]. The magic angle is about 55° relative to the z-axis in a static magnetic field. The equation for determining this angle is as follows[8), 9)]: $Bz = \mu_0 \mu (3\cos^2\theta - 1)/4\pi r^3$, where Bz represents the z-direction component of a static magnetic field, μ represents the magnetic moment of an atomic nucleus, θ represents the angle of rotation around z-axis, and r represents the distance from the atomic nucleus. If $Bz = 0$, the z-direction component in the magnetic field on a magnetic moment of an atomic nucleus can be described by the following equation: $3\cos^2\theta - 1 = 0$, or $\cos\theta = 1/\sqrt{3}$, or $\theta = 54.7°$ or $125.2°$.

Fig.1 shows this angle domain for the static magnetic field. The tendons and ligaments are comprised of collagen fibers (protein) present

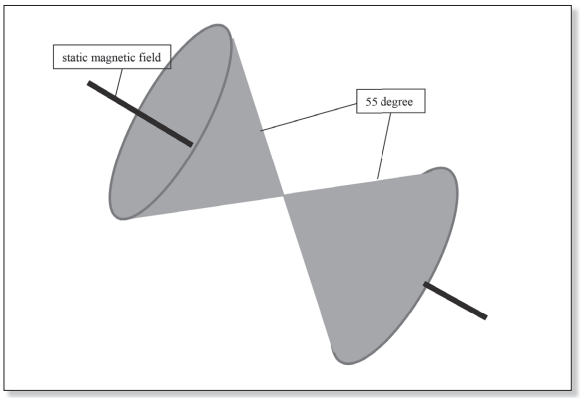

Fig.1 Area of 55 degree for the static magnetic field.

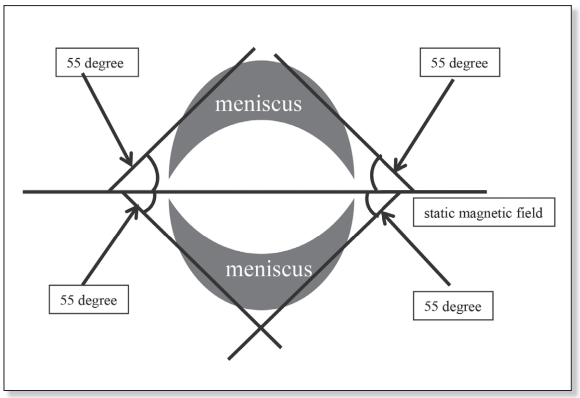

Fig.2 A part of 55 degree for the static magnetic field in the meniscus.

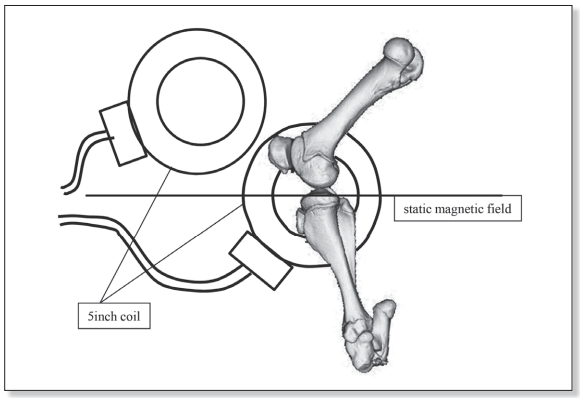

Fig.3 The imaging position

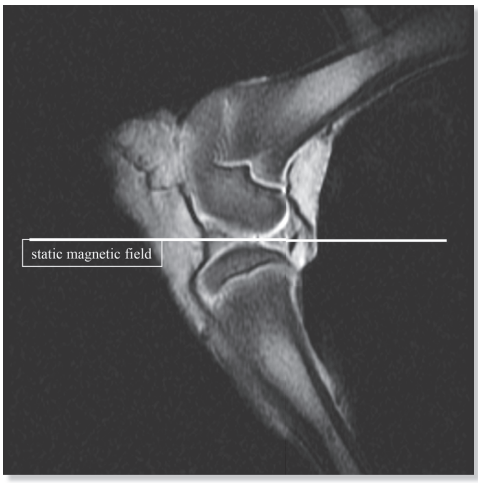

Fig.4 Direction of the static magnetic field in the meniscus.

in such a manner that the water molecules surrounding the collagen fiber are constrained and aligned along the direction of the fiber[10]. The magic angle phenomenon is observed when that angle approaches the angle of θ.

2. Methods

By acquiring the images with varying TE after placing the phantom of the meniscus at about 55° to the static magnetic field, changes in the signal of the phantom were measured at different TEs.

2-1. Equipment and coil

A 1.5 T Signa HDx MRI scanner, ver. 14 (GE) was used in this study. For evaluation of the phantom images, two 5-inch surface coils were used as a dual coil.

2-2. 3D imaging parameters

The imaging parameters of the sequence used in this study were as follows: repetition time (TR), 4000 ms; TE, 13.8-111.2 ms; flip angle, 90°; matrix, 256 × 256; field of view (FOV), 15 cm × 15 cm; number of excitations (NEX), 2; slice thickness, 1 mm; fat suppression, none; sensitivity correction, none; bandwidth (BW), 13.16 kHz; number of slices, 25; acquisition time, 264 s.

2-3. Phantom

Pig meniscus, which is similar to human meniscus[11], was enclosed in a joint capsule and used as the phantom in this study. Either of the regions could become the magic angle (about 55°) once the meniscus is oriented in a similar direction as in Fig.2. For the positioning, the

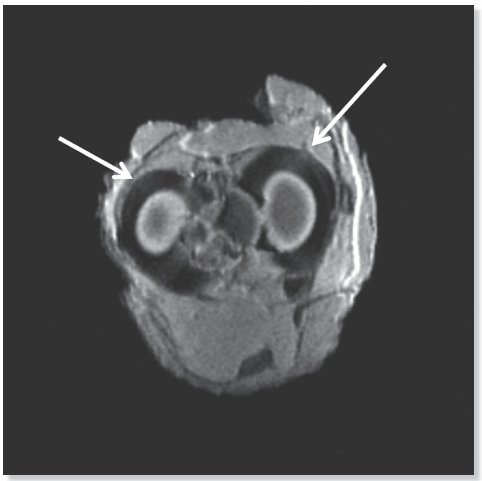

Fig.5 a Meniscus image in short TE sequence.
(←) : High signal part in the meniscus.

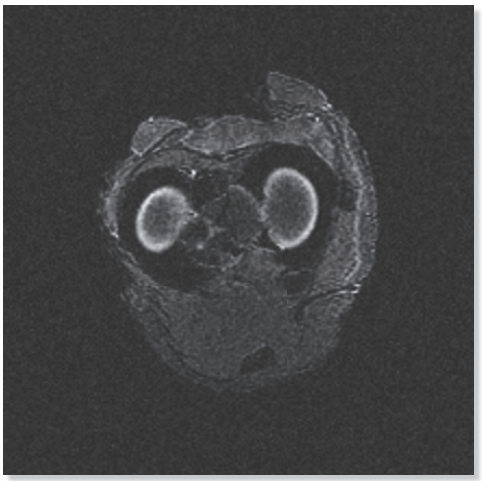

Fig.5 b Meniscus image in longTE sequence.

tibial articular surface was placed at the center of the surface coil and was fixed by securing the surface coil with two towels (Fig.3). After acquiring several images for positioning, we made fine adjustments so that the tibial articular surface aligned with the direction of the static magnetic field (Fig.4). This study was performed after obtaining the approval of the medical research ethics committee of our hospital. After the imaging, one orthopedist and six radiologic technologists examined the joint and confirmed that the meniscus used for the phantom was normal (without any pathological abnormalities).

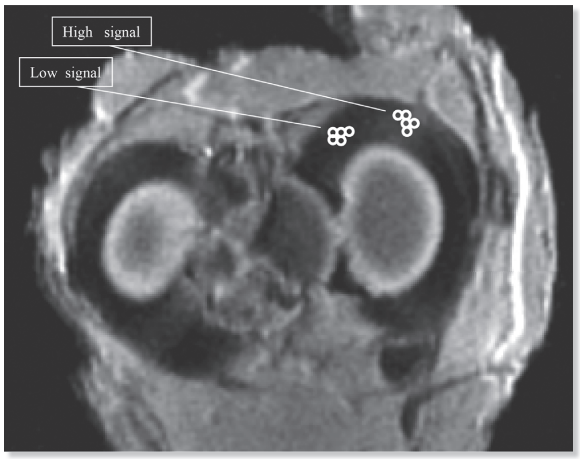

Fig.5 c ROI setting of high and low signal area.

2-4. Examination of phantom images

Using a short-TE to long-TE sequence, 3D images of the region that included the meniscus were acquired. The images acquired for the evaluation of the meniscus were generated by reconstruction of the sequence from the original image to compare the signal levels by each sequence. With the fast spin echo (FSE), the images were acquired using a sequence that can change from a short-TE to long-TE by adjusting the TR and BW. The images were acquired at the following TE values (in ms): 13.8, 27.8, 41.7, 55.6, 69.5, 83.4, 97.3, and 111.2. In each TE sequence, five regions of interest (ROI) were set in the low signal value region (A) and the high signal value region (B) of the meniscus, and the mean signal value was calculated to measure the contrast ratio of B/A. In this study, the size of the ROI was defined as 1 ± 0.1 mm^2 based on the results of the ROI viewer measurement software. We examined whether there were differences in the contrast ratio between the shortest TE and the longest TE. By determining the TE at which the contrast ratio is close to 1, we also examined whether the TE value influences the results. Figs.5a, 5b, and 5c show representative images that were used for the evaluation.

3. Results

With the shortest TE sequence, the mean ROI value of the low signal region in the meniscus was 361.2, while the mean ROI value of the high signal region in the meniscus was 923.2, and its contrast ratio was 2.56. With the longest TE sequence, the signal value for the same region was 193.6 to 188, and its contrast ratio was 0.97. The contrast ratio of the low signal value to the high signal value in the meniscus in each TE (ms; represented as TE [B/A]) was 13.8 (2.56), 27.8 (1.67), 41.7 (1.32), 55.6 (1.21), 69.5 (1.21), 83.4 (1.08), 97.3 (0.96), and 111.2 (0.97).

4. Discussion

Since MRI images with short-TE imaging sequence are often used to visualize the meniscus, hyperintensity caused by the magic angle may cause an error in a diagnosis that is based on MRI examination alone. This study examined whether magic angle phenomenon occurred in the tissues of the meniscus by placing the meniscus at approximately 55° relative to the static magnetic field. The results obtained suggest that a clear magic angle phenomenon was observed in the short-TE sequence images. The low signal value region of the meniscus more than doubled in signal intensity compared with the initial signal value, and the contrast ratio was 2.56. Conversely, the signal/contrast ratio of the same regions using the long-TE sequence images was 0.97, which was close to 1. These results imply that in short-TE imaging sequence of the meniscus tissues, signal values increased in the regions where collagen fibers of the meniscus were present at about 55° relative to the static magnetic field. In this study, the region where images for positioning aligned at about 55° relative to the static magnetic field almost corresponds to the region where the signal value was increased. The arrangement of the meniscus collagen fibers in this study was radial in structure at the surface, but was circular at the interior and the radial fibers mixed with the circular fibers around the circumference[12]. Therefore, the region with the high signal value seemed to correspond with the circular fibers present at the interior. Evaluation of the contrast ratio for each TE revealed that the contrast ratio was close to 1.00 when the TE was 83.4 ms or more; at these TE values, the magic angle phenomenon was not observed. The TE values that rule out the magic angle phenomenon are expected to vary depending on the sequence. Nevertheless, TE can be considered an indicator to rule out the magic angle phenomenon. The magic angle phenomenon shows increased signal value with short-TE at the region that is about 55° to the static magnetic field. When the tendon and ligament align in a particular direction that is not close to the magic angle, the positions of the protons are constant, and T_2 relaxation may be promoted by dipole interaction. However, when the position reaches the magic angle, it cannot be influenced by dipole interaction. Therefore, extension of T_2 occurs and the signal of the tissues can be obtained with a short-TE sequence. However, T_2 of the water molecules that are bound to macromolecules present in the tendon or ligament is considered as $< 200\ \mu s$[13]. Consequently, TE is very less that even if extension of T_2 relaxation occurs in the tendon or ligament and decrement occurs before acquiring signals with long-TE, it does not significantly influence the signal strength. The regions with high signal values that are caused by the magic angle phenomenon actually show a normal signal at the tendon or the ligament, not an abnormal signal. Thus, it may be decayed with relaxation time[14], and its contrast cannot be detected like other tissues.

5. Conclusion

This study, which evaluated the magic angle

phenomenon of the meniscus revealed that the signal value with short-TE increased in the region at about 55° relative to the static magnetic field and that the imaging of the meniscus was influenced by the magic angle. In the vertical magnetic field, it is necessary to be cautious because the meniscus may orient in a direction that is close to the magic angle. In the horizontal or supine magnetic field, the meniscus is not close to the magic angle. Since imaging of the meniscus is not angularly influenced in the horizontal magnetic field, the meniscus can be examined using a conventional T_2*-weighted image with a short-TE, proton density-weighted image, and a T_1-weighted image. However, when meniscal tear occurs and dislocation or deformation is severe, magic angle phenomenon may be specifically observed[15]. To avoid the magic angle phenomenon, the patient should be placed in a position in which the fiber direction is not close to 55° relative to the static magnetic field[1], or images should be acquired with long-TE imaging sequences such as the T_2*-weighted imaging.

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Volumetry of the Liver: Effect of measurement using fusion images

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Key words: volumetry, liver, single-photon emission computed tomography (SPECT), computed tomography (CT), magnetic resonance imaging (MRI).

【Abstract】

Understanding liver function and volume as well as the positions of the blood vessels and organs before hepatectomy is important for preventing liver failure after surgery. Information regarding liver volume is acquired by SPECT, CT, and MRI, and a few studies have been published regarding the same. However, these studies are hampered by issues in the accuracy of measurements. The assessment of liver volume using SPECT/CT has been recently reported. However, not every hospital can perform this technique. Therefore, we analyzed MR images acquired during expiration in order to assess the liver volume using fusion images acquired by both SPECT and MRI.

First, we used a tailor-made phantom of the liver to measure the volume-changing image parameter in each modality. Then, we compared the images acquired using all three modalities. After obtaining the institutional review board approval and informed patient consent, we measured the liver volumes of 48 patients (mean age, 68 ± 10 years), using each of the modalities and compared them amongst each other. We assessed intra-observer reproducibility by performing the measurements twice.

The mean total liver volume measurements obtained using SPECT, CT, and MRI were not significantly different (1176.3 ± 330.3 cm^3, 1172.9 ± 341.7 cm^3, and 1187.6 ± 334.9 cm^3, respectively; $p = 0.289$). The mean residual liver volumes measured using SPECT, SPECT-CT fusion, SPECT-MRI fusion, CT, and MR images showed significant differences (511.8 ± 301.0 cm^3, 531.9 ± 266.7 cm^3, 551.9 ± 269.8 cm^3, 555.6 ± 259.0 cm^3, and 558.0 ± 243.3 cm^3, respectively; $p < 0.05$). The residual liver volumes measured using SPECT, SPECT-CT fusion, and SPECT-MRI fusion images showed good intra-observer positive correlations ($\rho = 0.88$, 0.91, and 0.97, respectively).

We conclude that the measurement of liver volume using fusion images acquired by SPECT and MRI shows good reproducibility.

Introduction

Liver cancer is the fourth leading cause of death in Japan, after lung, stomach and colon cancer[1)]. The incidences of lung, colon, and pancreatic cancer continue to increase, whereas that of liver cancer has decreased after peaking in the mid-2000s. There were about 33,000 cases of liver cancer in 2010[1)]. The main methods of liver cancer treatment are surgery, percutaneous ethanol injection therapy, and transcatheter arterial embolization. Many patients with liver cancer experience complications such as chronic liver disease, hepatitis, cirrhosis, and fatty liver. Treatment selection takes into consideration liver function as well as the stage of cancer. It is important to understand liver function and volume as well as the locations of the organs and vessels before liver excision in order to prevent liver failure. Technetium-99m diethylenetriamine pentaacetic acid galactosyl human serum albumin (^{99m}Tc-GSA) scintigraphy and X-ray computed tomography (CT) can provide this information[2)–6)]. At our hospital, liver function is measured using ^{99m}Tc-GSA scintigraphy prior to hepatectomy. Liver volume is measured using single-photon emission computed tomography (SPECT), which provides an indication of reserve capacity after hepatectomy. In many cases, liver volume is evaluated using CT and magnetic resonance imaging (MRI)[7)–11)]. Measurement of liver vol-

ume using SPECT images provides inadequate information about the vessels and lacks accuracy[12]. In comparison, CT provides excellent accuracy of measurements. The volume of the liver, however, is not a reflection of liver function[13]. The evaluation of liver function from MR images was recently attempted using gadoxetic sodium (Gd-EOB-DTPA). However, it does not become instead of SPECT yet[14), 15]. In addition, liver volume measurements acquired using CT and MRI tend to be greater than the actual liver volume[16]. It is necessary to evaluate the information and confirm the accuracy of liver volume measurements using each modality prior to hepatectomy. Accuracy has been a problem when SPECT and CT, CT and MRI were used to measure liver volume[16)–19)]. The fusion of SPECT and CT images in order to improve the accuracy of liver volume measurements was reported by a study. The accuracy of image fusion poses a problem because CT images are usually obtained during inspiration, while SPECT images are acquired during free breathing. Recently, SPECT/CT has been used in a study as a method to compensate for these deficiencies[20]. However, not every hospital has the facilities for SPECT/CT imaging. The purpose of this study was to evaluate liver volumes using a custom-made phantom as well as clinical images acquired using three modalities — SPECT, CT, and MRI.

Materials and methods

Experimental Setup

Each imaging modality was evaluated using a custom-made phantom. The phantom was composed of polymethyl methacrylate (PMMA) in a 500 cm^3 solution of contrast agent (Fig.1).

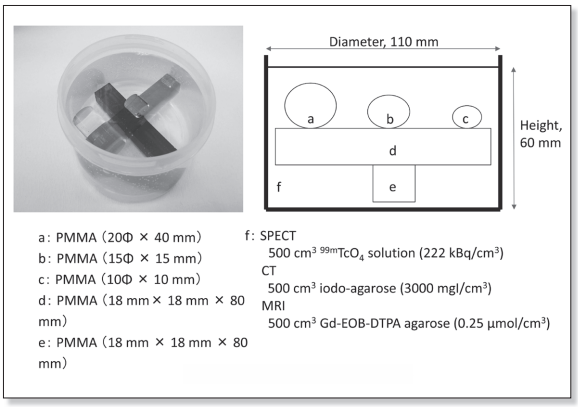

Fig.1 Tailor-made liver phantom.

Patients

The study included 48 patients (male, 31; female, 17) with or without an injured liver, who underwent hepatectomy at the Showa University Hospital between March 2012 and August 2013. The mean (SD) age of the patients at the time of surgery was 68 ± 10 years (range, 35–83 years). The participants underwent SPECT, CT, and MRI examinations within 2 weeks prior to hepatectomy. Finally, patients undergoing right (n = 34) or left (n = 14) lobe hepatectomy were included, and those undergoing partial hepatectomy were excluded. Patient consent was obtained after approval by the institutional review board of the hospital.

Imaging Acquisition

The studies were performed using a SPECT system (Symbia S; Siemens Healthcare, Erlangen, Germany) with low-energy high-resolution collimators, a CT scanner (SOMATOM Definition AS+; Siemens Healthcare, Erlangen, Germany), and a similar 3.0 Tesla MRI system (MAGNETOM Trio A Tim; Siemens Healthcare, Erlangen, Germany) with a body-matrix coil as well as a spine-matrix coil consisting of 12 coil elements. In the phantom study, the parameters for SPECT image acquisition included the following: each set of projection data was obtained in 64 projections (5.6°/step, 20 s/step), and the energy window was 20% width at photo-peak; for each image, the acquisition time was assumed to be constant, and the voxel size was changed (matrix, 64 × 256) as shown in Table 1. The reconstruction parameters used after data collection were as follows: reconstruction method, filtered back projection; filter, Butterworth; cutoff, 0.15 cycles per pixel; attenuation

correction, none; scatter correction, none. For volumetric imaging with CT, the acquisition parameters were as follows: tube voltage, 120 kV; tube current, 200 mA; collimation, 0.6×64 mm; pitch factor, 1.0; and rotation time, 0.5 s. The field of view (FOV) and slice thickness values for each image are shown in Table 2. For MRI volumetric imaging, we used the Volumetric Interpolated Breath-hold Examination (VIBE) with 3D-GRE-T1WI sequence. The parameters included the following: repetition time, 3.8 ms; echo time, 1.5 ms; flip angle, 10°; matrix size, 512×512; bandwidth, 444 Hz/pixel. The FOV and slice thickness values for each image are shown in Table 3. For image acquisition of the clinical cases, SPECT was performed with a voxel size of 9.6 mm, with free breathing during scanning. The spatial resolution for CT was 0.68 mm×0.68 mm×0.75 mm, and the images were acquired while holding inspiration. The spatial resolution for MRI was 1.46 mm×1.09 mm×3.5 mm, and the images were acquired while holding expiration. The patients were administrated total bolus intravenous injections of 185 MBq ^{99m}Tc-GSA at scintigraphy, 600 mg/kg iodinated contrast medium at CT, and 0.10 mmol/kg Gd-EOB-DTPA at MRI.

Image Analysis

In the phantom study, the phantom volumes measured using each modality were compared.

Table 1 Volume of tailor-made liver phantom with SPECT.

Voxel size (mm)								
0.8	0.9	1	2	3	3.9	4.8	6.6	9.6
299.9	460.2	481.7	553.1	548.6	548.7	548.3	561.3	673.0

(cm^3)

Table 2 Volume of tailor-made liver phantom with CT.

Pixel size (mm)	Slice thickness (mm)				
	1	2	3	4	5
0.6	499.4	533.1	562.6	594.3	626.5
0.7	505.8	538.9	567.6	599.0	630.5
0.8	511.6	543.3	571.7	602.9	634.3
0.9	516.5	547.3	575.2	606.4	637.8
1.0	523.1	552.6	579.2	609.7	641.2

(cm^3)

In the clinical cases, the liver volumes were measured using each modality and evaluated; both whole and partial liver volumes were measured. The SPECT images were acquired 20 min after ^{99m}Tc-GSA scintigraphy, CT images during the portal phase, and MR images during the hepatobiliary phase of Gd-EOB-DTPA imaging. The volumes were measured using the standard semi-automatic extraction function of the 3D application AZE Place Raijin, version 3.1 (AZE, Ltd Tokyo, Japan). In the horizontal view, a part of the solution was extracted by enclosing the border of the solution resembling liver tissue in the direction of the body axis, creating the mask shown in Fig.2, using the radial basis function (RBF) interpolation function. In the SPECT images, the cutoff value of the count was set using the threshold value change function to remove the background count. The cutoff value was assumed to be 35% of the maximum count value[21]. With CT and MRI, the liver volumes were measured using the semi-automatic extractor function, after the main blood vessels (portal and vein), intrahepatic bile ducts, and a part of the mass were excised at the workstation. Partial liver volumes of right and left lobes were measured separately, and the volume on the residual side was evaluated. The base that separated the right and left lobes was assumed to be the Cantlie line. Liver volumes were also measured using the fusion images of SPECT with CT and MRI. As shown in Fig.3, the fusion images were manually fitted using the workstation application.

The partial liver volumes were again measured a month later using SPECT, CT, and MRI,

Table 3 Volume of tailor-made liver phantom with MRI.

Pixel size (mm)	Slice thickness (mm)				
	1	2	3	4	5
0.6	502.1	535.3	570.8	603.0	640.6
0.7	506.6	538.3	573.6	605.8	643.1
0.8	511.3	541.7	575.6	608.3	645.5
0.9	516.1	545.5	579.5	610.4	648.9
1.0	519.6	550.5	583.2	614.1	652.2

(cm^3)

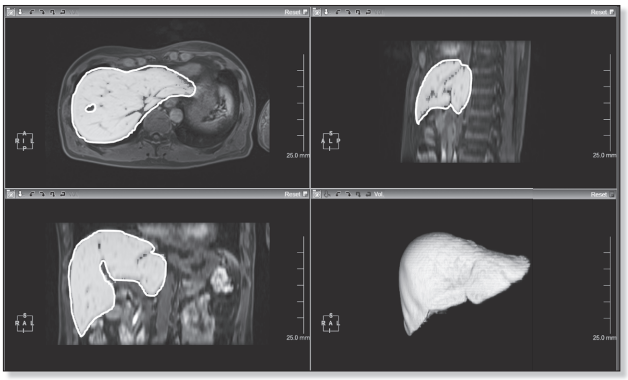

Fig.2 Liver extraction using Virtual Place. Areas within the white enclosure show masked images.

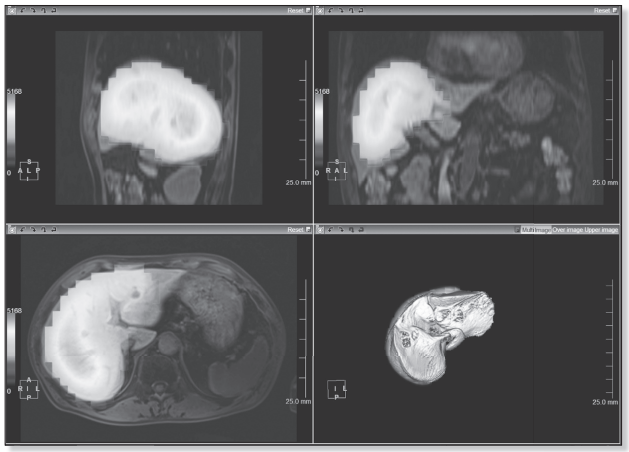

Fig.3 Liver Fusion by Virtual Place; The images were acquired by SPECT and MRI.

and the intra-observer reproducibility was evaluated.

Statistical Analysis

The Friedman test was used to determine the significance of the differences between the SPECT, CT, and MRI measurements. Spearman's rank correlation coefficient and Passing–Bablok regression analysis[22] were used to evaluate the whole liver volumes measured using each modality, based on the best result of the phantom study. Intra-observer reproducibility was evaluated using Spearman's rank correlation coefficient, Bland–Altman analysis, and Passing–Bablok regression analysis. All of the statistical analyses were performed using MedCalc, version 13.1 (MedCalc Software, Mariakerke, Belgium).

Results

Phantom study

The liver volume parameters measured using SPECT, CT, and MRI are shown in Tables 1, 2, and 3. The volumes obtained using SPECT showed a tendency to be underestimated with decreasing voxel size, resulting in values lower than the true value at a voxel size of 0.8 mm. Moreover, as the voxel size increased, the volumes also increased, resulting in an approximately 10% error compared to the true value. The CT and MRI measurements approached the true values when the slice thickness was thin and the pixel size small, and were closest when the slice thickness and pixel size were 0.6 mm and 1 mm, respectively. The volumes were overestimated by CT and MRI when the pixel size and slice thickness were increased.

Clinical study

There were no significant differences in the mean whole liver volumes measured using SPECT, CT, and MRI (1176.3 ± 330.3 cm^3, 1172.9 ± 341.7 cm^3, and 1187.6 ± 334.9 cm^3, respectively; $p = 0.289$) (Table 4). The SPECT and MRI measurements were positively correlated to the CT measurements ($\rho = 0.88$ and 0.99), as demonstrated by the Passing–Bablok regression plots in Fig.4. The mean residual liver volume measurements acquired using SPECT, SPECT-CT fusion, SPECT-MRI fusion, CT, and MRI showed significant differences (511.8 ± 301.0 cm^3, 531.9 ± 266.7 cm^3, 551.9 ± 269.8 cm^3, 555.6 ± 259.0 cm^3, and 558.0 ± 243.3 cm^3, respectively; $p < 0.05$; Table 4 and Fig.5).

Intra-observer reproducibility

The liver volumes (measured twice) are shown in Table 5. The residual liver volumes measured using SPECT, SPECT-CT fusion, and SPECT-MRI fusion showed positive intra-observer correlations ($\rho = 0.88$, 0.91, and 0.97, re-

Table 4 Liver volume in clinical cases.

Segment	SPECT (Non-fusion)	SPECT (Fusion with CT)	SPECT (Fusion with MRI)	CT	MRI	p-value*
Total	1176.3 ± 330.3 (1127.5)	–	–	1172.9 ± 341.7 (1080.0)	1187.6 ± 334.9 (1100.0)	0.289
Right lobe	813.7 ± 246.1 (845.0)	723.8 ± 227.1 (727.0)	731.5 ± 229.8 (758.0)	698.4 ± 249.3 (701.5)	706.3 ± 231.6 (716.5)	< 0.05
Left lobe	362.6 ± 213.2 (287.0)	452.5 ± 261.8 (405.5)	444.8 ± 237.2 (381.5)	474.5 ± 218.3 (418.0)	481.3 ± 213.6 (428.5)	< 0.05
Resection lobe	664.5 ± 327.8 (690.0)	664.4 ± 283.1 (678.5)	624.4 ± 274.8 (687.0)	617.3 ± 257.2 (657.5)	629.7 ± 251.6 (631.5)	0.073
Residual lobe	511.8 ± 301.0 (409.0)	531.9 ± 266.7 (501.0)	551.9 ± 269.8 (502.5)	555.6 ± 259.0 (487.5)	558.0 ± 243.3 (498.5)	< 0.05

(cm^3)

Values are represented as Mean ± SD (Median); SD: standard deviation.
*Friedman test.

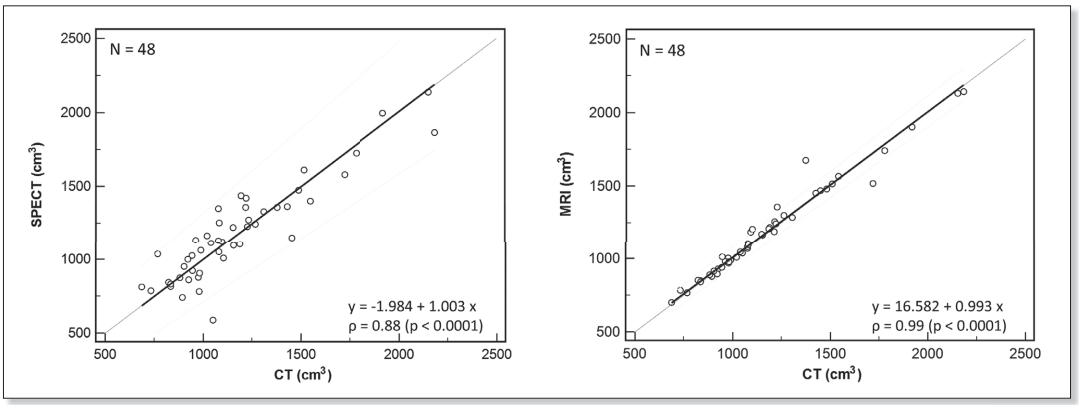

Fig.4 Passing-Bablok regression analysis of total liver volume.

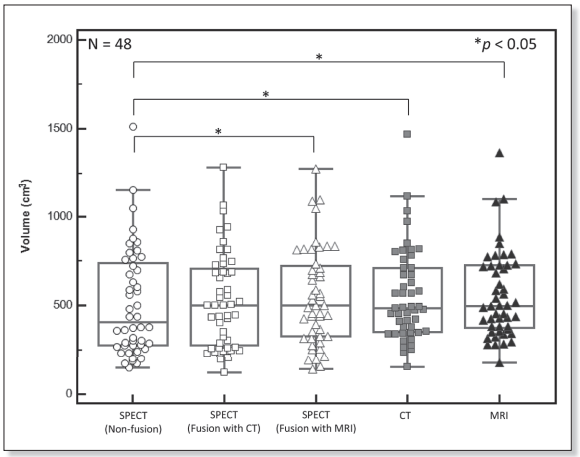

Fig.5 Box plot of residual liver volume in clinical cases.

spectively); the mean differences were -13.7 ± 124.0 cm^3, -38.3 ± 92.3 cm^3, and -4.6 ± 73.5 cm^3, respectively (see Bland–Altman and regression plots in Fig.6).

Discussion

In the phantom study, the volumetric measurements acquired using SPECT were underestimated when the voxel size was 1 mm or less, with a deficiency of count for each voxel. It was, therefore, assumed that a voxel size of 1 mm or more was necessary for volumetric measurement using SPECT. When the voxel size increased, the volumes were overestimated. The resolution ability at the PMMA-solution border changed as the voxel size increased, and the actual solution volume measured was greater than its true value, possibly because of the partial volume effect[23), 24)]. It is necessary to extend the acquisition time in order to achieve SPECT images with quality similar to that of CT or MR images. However, this requires deviation from a realistic examination time. Additionally, it is assumed that the spatial resolution of SPECT is lower than that of CT and MRI. Therefore, we concluded that the volumes were overestimated in the clinical cases. In the CT and MR images, the volumes were overestimated at greater pixel size and slice thickness values. This is similar to the phenomenon observed in SPECT, where the volume varies

Table 5 Intra-observer reproducibility of liver volume in clinical cases.

Modality	Segment	Time 1	Time 2	Mean difference(SD_2)	ρ
SPECT	Right lobe	813.7 ± 246.1 (845.0)	752.3 ± 253.4 (790.5)	61.4 (108.3)	0.92*
(Non fusion)	Left lobe	362.6 ± 213.2 (287.0)	424.0 ± 246.7(359.5)	−61.4 (108.3)	0.87*
	Resection lobe	664.5 ± 327.8 (690.0)	650.8 ± 304.5(688.5)	13.7 (124.0)	0.92*
	Residual lobe	511.8 ± 301.0 (409.0)	525.5 ± 281.7(452.0)	−13.7 (124.0)	0.88*
SPECT	Right lobe	723.8 ± 227.1 (727.0)	684.5 ± 240.0 (725.0)	39.3 (91.9)	0.92*
(Fusion with CT)	Left lobe	452.5 ± 261.8 (405.5)	491.8 ± 241.2 (456.5)	−39.3 (91.9)	0.87*
	Resection lobe	664.4 ± 283.1 (678.5)	606.1 ± 265.8 (618.0)	38.3 (92.3)	0.93*
	Residual lobe	531.9 ± 266.7 (501.0)	570.2 ± 251.8 (527.5)	−38.3 (92.3)	0.91*
SPECT	Right lobe	731.5 ± 229.8 (758.0)	700.6 ± 230.6 (705.5)	30.8 (66.8)	0.92*
(Fusion with MRI)	Left lobe	444.8 ± 237.2 (381.5)	475.6 ± 241.8 (461.0)	−30.8 (66.8)	0.95*
	Resection lobe	624.4 ± 274.8 (687.0)	619.8 ± 259.2 (634.5)	4.6 (73.5)	0.95*
	Residual lobe	551.9 ± 269.8 (502.5)	556.5 ± 261.2 (532.5)	−4.6 (73.5)	0.97*
CT	Right lobe	698.4 ± 249.3 (701.5)	715.5 ± 261.2 (532.5)	−17.1 (59.7)	0.97*
	Left lobe	474.5 ± 218.3 (418.0)	457.3 ± 218.9 (418.0)	17.1 (59.7)	0.95*
	Resection lobe	617.3 ± 257.2 (657.5)	630.9 ± 257.4 (637.5)	−13.6 (60.9)	0.96*
	Residual lobe	555.6 ± 259.0 (487.5)	542.0 ± 253.5 (457.0)	13.6 (60.9)	0.96*
MRI	Right lobe	706.3 ± 231.6 (716.5)	721.5 ± 230.4 (745.0)	−15.2 (36.3)	0.98*
	Left lobe	481.3 ± 213.6 (428.5)	466.1 ± 212.7 (426.5)	15.2 (36.3)	0.97*
	Resection lobe	629.7 ± 251.6 (631.5)	633.3 ± 258.0 (639.5)	−3.6 (39.2)	0.98*
	Residual lobe	558.0 ± 243.3 (498.5)	554.4 ± 248.8 (473.0)	3.6 (39.2)	0.98*
					(cm^3)

A1

Value are Mean±SD1 (Median), SD1: standard deviation, SD2: standard deviation of mean difference.
*p < 0.0001.
A1: Values are represented as Mean ± SD1 (Median); SD1: standard deviation; SD2: standard deviation of mean difference.

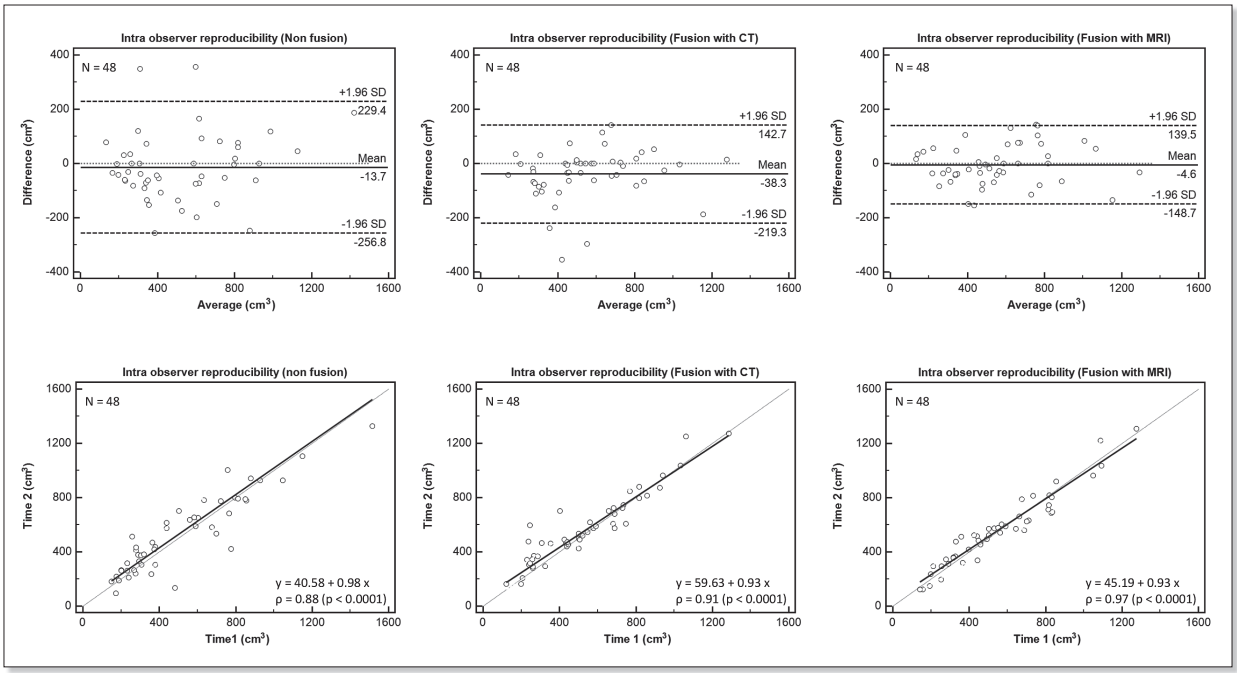

Fig.6 Intra-observer reproducibility of residual liver volume: Bland-Altman plot (above) and Passing-Bablok regression (below); SD = Standard deviation.

greatly with slice thickness. We believe that the influence of the partial volume effect caused this variation, because the resolution ability at the PMMA-solution border decreased as the voxel size increased, and the actual solution volume was greater than its true value[23), 24)]. The volume variable was influenced by pixel size and slice thickness. However, the effect of

pixel size on the volume is lower than that of slice thickness. Therefore, we concluded that the change in slice thickness greatly affected liver volumetry in the clinical cases. Finally, we believed that CT could measure liver volume with greater accuracy than the other two modalities. However, no statistically significant differences were not found between the whole-liver volume measurements acquired using SPECT, CT, and MRI in clinical cases. It is possible that portions of the vessels and bile duct volumes were included in the CT image measurements. It is necessary to recognize this error in liver volumetry. Moreover, owing to the influence of the partial volume effect, a greater liver volume reduction might have occurred in the clinical study compared to the phantom study.

The patients underwent examinations with SPECT, CT, and MRI within a 2-week period. The doubling speed of an indistinct boundary tumor is 106.8 ± 20.9 days[25], and, therefore, we assumed that the tumor size would not change in 2 weeks.

Statistically significant differences were found in the partial volume measurements between the three modalities. The inaccuracy of the volume measurements by SPECT might have influenced results. In addition, anatomical information is scarce for accurate SPECT image evaluation. Therefore, the accuracy of measurement was improved by using a combination of SPECT with CT or MRI. The combination of CT and MRI data did not demonstrate any significant differences in the residual liver volumes. The mean difference of the SPECT volumetric measurements combined with the MR images was less than that of their combination with the CT images. We believe that the accuracy of the fusion measurements was influenced by the differences in the breath pattern during image acquisition between CT (inspiration) and MRI (expiration). We also believe that the image locations obtained by image acquisition during expiration are closer to those obtained during free breath than to those obtained during inspiration.

Study limitations

The cutoff value used in the present study was assumed to be 35% of the maximum count value at scintigraphy, based on a previous study[21]. However, the reconstruction parameters used in this study might have been different from those in the previous study. The previous study performed assessments with attenuation correction, whereas, in the present study, attenuation correction was not performed. Therefore, the hepatic volumes measured using SPECT in the present study might have been overestimated.

Additionally, SPECT examinations of the clinical cases did not include the evaluation of some of the parameters (e.g., voxel size changes from 2.0 mm to 4.8 mm) because such high resolution imaging is not practical in clinical studies. We believe that, had the images been obtained at a higher resolutions, the SPECT-based volumetric measurements might have been more accurate. Additionally, image reconstruction in this study was performed only using filtered back projection; we have not evaluated different reconstruction methods for SPECT since there was no need to consider using a different method in this study.

Conclusion

The combination of SPECT and MR images for the measurement of liver volume could improve the reproducibility of the measurements.

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The Influence of Incubators on Mobile Radiography of Low Birth Weight Infants

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Key words: Mobile X-ray imaging, incubator, low birth weight infants

【Summary】
Mobile X-ray imaging of low birth weight infants is performed with the infant in an incubator. However, the image quality is decreased by the absorption of X-rays by the incubator.

X-ray image quality when using an incubator was estimated using image quality figures (IQFs) with a contrast detail phantom in CR and flat panel detector systems. Furthermore, the air kerma was measured using a silicon dosimeter.

The tube voltage for an infant in incubator needed to be increased by 4–6 kV to reach an IQF equal to that when obtaining an image without an incubator. The air kerma was increased by 4–9 μGy in this situation.

In conclusion, the influence of the X-ray absorption by an incubator is important to consider during mobile X-ray imaging of low birth weight infants.

Introduction

At present, hospital neonatal intensive care units (NICU) use incubators to warm, isolate, and monitor low birth weight (LBW) infants who have difficulty surviving outside the natural environment of the womb[1)-3)]. There are closed and open types of incubators. When X-ray imaging is performed with a closed incubator, a mobile X-ray device is used in order to obtain images with the LBW infant inside the incubator while maintaining proper hygiene. During imaging, an imaging plate (IP) cassette or other type of X-ray detector needs to be placed directly beneath the infant. However, recent closed incubators (hereafter, incubators) have a built-in cassette tray beneath the bed, such that X-ray imaging can be performed without having to lift up the infant. A mechanism that allows X-ray imaging to be performed without lifting the infant reduces unnecessary contact between the infant and the X-ray detector, helping to prevent infections.

However, compared with placing the X-ray detector directly beneath the infant, incubators with cassette trays have led to concerns regarding X-ray absorption by the acrylic hood, sponge mat, plastic bed, and other parts of the incubator. Further, the increased distance between the X-ray detector and infant's body may lead to an insufficient radiation dose when compared with imaging conditions when the X-ray detector is placed directly beneath the infant, potentially resulting in lower image quality. This means that the radiation dose would have to be increased to obtain the same image quality. However, this is not recommended with LBW infants because they are highly sensitive to radiation.

Therefore, we photographed and visually evaluated images obtained of a contrast-detail (C-D) phantom to investigate the effects on image quality.

We also used a silicon dosimeter with a water-equivalent phantom to measure air kerma to examine the effects of different imaging conditions.

1. Methods

1-1. Visual evaluation of the C-D phantom

A mobile X-ray device (Sirius Star Mobile 130HP, Hitachi Medical Corp.) was used to obtain the materials for visual evaluation. The closed incubator (V-2100G HL B, Atom Medical Corp.) used in this study has a plastic X-ray cassette tray underneath the LBW infant bed. This tray is pulled out to insert an IP cassette, flat panel detector (FPD), or other device (Fig.1). For this study, we reproduced imaging conditions by removing only the cassette tray and sponge mat. The acrylic hood was simulated using a 5-mm acrylic board.

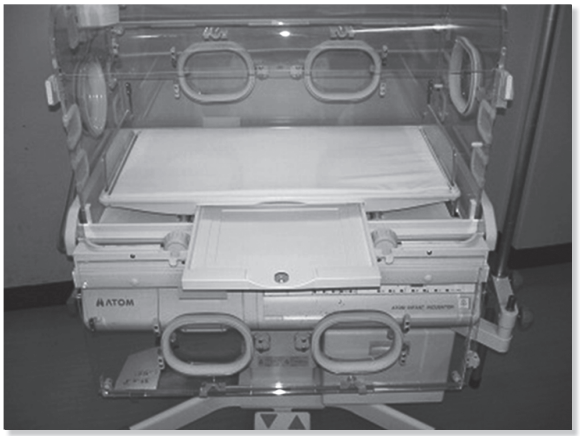

Fig.1 Incubators that are used in our hospital (pull-out cassette tray)

A CR system (IP: ST-VI, IP reader FCR PROFECT CS Plus, Fujifilm Medical) and FPD system (CALNEO C mini Wireless SQ system, Fujifilm Medical) were used for the X-ray detectors.

The C-D phantom (Kyoto Kagaku Co.) used for the visual evaluations had signals (concave signals) of diameters ranging from 0.3 to 8.0 mm in 15 steps and depths from 0.3 to 8.0 mm in 15 steps. For the three largest diameters, there was a single signal in the center, similar to conventional C-D phantoms. However, four-point selective C-D phantoms were used for the remaining signals, comprising a signal in the center and in one of the corners. Two different arrangement patterns were used in the C-D phantom[3)-4)].

1-1-1. Sample preparation

To simulate the geometric arrangement of the incubator, imaging was performed with an IP cassette placed directly beneath the C-D phantom and with it placed in a cassette tray (Fig.2). When the cassette tray was used, an acrylic board of the same thickness as the incubator's acrylic hood was placed between the X-ray tube and acrylic phantom. With both the CR and FPD systems, imaging was performed with a tube current-time product of 2.5 mAs and tube voltage from 46 to 58 kV in 2-kV intervals. To ensure the C-D phantom's holes did not warp, the distance between the focal spot of the X-ray tube and the X-ray detector was set at 120 cm.

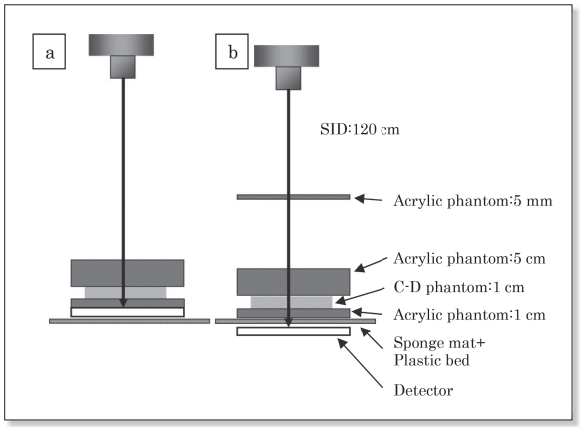

Fig.2 Experimental design for contrast detail measurement.
a) Direct measurement
b) Measurement using a cassette tray

1-1-2. Visual evaluation method

The samples were observed on medical-use liquid crystal displays (RadiForce RX340: EIZO). The brightness was fixed, but the assessors could observe the samples at any distance and for as long as they wanted. The evaluations were performed independently by five radiologists. Each assessor recorded the depth at which each signal size in the C-D phantom could be recognized with 50% confidence. Diagrams of the mean C-D were created for each

imaging condition and then compared. Image quality figures (IQFs) were calculated from the mean C-D diagrams to compare the IQF between imaging conditions[4)-5)].

1-2. Air kerma measurement

The same mobile X-ray device was used to measure the radiation dose with a silicon dosimeter (Unfors Xi: Toyo Medic). An R/F detector was used as the radiation detector (Fig.3).

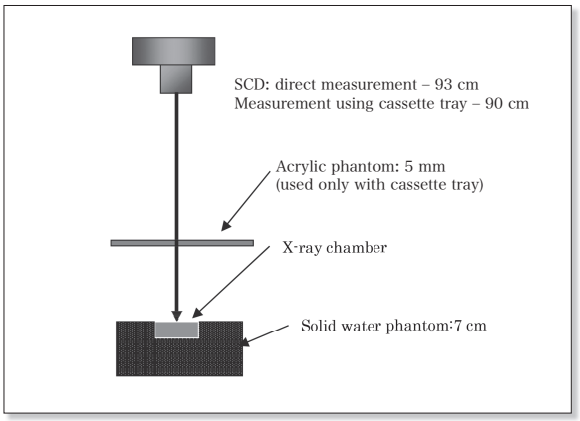

Fig.3 Air kerma measurement method

1-2-1. Air kerma measurement method

The distance between the X-ray tube focal spot and X-ray detector was set at 93 cm (90 cm with the cassette tray). The dosimeter was placed on the surface of a 7-cm thick water-equivalent phantom. A 5-mm thick acrylic board was placed 20 cm from the dosimeter to simulate the incubator's acrylic hood. Irradiation was performed under the same imaging conditions as for the visual evaluations (Fig.3).

2. Results

2-1. Visual evaluation of the C-D phantom

Figs.4 to 7 show the results of the visual evaluations of the C-D phantom when it was placed directly underneath and when using the cassette tray. Discrimination contrast of the C-D phantom decreased when the cassette tray was used with both the CR and FPD systems.

The IQF was, on average, 13% and 12% higher with the CR system and FPD system, respectively, when the cassette tray was used compared with when it was placed directly un-

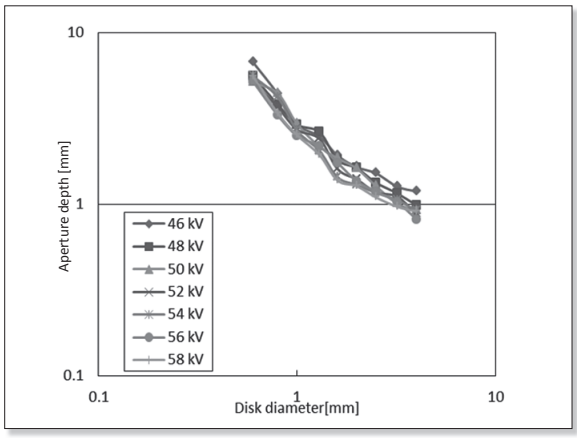

Fig.4 Contrast detail curves of images acquired using direct measurement with the CR system.

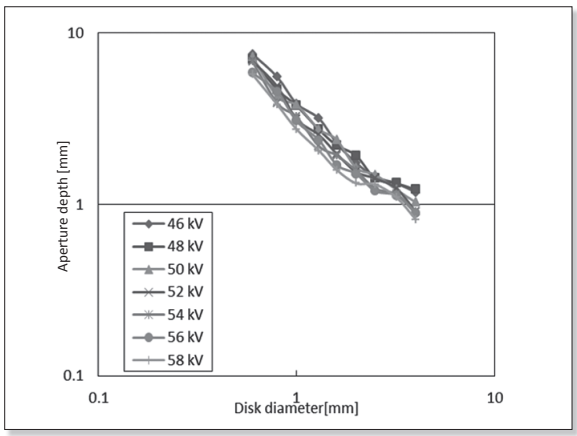

Fig.5 Contrast detail curves of images acquired using the cassette tray with the CR system.

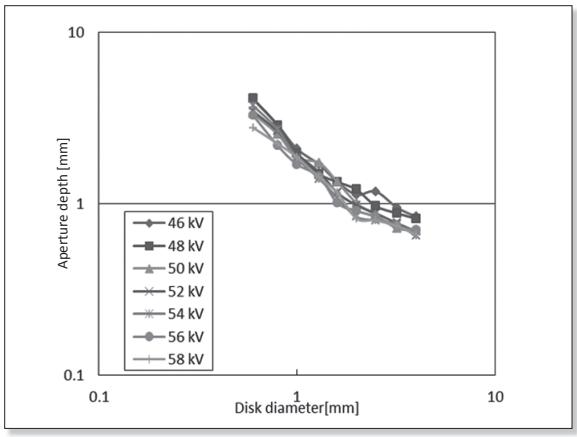

Fig.6 Contrast detail curves of images acquired using direct measurement with the FPD system.

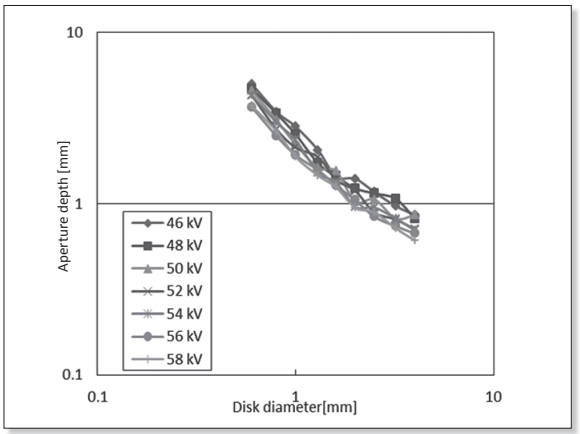

Fig.7 Contrast detail curves of images acquired using a cassette tray with the FPD system.

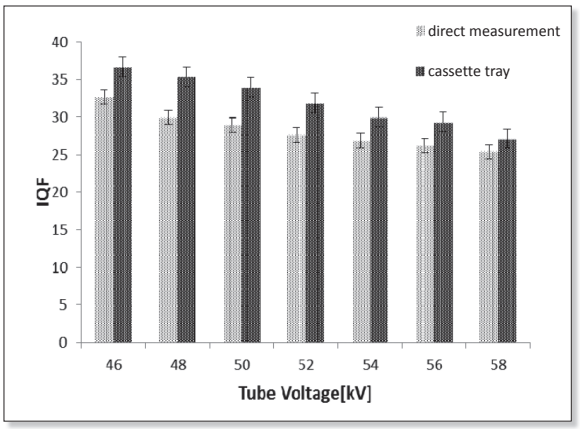

Fig.8 IQF of images acquired using the CR system.

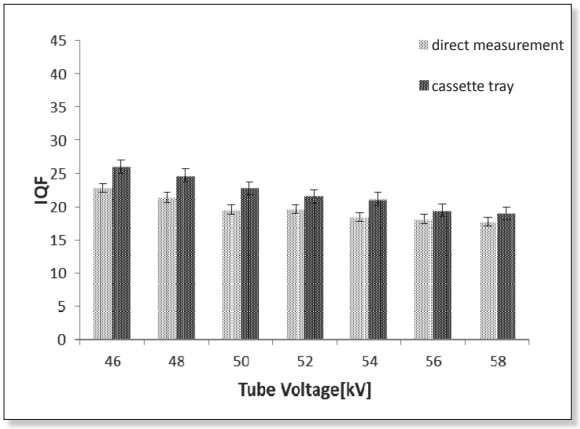

Fig.9 IQF of images acquired using the FPD system.

derneath, indicating poorer image quality (Figs.8, 9). The IQF was, on average, 30% lower with the FPD system compared with that of the CR system, indicating superior image quality.

2-2. Air kerma measurement

The tube voltage had to be increased by 4 to 6 kV to obtain the same image quality using the cassette tray as when it was placed directly underneath. This increased the air kerma by about 4 to 9 μGy (Fig.10).

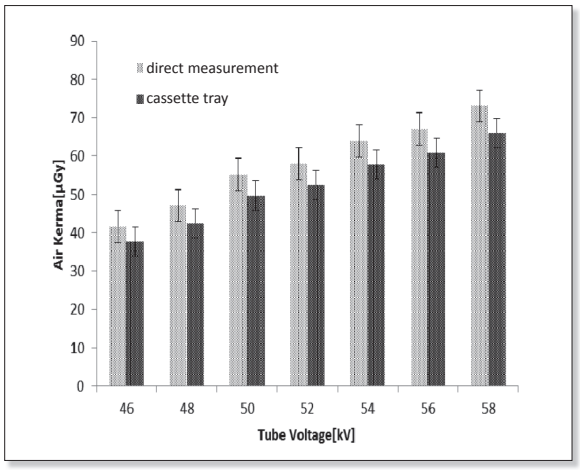

Fig.10 Air kerma measured using a silicon dosimeter at different tube voltages.

3. Discussion

LBW infants have low adaptability, so great care needs to be taken when imaging infants in incubators. When an incubator's built-in cassette tray is not used, the infant has to be lifted up so the X-ray detector can be placed underneath. Coming into contact with an unhygienic X-ray detector increases the risk of infection. To reduce this risk, it is preferable to use an incubator with a built-in cassette tray during imaging. However, this creates problems with X-ray absorption and increases the distance between the X-ray detector and LBW infant. The effects of these issues have not been clarified.

In this experiment, we found that to obtain the same image quality when using a cassette tray as that obtained when the X-ray detector is placed directly underneath the infant, the tube

voltage had to be raised by 4 kV, which increased the radiation dose, leading to greater radiation exposure. Based on a proper understanding of these issues, incubators should be made from materials that have low X-ray absorbencies.

Moreover, the FPD system exhibited superior detectability of the C-D phantom signals than the CR system. The FPD system has better detective quantum efficiency (DQE) than the CR system, which leads to better signal detectability with the same dose[6]. Replacing CR systems with FPD systems could both improve image quality and reduce radiation exposure.

As Figs.8 and 9 show, increasing the tube voltage to deal with X-ray absorption by the incubator body decreased IQF, i.e., improved image quality. However, Fig.10 shows that raising tube voltage by 4 kV increased the radiation dose by about 4 μGy. Thus, it is important to minimize radiation exposure in each imaging session.

4. Conclusion

We used a C-D phantom to visually evaluate the effects of an incubator on the mobile X-ray imaging of LBW infants. The results showed that to obtain the same image quality when using a cassette tray inside the incubator as that obtained when the X-ray detector is placed directly underneath the infant, the tube voltage had to be increased by 4 kV, subsequently increasing the air kerma by 4 μGy.

It would be best to design incubators that use materials with low X-ray absorbency.

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