2020

Journal of

JART

—English edition—

2020

The Japan Association of Radiological Technologists

Journal of JART —English edition— 2020
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.

Regarding Publication of the English Edition

Yasuo Nakazawa (President)

Reflecting on the activities of 2019, we conveyed the policies of the Japan Association of Radiological Technologists by dispatching committee members to events such as the Ministry of Health, Labour and Welfare's "Investigative Commission for Revising Radiation Exposure Limits of Eye Lenses," the "Investigative Commission for Improving the Curriculum of Medical Radiologic Technologist Schools," and the "Investigative Commission for Promoting Task Shift/Task Sharing to Encourage Physician Workstyle Reform." We have communicated the activities of these committees to our organization members through our journal. *The journal of the Japan Association of Radiological Technologists* (JART) has a monthly circulation of around 30,000 copies, and has been well received by our members and the public.

To give our radiological technologists from across the globe an insight into our business, I will briefly explain the history of JART. In March 1896, we succeeded in taking the first X-ray image in Japan. In 1897, Shimadzu Corporation released an X-ray generator for educational use. In 1925, there were approximately 1,500 X-ray technicians. In 1927, the first Shimadzu X-ray Technician Training Institute was established, and evidence-based education was put in place. JART was founded in 1947 to make "radiological technologist" a national qualification. Since its establishment, we have worked towards broad acceptance of this national qualification, in collaboration with the government, the Diet, the Japanese Medical Association, and occupational military authorities.

As a result of our blood, sweat, and tears, in June 1951, we were finally able to see the promulgation of the Radiology X-ray Technicians Act, Act No.226 of 1951. Since then, we have responded to the changing needs of the society, revising the original act to get the Radiology X-ray Technicians Act of 1968 passed, and partially revising that to get the Radiology Technicians Act and Radiology X-ray Technicians Act of 1983 passed, and finally getting the Radiology Technicians Act, which is in place currently, passed. Back then, the scope of work was limited to general X-ray testing, television X-ray testing, angiography, X-ray computed tomography scanning, RI scanning, and radiation therapy. In 1993, the Radiology Technicians Act was further revised, and MRI scanning, ultrasonic testing, and non-mydriatic fundus camera examination were added to the list. In 2010, image interpretation assistance, radiation examination explanation, and consultation work were added. In April 2015, intravenous contrast agent injection using automated contrast injectors, needle removal and hemostasis, lower digestive tract examination (anal catheter insertion and administration of contrast medium), anal catheter insertion, and oxygen inhalation during radiation therapy were further added as new operations that could be performed by radiological technologists.

JART will continue to respond to the needs of the medical industry, and we hope to broaden the operational scope of radiological technologists based on our foundation in scientific evidence. We will feature clinical, educational, and research-based achievements by radiological technologists in the monthly issues of the JART journal, and continually work to improve the magazine. I truly hope that this English edition will benefit radiological technicians worldwide.

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

2017

- Event to mark the 70th anniversary of founding and transition to a public interest incorporated association (June 2)

2018

- Notice from the Regional Medical Care Planning Division Director, Health Policy Bureau, Ministry of Health, Labour and Welfare, and Director of the Economic Affairs Division regarding Operational Considerations for Securing a System for Safety Management pertaining to Medical Equipment

2019

- Notice from the Health Policy Bureau on a Safety Management System for Medicinal Use of Radiation

Note: This article is secondary publication, the first paper was published in the JART, vol. 67 no. 807: 44-55, 2020

The 35th Japan Conference of Radiological Technologists

Invited lecture

Current Status of Post-Primary Credentials: Benefits versus Disadvantages

Dr. Michael D. Ward, Ph.D., RTR, FASRT, FMoSRT
Former President of ISRRT
Vice Dean for Student Affairs & Diversity and Professor
Goldfarb School of Nursing at Barnes-Jewish College
St. Louis, Missouri
United States of America

【Abstract】

Over the decades, in the United States, the radiologic sciences have grown beyond the disciplines of radiography, nuclear medicine and radiation therapy. There have been new developments and advances in technology and improvements in medical imaging and radiation therapeutics. We now have five "**primary**" categories of certification and registration which include, radiography, nuclear medicine technology, radiation therapy, magnetic resonance imaging, and sonography.

In 1922, the American Registry of X-Ray Technicians (later the American Registry of Radiologic Technologists – ARRT) came into being with the collaboration of its founding societies – the Radiological Society of North America (RSNA), the American Roentgen Ray Society and the American Society of X-Ray Technicians (later the American Society of Radiologic Technologists – ASRT). By the end of the 1930's there would be more than 2,400 Registered Technologists.

In 1962, the Registry expanded its program of examination and certification by adding exams in nuclear medicine technology and radiation therapy. By the end of the 1960's, ARRT would boast a total of 56,000 certificates – some 700 in nuclear medicine and nearly 300 in radiation therapy. The decade of the 1990's saw a sweeping expansion of ARRT's offerings. The new **post-primary** category was launched with certification in cardiovascular-interventional technology and mammography. New disciplines were added as technology emerged. By 2019, more than 337,000 Registered Technologists, known as "R.T.'s" attest to the success and strength of the American Registry of Radiologic Technologists.

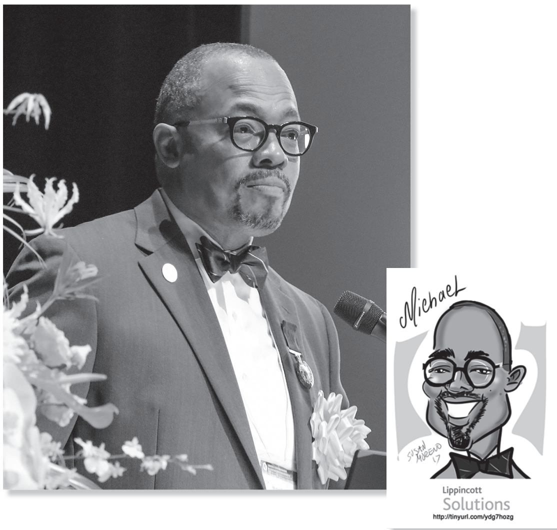
The mission of the ARRT is to promote high standards of patient care by recognizing qualified individuals in medical imaging, interventional procedures, and radiation therapy. The ARRT offers a post-primary category of certification and registration in mammography, computed tomography, quality management, bone densitometry, cardiac-interventional radiography, vascular-interventional radiography, cardiovascular-interventional radiography, vascular sonography and breast sonography. The ARRT also offers certification and registration for radiologist assistants.

Besides broadening the career ladder and advancement opportunities in the medical imaging and radiation sciences, technologists typically see increases in salaries and expansion in technical competencies and skills. Additional benefits and advantages will be discussed during this presentation. Whenever advances take place in a profession, there could be a downside or disadvantages that come along with those changes. One of those could be described as a "fragmentation of the profession" and "loss of identity" due to the vast array of titles as viewed by the general public.

The role of the Registered Radiologist Assistant along with the scope of practice, general competencies, and basic salary will be discussed. As time permits, we will discuss transferability of credentials into the United States from the international community.

Chair Person, Nakazawa:

So just from now on, we will hold an invited lecture. The presenter is the Former President of International Society of Radiographers and Radiological Technologists whose name is Dr. Michael Ward. But first, I will introduce his history a little. Dr. Ward is the Vice Dean for Student Affairs and Diversity & Professor for Goldfarb School of Nursing at Barnes-Jewish College in St. Louis, Missouri. At the national level, Dr. Ward has served as Vice-President, President and Chairman of the Board of the American Society of Radiologic Technologists. In June of 1988, he was elevated to Fellow of the ASRT. ASRT awarded Dr. Ward with the highest honor, that of Life Member in June 2011. In its 90 plus year history, only 21 other members had been given this honor at the time of his recognition. On September 7, 2010, Dr. Michael D. Ward was elected the 13th President of the International Society of Radiographers and Radiological Technologists (ISRRT) at the meeting held in Gold Coast, Australia. He was first American to serve in that position, which



came with a four years term of office. Prior to assuming the ISRRT Presidency, he served seven years on the board as the Regional Director for the Americas. Dr. Ward has served on and chaired numerous committees and commissions and has been very active in local, state, national, and international radiologic science organization. His personal motto is to “Always Strive Towards Excellence.” Then, talk to about current status of post-primary credentials, benefits versus disadvantages. Dr. Michael Ward, please start.

Dr. Michael D. Ward:

Thank you very much. First of all, I want to thank everyone for coming out this morning. I know you have had a very busy morning so far and to come and hear me, it brings me great pleasure. So, thank you. I am very happy to be here for the 35th Japan Conference of Radiological Technologists. And I want to thank my dear friend, Dr. Nakazawa, President of the Japan Association of Radiological Technologists, and Mr. Tanaka, the conference coordinator, for this invitation.

I want to first distinguish between the two essential players in the radiological sciences in the United States (Fig.1). The ASRT, the American Society of Radiological Technologists is the membership organization that was founded in 1920. It is the professional membership society with its mission to advance the medical imaging and radiation therapy profession and to enhance the quality of patient care. The ASRT has over 150,000 members. So, the ASRT is the professional organization. The ARRT is the American Registry of Radiologic Technologists. It was founded in 1922 and it was established as the professional certification organization. So, they are the ones that write the exam for people to become registered or certified in the United States. And the ARRT has over 350,000 registered technologists that they are responsible for. For the purposes of this presentation, I will focus on the ARRT, the American Registry of Radiologic Technologists, as the credentialing organization. The ARRT establishes the education standards for certification.

All candidates for certification must graduate first from an accredited educational program that is recognized by the ARRT and since 1930, the number of certified technologists has grown. In 1930, there were 2,400 certified technologists; in 1962, that grew to 56,000 registered technologists; in 2012 that grew even greater to 325,000 certified technologists; and today, the ARRT has 340,000 certified

Fig.1

radiographers or certified technologists that are credentialed through the ARRT (Fig.2). In 1922, the ARRT offered only three primary categories for certification: radiography, nuclear medicine and radiation therapy. Today, there are five primary categories in the United States: radiography, nuclear medicine, radiation therapy, magnetic resonance imaging, and sonography (Fig.3). Each one of these five primary categories has accredited programs that prepare individuals to become one of these particular categorized professionals. The students that graduate either come out with certificates or they may be graduating from a degree program. I will say more about that later.

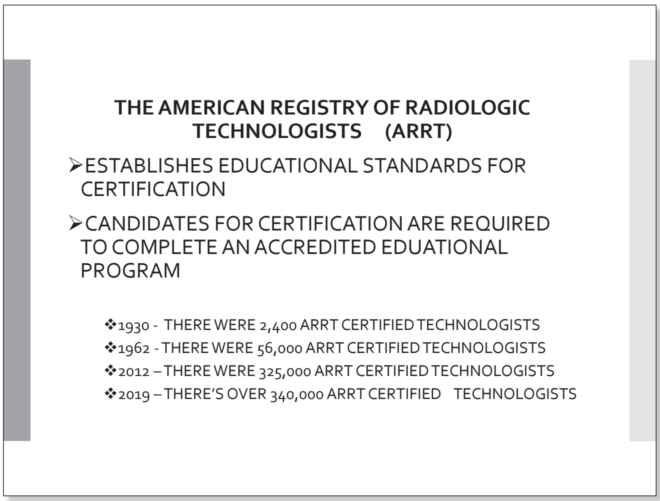


Fig.2

In the 1990s, the ARRT expanded their offerings by developing post-primary certifications and, as the name implies, post-primary, the 10 certifications must be achieved after one of the five primary certifications (Fig.4). So, for example, in order for someone to become a mammographer, they first must be a radiographer. So, these that I have listed here, mammography, computed tomography, magnetic resonance imaging, bone densitometry, cardio-interventional radiography, vascular-interventional radiography, sonography, vascular sonography, breast sonography, and the physician extender or radiologist assistant. All where it can be one of these post-primary, you must have one of the five primary credentials first.

When I entered the radiologic technology profession in the mid-70s, in 1970, I began as a certified radiographer. So, my background is in diagnostic radiography. There were limits on advancement opportunities when I graduated from school. There are many more now. But if you wanted to advance in the profession, you had to go into teaching, management, or perhaps special procedures. The number of years on the job was just about the only way to advance in salary or to expand your technical skills. So, it was just a matter of what you knew and how long you worked in the profession

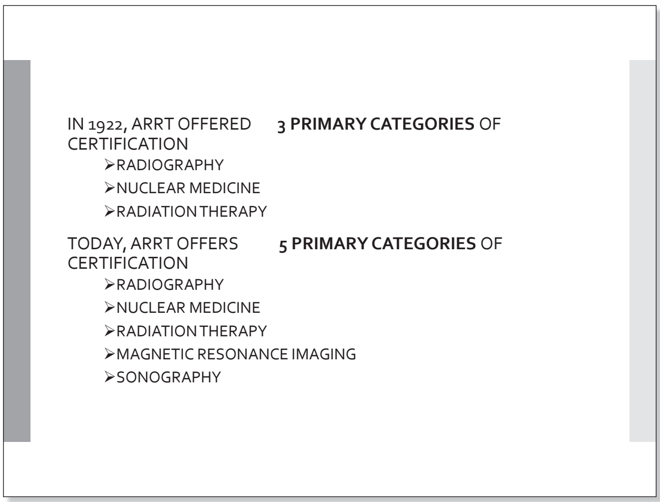


Fig.3

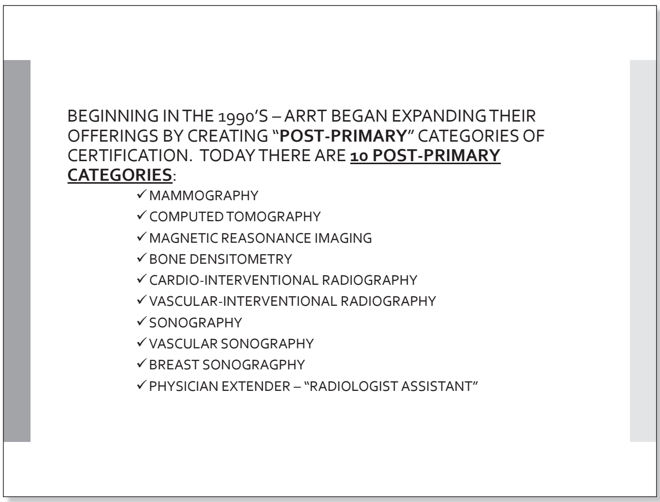


Fig.4

in order to raise up to advanced levels. But with post-primary certification, it has greatly enhanced the radiologic technologist's career ladders, so there is many more opportunities for us as technologists to advance into other modalities in the United States (Fig.5). There is a precise method to create new certification specialties in the United States.

So, in order to establish new certification categories, these have to include a practice or job analysis that must be conducted (Fig.6), where they review every entry-level job responsibility, they will monitor and then look at what tasks are involved with that particular job. They will identify the basic knowledge and skills required in the particular job category, then the specific educational and clinical requirements have to be established, and then the certification examination content, specifications have to be developed in order to meet the criteria for establishing a new credential, and then finally, the training material, the curriculum, the job descriptions, and even the performance tools have to be created. So, there pretty much a greatly involved step, many steps in order to create a new certification credential.

Take a look at the average pass rates for the primary and post-primary certifications in the United States, and these data come from 2017. So, for example, in 2017 (Fig.7), 11,166 students took the certification exam in radiography, with an 89.3% pass rate. For nuclear medicine, a much smaller number of people took the exam, only 379, but the pass rate was 88.7%. In radiation therapy that same year, only 807 students graduated and took the certification exam in radiation therapy with the pass rate of 88%. And you can see the other post-certification pass grades. The largest was in computed tomography were 6,423 individuals took the exam, followed by MRI were 2,649 took the exam, then mammography with 1,595, but you will notice

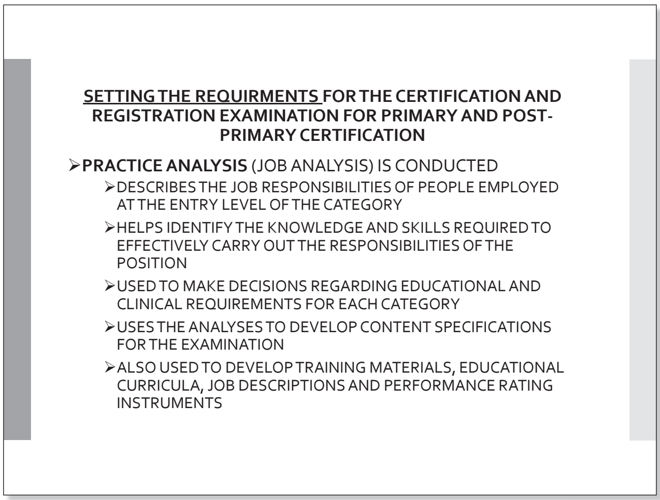


Fig.6

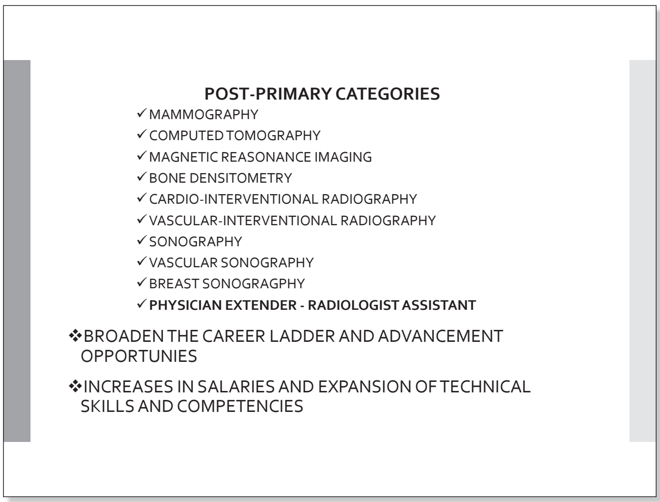


Fig.5

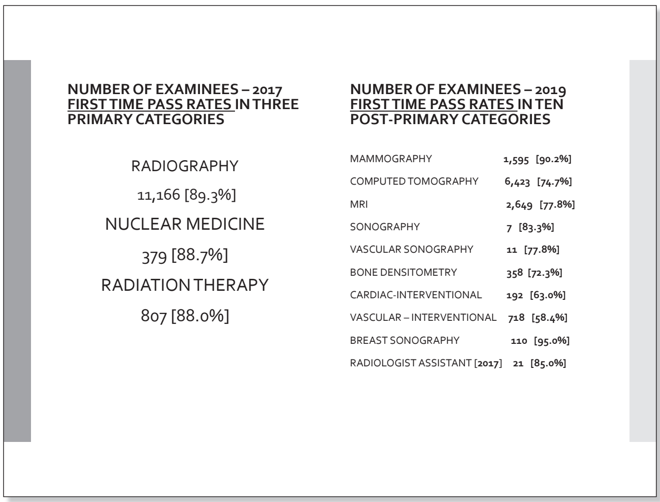
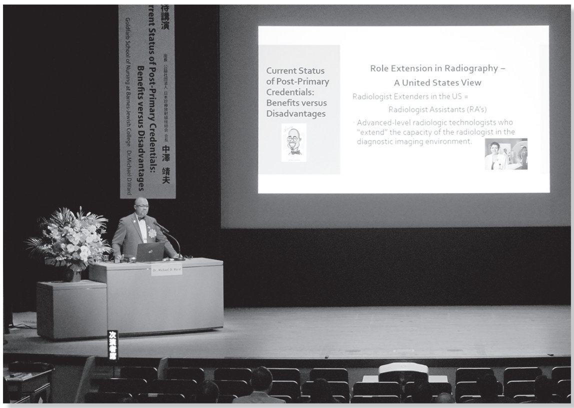


Fig.7



that at the very bottom, only 21 individuals took the radiologist assistance examination. So, there is a smaller number of individuals being prepared to become, at least at this time, radiologist assistants, and I am going to spend some time speaking more about that particular classification and the job responsibilities. It might be interesting just to know the salary or the annual compensation for technologists of the various sorts in the United States. So, I took a sample just before I left to come here to give you an idea of what the salaries are like (Fig.8).

For radiographers, you will see that the average salary is $57,865. And just to give you a comparison, 1 dollar in US is 108 yen today; I looked it up before I came this morning. So

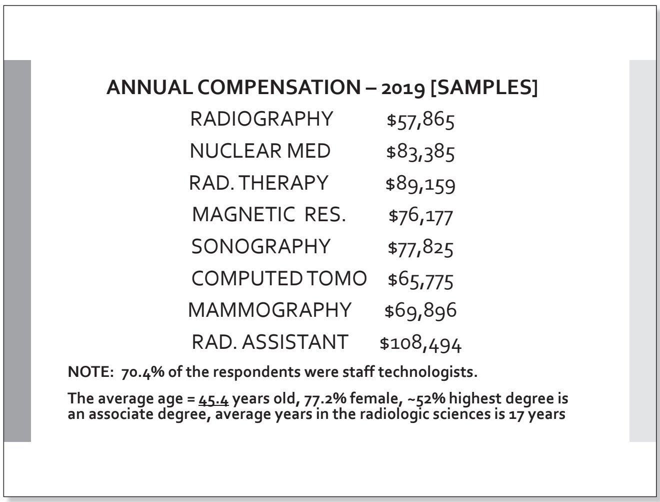


Fig.8

that is the rate of exchange. And you can see the rest of the salaries. It looks like the highest is radiation therapy, 89,159, and the radiologist assistants is 108,494 dollars. So that is just the average salary. If you have been in the field much longer time, the salary is higher than that. But I just wanted to give you a sense of the differences. When they did this survey in this past year, 70.4% of those surveyed were staff radiographers, so the largest number that participated in the survey were technologists. The average age was 45.4 years old, 77.2% were female, about 52% had their highest degree at the associate's degree level, and I am just telling you for a moment, in the United States, there are several routes that one can take in terms of their academic levels to become a diagnostic radiographer. You can graduate from a hospital and get a certificate. You can graduate from a two-year degree program and have your associate degree.

A four-year program will offer you the baccalaureate degree and then beyond that, technologists will have the master's degree and fewer technologists will have their doctorate degrees. But most of those that pursue a doctorate degree are either going teaching or research, and some are in management roles. So, my particular degree is a PhD in higher education administration. So, it is not in radiologic science, but my desire was to be in higher education, to work as a professor and a dean in a college and university. So that was the direction that I personally pursued.

I am going to spend a little bit more time focusing just on the radiologist assistant or in the US they may be referred to as a radiologist extender. They are advanced - level radiologic technologists who have advanced or enhanced patient care but that enhance patient care by extending the capacity of the radiologist, the physician, in the diagnostic imaging environment. So, radiologist assistants have been around in the United States for the last 10 years. But I would say that more and more, they are becoming a vital part of the radiologic team in hospitals and clinics across the United States. Radiologist assistants must first be credentialed as a registered radiographer through the American Registry of Radiological Technologists or the ARRT (Fig.9). So, this is a post-primary credential. They are experienced radiographers who have completed advanced academic studies through an accredited radiologist assistant program that utilizes the nationally recognized curriculum. So, there is a very specified curriculum for the RA candidates. They must complete an extensive clinical preceptorship directed by a radiologist. So, they are very closely connected with working with the radiologists in this particular role.

Upon completion of the program, the students then take the RA certification exam that is offered by the ARRT and once they become a registered radiologist assistant, they must continue their education. So most of us that are coming to conferences like this realize that just because we may have graduated from school 3, 5, 20 years ago, or 40 years ago like me, we still have to keep our educational standards up and keep our knowledge up

because the technology and our radiologic science is advancing day after day. Before coming here, I had a chance to sit in on three lectures upstairs or in the other building with technologists that presented on a number of categories. And I just have to say that the quality of the presentations that I have come to hear, when I have been to Japan, this is my third time, are very high level. So, you should be very proud of yourself for what you do here for keeping the Japanese technologists up to speed. So, I salute you for doing that.

This is a quick, very high-level summary (Fig.10), the addition of RAs to the radiology team helps improve productivity and efficiency at the time when the demand for medical imaging services is soaring. In the United

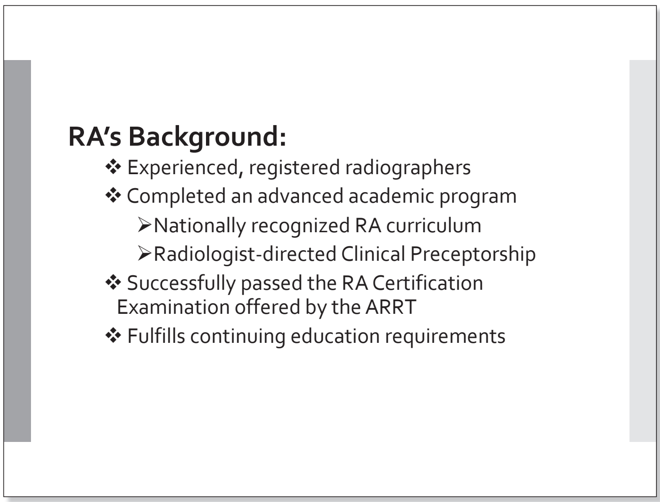


Fig.9

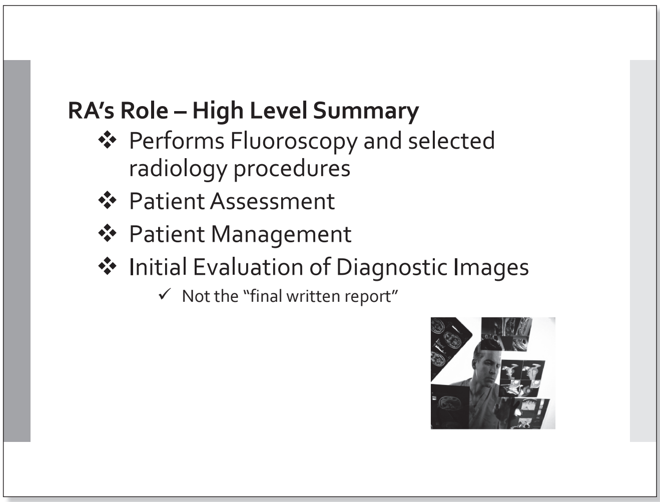


Fig.10

States, the number of requests for radiology services is going up so high. So, I would say especially for those services that are provided by the radiologists, the radiologist assistants are vital to making sure that they are very efficient. The RA works under the supervision of a radiologist to provide direct patient care. They perform fluoroscopy and selected radiology procedures, patient assessment, patient management, and the initial evaluation of the diagnostic image. However, in the United States, the RA does not provide the final or the official interpretation or the final written report and that is provided by the radiologist. The radiology department team overall benefits by having RAs available. For example, the average radiologist workload in the United States was 14,900 procedures. This has been an increase of 7% between 2002 to 2003 and 34% increase since 1991 and 1992 (Fig.11). So again, the number of procedures that have been asked for in radiology has increased and the workload of the radiologist is vastly increasing. So, in this case, the radiologist assistant can relieve the workload of the radiologist by performing exams that the radiologist is not always available to perform, increase productivity by freeing up radiologists to perform the more invasive procedures that are not within the RA scope of practice, improve efficiency by allowing radiologist to spend more time on image interpretation and diagnosis, and improve patient access to timely radiologic care by expanding workflow and capacity. So, the radiologist assistant is the professional that can step in for the radiologist, let them do other exams, and the radiologist assistant can take on a lot of the work that the radiologist would have been doing in the past.

The major responsibilities for the radiologist assistant is to take a leading role in patient management and assessment. Again, perform selective radiology examines and procedures under the supervision of a radiologist. And then again like I said evaluates it for image quality, makes the initial image observations and forwards those to the supervising radiologist (Fig.12). The RA, I think many of us as medical imagers are those that have been taking x-rays for a long time become very good at looking at images, not just for quality, but we can make, a lot of us are able to make an initial diagnosis. We do not ever say anything, but we know when we are looking at a chest x-ray that has a density in this area, we pretty much know what it most likely is. But the RA, the radiologist assistant, takes it a little bit further and through differential diagnosis will come up with the initial findings on those

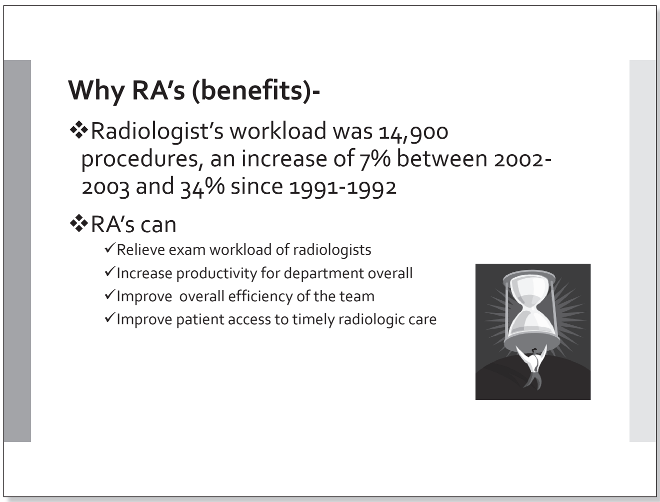


Fig.11

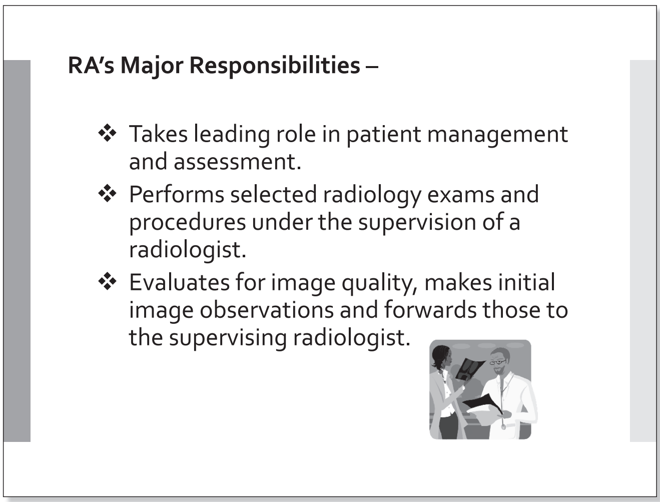


Fig.12

images, but the radiologist, again, does the final interpretation. The radiologist assistant educational requirements, there are different RA programs (Fig.13).

Most of them in the United States are at the master's level, but there are very few that are at the baccalaureate level. But minimally, they must graduate with a bachelor's degree. The majority of the programs, they are masters. The length of the programs is anywhere between two to two and a half years, and the clinical portion of their training and their education is at least a year and a half or 18 months. So, there is a very large component of clinical work that is required to become an RA. The RA programs require instruction in systematically evaluating static and dynamic images for normal anatomy and physiology. They look for normal variants as well as variations in appearance that may indicate pathology. Most of us, I would say for radiographers, we can look at an image and see a change in density or notice something that looks pathological, but the radiologist assistant goes through more education and experience in the actual interpretation of what those changes may be looking like. So, it is a little bit more than just recognizing a change, it is actually going through more, again, differential diagnosis.

This is the listing of the core courses that make up the curriculum for an Accredited Radiologist Assistant Program in the United States (Fig.14). As you can see, the range of courses is quite comprehensive and focused on advanced topics from patient assessment and patient management, clinical decision making, radiation safety and radiation biology, it has correlation with anatomy and pathology, legal and professional standards, all of this accumulates with extensive time with the radiologist acting as a mentor and supervising the clinical experience. So, the way I look at it is that those that are in the RA programs are pretty much similar to a full-time fellow radiologist, so they are almost like sitting with the radiologist as a trainee to be a radiologist. But the RA is right there with the radiologist looking at the images and listening to the diagnosis and being consulted when the radiologist is making that final diagnosis.

In practice, radiologist assistants perform a wide range of patient care activities and radiographic procedures (Fig.15). Much of this will have a lot to do with the type of experiences they have during the radiologist preceptorships and the type of practice that is run by the radiologist. So, these are the kinds of things that the RA will participate in,

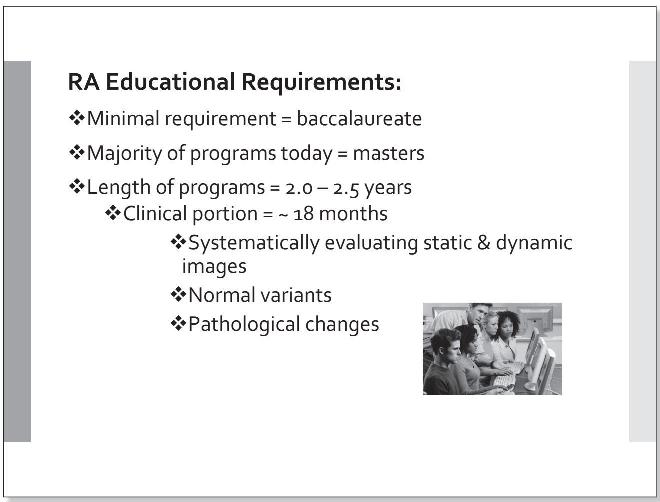


Fig.13

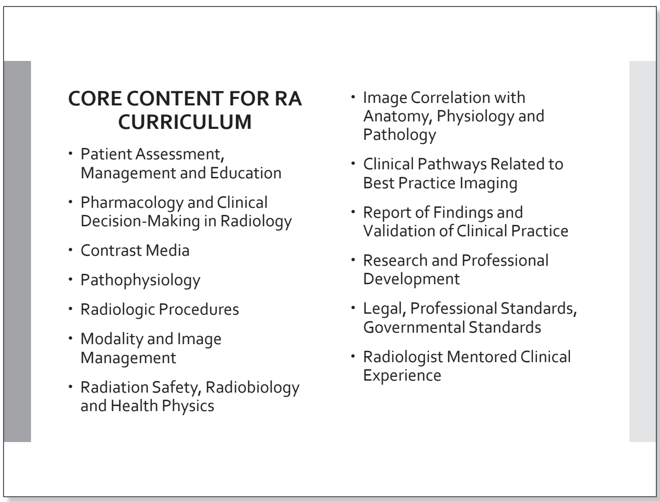


Fig.14

taking histories, doing physical exam, they will be very active in patient follow up, they will evaluate our laboratory work that is run on the patient, and they will consult with the patient to talk them through the procedures that they are going to be performing. And these are the kinds of procedures that many of our RA colleagues are involved with: lumbar punctures, GI studies, arthrogram studies, venograms, arteriograms, thoracentesis, cystograms, feeding tube placement, they will be right there to help interpret CT exams of the head and body, MRI exams of the head and body, and much, much more. So, depending on the practice of the radiologist, the radiologist assistant will be right there with them participating in the doing the procedures, following up on the procedures and then finally, giving their first initial review of the findings for those procedures.

In the United States, we have 50 states and each one of those states has the ability to come up with the requirements for licensure for their particular state (Fig.16). If you go to United States, we all do not do the same thing the same way. So, I am from St. Louis, Missouri side, I live in the state of Missouri, but the other 49 states can have laws that are different than the way that we license or recognize these radiologist assistants. So, I will tell you that 31 of the 50 states currently license and recognize radiologist assistants. State laws or procedures determine RA scope of practice. So again, the scope of practice can be slightly different depending on what state the RA is working. So that can be a little bit of a problem if an RA wants to travel from one state to the next, they need to make sure that if they want to leave California and go to Texas, that the regulations in Texas are satisfactory for the kind of practice that they want to do when they move there.

So unfortunately, whilst the RA increases access of care for patients, especially in rural areas, by allowing radiologists to work in a more productive manner, so we are finding that RAs get to practice at a higher level in more rural communities, communities that do not have as many physicians or radiologists. Unfortunately, though, there are still limitations in some states that limit the ability for RAs to fully and effectively practice. And this unfortunately can have a bit of an adverse effect on patient care. This is one of the problems that we have in the United States for RAs. But at the federal level, we have what is called the MARCA or the Medicare Access to Radiology Care Act and this is a federal legislation that widely supports for

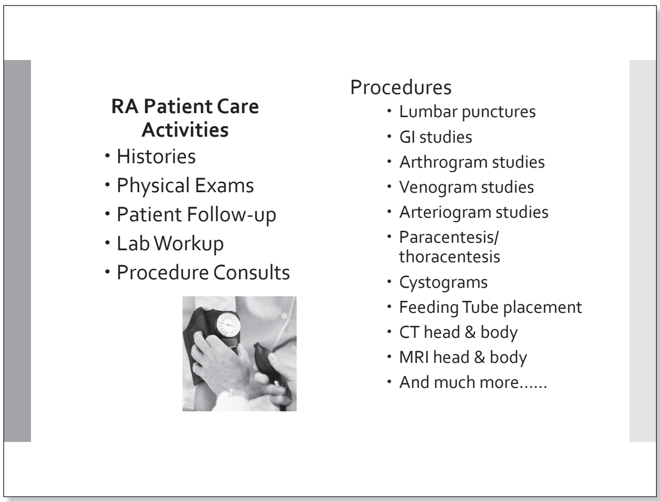


Fig.15

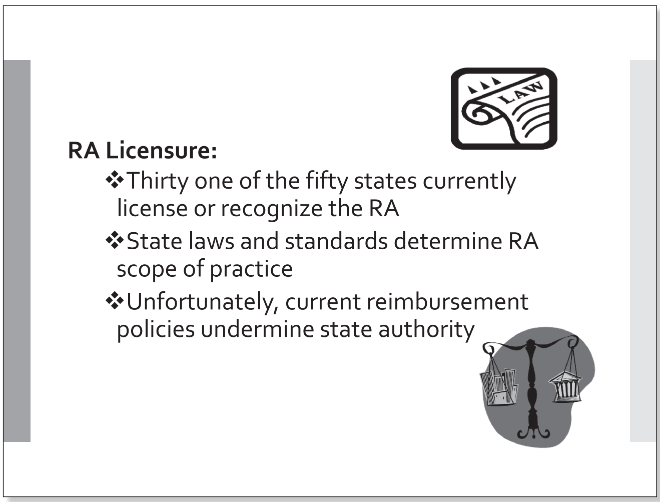


Fig.16

organizations that are national radiographer societies, radiologist, and physician extender organizations (Fig.17). This particular legislation is well supported by the ASRT, ARRT, the American College of Radiology, and the Society for Radiology Physician Extenders.

Currently, Medicare payment policy allows RAs to perform medical imaging procedures only if they are under the supervision of a radiologist. So that is the thing to consider. In order for insurance to pay for the services of a radiologist assistant, they must have their work under the supervision of a radiologist. So, the radiologist has to sign off on the final imaging. And then finally, the use of physician extenders is likely to increase and the knowledge level and care that the RA provides will greatly benefit our patients and their access to radiological services. So, I see the use of radiologist assistants growing in the years to come.

Now, sometimes I get the question about the transfer ability of a technologist educated in a different country that wants to work in the United States. So, this question often arises from colleagues that are seeking to work in the US. Typical questions about transferring credentials from other countries is of interest for some professionals in medical imaging. The quick answer is, it is not very easy to come to the United States and practice your specialty of radiologic technology and medical imaging. It used to be a lot easier many years ago. But today, it is quite challenging for someone from outside of the US that may be very well credentialed in their country, but want to come to the US, it is not easy to do that. Prior to January 1, 2000, special eligibility was the typical route for candidates educated outside of the United States to take the ARRT certification exam (Fig.18). It was a case by case evaluation and candidates would have to provide the necessary documentation of educational and experiential preparation. There was not really a standard way of evaluating or being able to say yes, you can come from your country to the United States. It was evaluated case by case, person by person, and I would say that posed the problem for many, but today it has not gotten any easier.

So, for today, in order to take the ARRT certification exam, if you are outside of the US, you must graduate from programs that are recognized by the ARRT. You must seek advanced placement in an accredited program. So, upon meeting the program's graduation requirements and receiving the program's

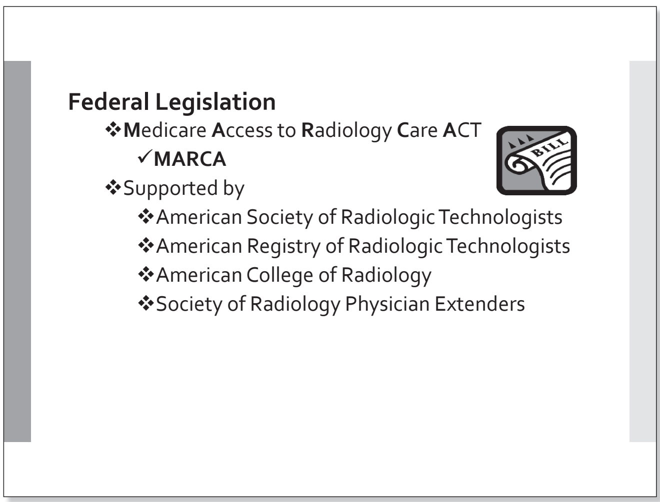


Fig.17

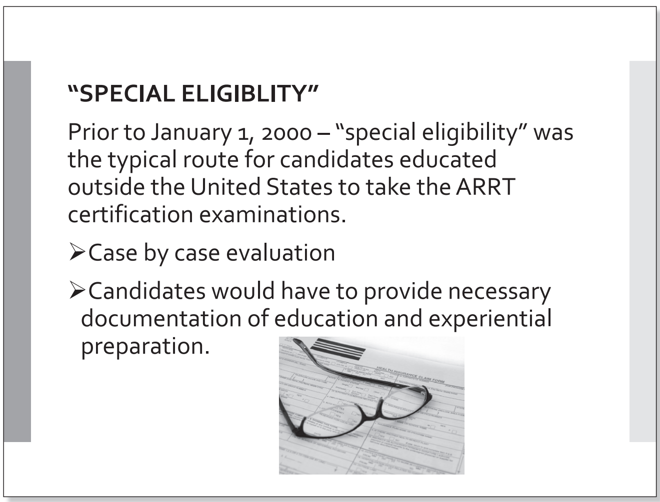


Fig.18

final endorsement, a candidate may apply for the ARRT certification exam (Fig.19). What individuals, what professionals outside the country have done, there are programs in the United States that do accept colleagues to come to their program. They will do advanced placement. So instead of taking maybe two years for them to graduate from the program, you will get an advanced standing, and maybe it will just take you one year and they will kind of expedite your going through the program, but you must graduate from a program recognized by the United States or by the ARRT.

You know, whatever advances take place in our profession, there are at least some downsides or disadvantages that come along with it, but only really a very few. The disadvantage that I can see is that there is a little bit of a fragmentation of our profession and sometimes accompanying that will be a loss of identity due to the number of titles within medical imaging (Fig.20). So, let's just talk about that for a second. In the United States, I told you when I graduated, I became a registered technologist in radiography and my credential was RTR, registered technologist in radiography. But there are other names for what I do, in the United States, in the history of our profession, so we could be called an

x-ray technician, an x-ray technologist, a radiologic technologist, a medical imager, a radiographer. There are so many different titles for who we are. The disadvantage is that we do not use, we have not always used a standard name for who we are. Now, think about with the different post-secondary, post-primary certifications, there are even more different types of titles for us. There are individuals who instead of calling themselves a radiographer with the advanced certification in computed tomography, they will call themselves a computed tomography technologist or a CT technologist. Instead of saying, I am a radiographer with advanced certification in magnetic resonance imaging, they will refer to themselves as an MRI technologist. And I am just talking about the disadvantages in the

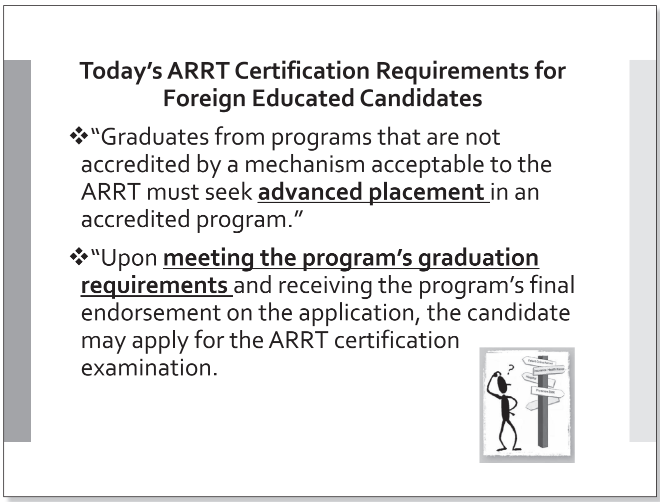


Fig.19

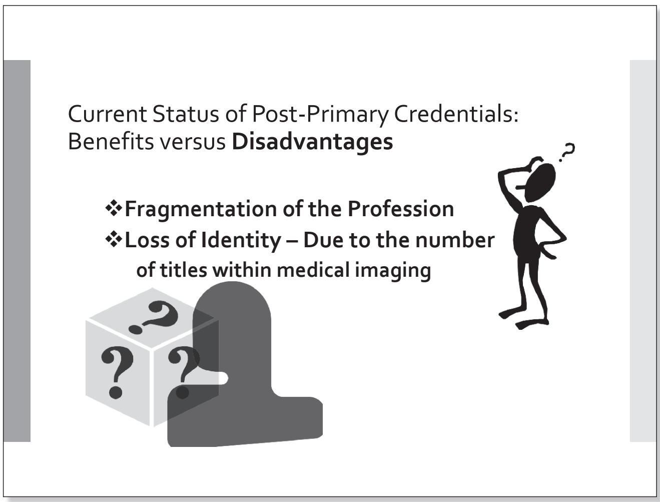


Fig.20

United States.

There may be different kind of standards in other parts of the world. So, I am only speaking for the US. For us, with all of our different titles, and once we have gone into an advanced certification, we do not go back and refer to our base, our foundation as a radiographer. We leave that to the side, and we call ourselves by our advanced certification. And let me just give you a comparison. In the United States, if a nurse graduates and goes into some specialty training, becomes a nurse practitioner, you will hear them always refer to themselves as a nurse practitioner or a primary care nurse, where we may be the only ones in the US that leave our original title behind and refer to ourselves as the advanced title. So, I see that as a disadvantage and it disturbed me a little bit, but it also causes us to lose our identity, especially when we are trying to make ourselves known to the outside community.

I will come back to this part on questions, but I wanted to go to the next slide firs (Fig.21). You know, this is my third time to Japan. I was here many, many years ago, when I was a delegate in the IRRT, representing the United States, and I was sharing with the president that my first time here was when Dr. Nakamura was the president of ISRRT and then about eight years ago. I put this slide here not to pat myself on the back, but just to say that I had the pleasure of serving our profession as the 13th President of the ISRRT and I was the first one to be president from the United States. Prior to my presidency, the 11th President is Dr. Tyron Goh from Singapore, and the 12th President was Mr. Robert George from Australia.

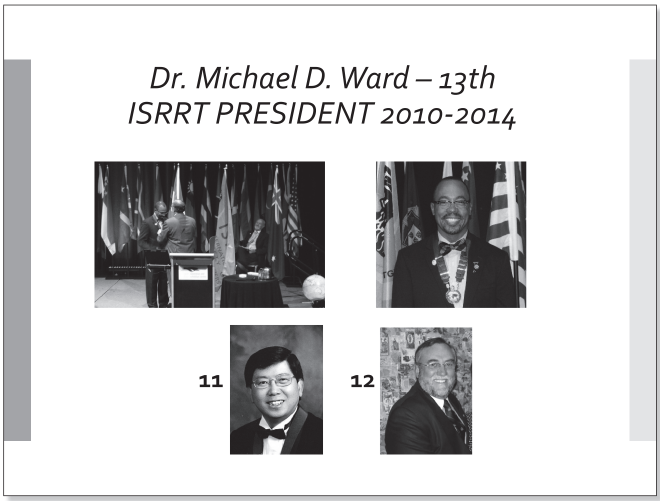


Fig.21

And after me, it was Dr. Fozy Peer from South Africa and the second president of ISRRT from the United States is now the current president, Donna Newman. But I am looking at friends that I have known for a long time and again, your president and I have been friends for a very long time. But I got to tell you, I am so proud to be a radiologic technologist. I am proud that I have had the opportunity to serve with some very fine individuals on the council, on the board of management. I have lifelong friends that when I come to Japan, there were faces that I have seen at a lot of different conferences and it makes me feel very proud and very happy to be a part of what I would say is a brotherhood and a sisterhood of professionals that we all may look different. The thing that brought us into the profession is our desire to take care of patients and to provide high quality imaging and radiologic science care for our patients and their families. That is the thing that has brought all of us together.

I have had the chance to go across the world to represent our profession, and everybody that I have run into in our radiology family, all care so much about what we do and I have seen the pride that is in every one of our faces when we stand up in front of a group and tell people that we are part of the radiologic science family.

Note: This article is secondary publication, the first paper was published in the JART, vol. 66 no. 799: 40-43, 2019

Future collaboration with the European Society of Radiology and European Federation of Radiographer Societies

Naoki Kodama, Niigata University of Health and Welfare

Approach from the European Society of Radiology

In January 2017, the secretariat of the European Society of Radiology (ESR) emailed the office of the Japan Association of Radiological Technologists (JART). In April, the president of ESR Dr. Bernd Hamm arrived in Japan and requested a meeting. I was unaware of the context of the discussion but decided to have the meeting on April 14, 2017.

On April 14 at 01:00 PM at the Yokohama Washington Hotel, we had a meeting with the board members of JART and ESR president Dr. Bernd Hamm. The main content of the meeting was the consideration for promotional activities for radiological technologists at my association because the president wanted to participate in many meetings of Japanese radiological technologists in the European Congress of Radiology (ECR). In addition, the board members of JART wanted to participate in the next ECR and wanted to discuss future collaborations. JART accepted the proposal.

Figure 1　Meeting in Japan

Promotional activities by ECR 2018

As a promotional activity of ECR 2018, JART published information on ESR and ECR 2018 in JART magazines and newsletter and publicized it widely among the members. ESR launched a corresponding membership system this year. It is a program that exempts radiographers and radiological technologists outside European regions from the membership fees of ESR. These members are entitled to free access to magazines, such as European Radiology, Imaging in Insight, and European Radiology Experimental. Moreover, upon registering for the corresponding membership of ESR by August 31, the registration fee for participation in ECR was discounted from the normal registration fee for participation.

Since 2018, the Shape your Skills program has also been held. Authors are exempt from the registration fee of ECR 2018 and an additional 200 euros if their abstract is accepted by the Shape your Skills program. This greatly benefits the Japanese radiological technologists.

Our participation in ECR 2018

We participated in ECR 2018 held from February 28 to March 4, 2018. A meeting between ESR and JART was held on February 28, 2018. During the meeting, the number of registered Japanese radiological technologists for ECR 2018 was 126, an increase of approximately

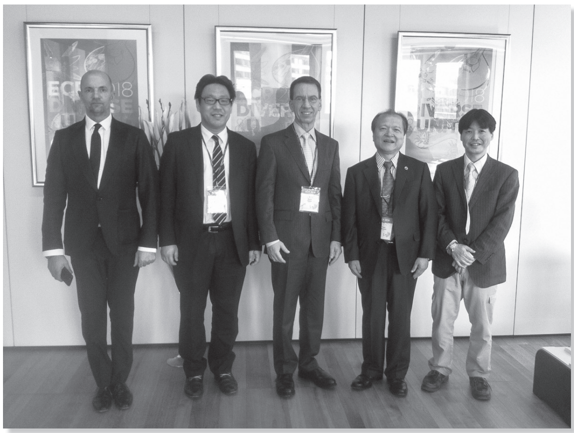


Figure 2 ESR President's Office

43% from the previous year, and the number of abstract subjects registered by Japanese radiological technologists was 119, an increase of approximately 20% from the previous year. The reported increase made the participants very grateful. As for the number of accepted Japanese radiological technologists, 11 out of 14 subjects were accepted by the Scientific Paper and 87 out of 105 subjects were accepted by the Electronic Presentation Online System (EPOS). This was the second place in the national ranking of radiological technologists. He said he would like to continue promotional activities in cooperation with JART from the next fiscal year.

We had a meeting with the European Federation of Radiographer Societies (EFRS) on the same day. EFRS was established in 2008 and currently has 32 European countries, 38 academic organizations, and 49 educational institutions, representing approximately 100,000 radiographers or radiological technologists. The former president Dr. Håkon Hjemly delivered an invited lecture at the 33rd Japan Congress of Radiological Technologist (Hakodate). Since 2018, Dr. Jonathan McNulty from Ireland has been the appointed president. We discussed the educational system for radiological technologists in Japan and Europe, especially for the postgraduate education of radiographers or radiological technologists. We agreed to discuss the enhancement of education in the future in cooperation with JART and EFRS and to hold regular meetings.

Promotional activities for ECR 2019

Since last year, promotional activities for ESR 2019 have included publication of information on ESR and ECR 2019 in the JART magazine, newsletter, and mailing list, and have been widely disseminated to the members. Upon registering for corresponding membership of ESR by August 31, the registration fee for ECR 2019 was discounted from the regular registration fee, resulting in a final registration fee of 99 euros. JART has decided to encourage participation in ECR, including ECR in the target academic societies for overseas presentations.

In addition, there was a proposal from ESR to select 100 subjects that Japanese radiological technologists are interested in from the ECR Online streaming platform, translate them into Japanese at the ESR, and make them available to the Japanese radiological technologists. ECR Online is a streaming platform that can be accessed for free until ECR 2019 From the presentations of ECR 2018, mainly from the JART International Committee, we selected 100 presentations that Japanese radiological technologists would be interested in and sent them to ESR in May 2018.

In addition, ESR will create Radiographers' Lounge in ECR 2019, so the installation of a free-of-charge JART booth and setting-up of a Japanese session in the Voice of EPOS session were proposed, and JART accepted the proposals. The Japanese radiological technologists submitted an abstract, selected 16 subjects from the accepted subjects, and set-up a Japanese session for the Voice of EPOS.

Voice of EPOS Japanese session at ECR 2019

At ECR 2019, which was held from February 27 to March 3, 2019, the Radiographers' Lounge installed the International Society of Radiographers and Radiological Technologist (ISRRT) booths and booths for radiographers or radiological technologists in various countries. JART booths have also been installed in the same way. At the JART booth, members selected for

Figure 3 At the ISRRT booth, with ISRRT President Ms.Donna

Figure 5 Voice of EPOS Japanese Session

Figure 4 Awards ceremony

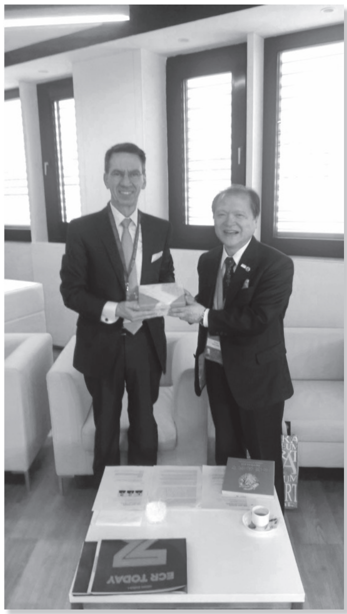


Figure 6 ESR Director, Dr. Bernd Hamm

travel support grants were awarded. The Voice of EPOS Radiographer stage was set-up right next to the Radiographers' Lounge, where sessions of the Voice of EPOS were held every day. The Japanese sessions of the Voice of EPOS (VoE-130, VoE-139) were held on February 28 and March 1. The president Dr. Nakazawa chaired the session for two days, and Japanese radiological technologists presented.

As the first attempt at ECR 2019, an interview was conducted at ESR Connect Studio. This interview was conducted for ESR presidents and representatives of each organization. In the interview with JART, president Dr. Nakazawa asked about the Japanese session of the Voice of EPOS, impression of the Radiographers' Lounge, and promotional activities for Japanese radiological technologists.

Cooperation with ESR, EFRS, and ISRRT at ECR 2019

At ECR 2019, JART held many meetings with other organizations, such as ESR, EFRS, and ISRRT. At the meeting with ESR, 697 members from Japan registered for ESR corresponding membership. As for the accepted number of abstracts by Japanese radiological technologists at ECR 2019, the Scientific Paper accepted 6 out of 13 presentations, and EPOS accepted

Figure 7 EFRS president, Dr. Jonathan McNulty

Figure 8 After ISRRT informal meeting

90 out of 105 presentations. As in the previous year, these radiological technologists ranked second in the country. In addition, 26 Japanese radiological technologists were selected for the Shape your Skills programme. ECR 2020 will be held in Vienna, Austria from March 11 to 15, 2020, and the deadline for abstract submission is October 10, 2019.

Since last year, we have been holding meetings with EFRS. President Dr. Jonathan McNulty, vice president Ms. Charlotte Beardmore, finance director Mr. Vasilis Syrgiamiotis, and other board members discussed the Radiographer Practitioner, graduate education for radiological technologists, especially the doctoral course. We decided on another meeting at ECR next year.

We participated in an informal meeting with ISRRT Society Members' leaders during ECR 2019. At this meeting, issues related to the revision of the ISRRT annual membership fee, which was currently a concern, and the global status of radiological technologists were discussed. After the meeting, ISRRT president Ms. Donna asked us to send a symposiast to Japan to hold an ISRRT meet's Asia Session at ECR 2020.

Conclusion

JART will continue to work with ESR, EFRS, and ISRRT to encourage members to participate in ECR. Planning sessions of the ECR and Japanese sessions of the Voice of EPOS will be held. In addition, based on the discussions with ESR, information on ECR 2020 will be conveyed to members through the JART magazine, newsletter, mailing list, and so on. We would like to make various requests to ESR for the benefit of JART members. I hope that many members will participate in ECR 2020.

Acknowledgements

We would like to thank Editage (www.editage.com) for English language editing.

Received June 8, 2018; accepted August 31, 2018

A Survey of Factors Influencing the Working Conditions of Radiological Technologists in Japan

Hiroe Muto[1), 2)], **Kanae Matsuura**[1), 2)], **Satoshi Nakanishi**[1), 2)]

1) The Japan Society of Education for Radiological Technologists
2) Dept. of Radiological Technology Faculty of Health Science, Suzuka University of Medical Science

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 795: 17-25, 2019.

Key words: radiological technologists, starting salary, degree holders, work environment, environment improvement

【Summary】
The purpose of this research is to contribute to the realization of a stable relationship between supply and demand regarding radiological technologists (RTs). We investigated the information provided on recruitment vouchers (number of job postings, initial salary, preference given or not given to holders of higher education degrees, holiday system, etc.) and analyzed the supply and demand trend regarding RTs. Results indicated that the demand for RTs is generally steady. However, the starting salary had decreased from our 2014's survey. There was also a regional difference in starting salary. In the short term, the ratio of supply and demand situation is stagnant or is falling slightly due to an increase in the number of RTs. However, facilities that give preferential treatment to degree holders have reached 60% in hospitals, so future demand for degree holders will rise.

1. Background and purpose

According to the population prediction of the Ministry of Internal Affairs and Communications Statistics Bureau [1)], the total population of Japan as of October 1, 2017 was 126.7 million. In Japan, the 0-14-year-old population has decreased, while the population of those aged 65 years or older has increased, with the result that after 1997, the older population exceeded the juvenile population in number. The juvenile population rate is now 12.3%, the lowest it has ever been, while on the other hand, the rate of the number of people aged 65+ population is record-high of 27.7% [1)].

According to the White Paper on the Ageing Society issued by the Cabinet Office in 2016, approximately half of all people in Japan over the age of 65 now complain of some subjective symptoms about ill-health, and for one out of four people, this affects their daily life. It is expected that the demand for healthcare professionals who support older people who are prone to illness will increase [2)].

There have been advancements in healthcare. Additionally, there have been changes in the medical needs of the public.

There have therefore been attempts to enhance team healthcare delivery that is performed by various medical staff who complement and cooperate with each other so as to practice their specialty most effectively. As a result, the scope of work of radiological technologists (RTs) has also increased [3-6)]. RTs are being trained in educational institutions such as four-year universities, which account for approximately 70% of all of the institutions offering such courses.

Regarding healthcare, a current problem is the lack or uneven distribution of medical staff across the country. The estimated number of nurses for 2025 is also expected to be insufficient according to a report [7)] presented in “the conference for the seventh projection of the estimated supply and demand of nursing personnel” held the Ministry of Health, Labr and Welfare (MHLW) of Japan. The Japanese Nursing Association continuously conducts surveys to determine the supply and demand or the work situation of hospital nurses as well as to gather information regarding the retention of these nurses [8].

With regard to RTs, however, although some reports on the supply and demand for RTs have been delivered [9-12], no studies have focused on RTs' starting salary, conditions of employment for females, or educational background. We therefore aimed to investigate the current status regarding the supply and demand and working conditions of RTs [13].

Employment of women as RTs is a further issue for investigation. In recent years the social participation of women has progressed, and people's way of life has diversified. However, efforts to support women's advancement in society, such as reduced working hours and childcare support, have not progressed. The Work-Life Balance Charter [14] was devised by the Cabinet Office to improve this situation.

In this study, we investigated the number of job postings, the salary, regional disparity in salaries, and regional disparity in supply and demand. The purpose of this study is to contribute to ensuring a stable future for RTs through maintaining demand and improving working conditions.

2. Subjects and methods

The present study was conducted on 648 job postings that were sent from medical institutions to the Suzuka University of Medical Science between April 1, 2016, and March 31, 2017. One job posting was also sent from a non-medical institution, which was excluded from the present study.

The following 11 items were investigated: ①receipt date of the job posting, ②location of institution (prefecture), ③category of institution (hospital, clinic, or other), ④employment pattern (full-time, part-time, fixed-term, etc.), ⑤conditions regarding the employment of women (only women employed or given preference), ⑥restriction of application according to educational background, ⑦differentiated starting salary according to educational background, ⑧payroll system (monthly salary, annual salary, etc.), ⑨base salary, ⑩qualification allowance or extra allowance, etc. ⑪holiday system.

The results were analyzed to examine the following aspects: employment overview, requirements for employment (enhanced employment of women), salary based on payroll system, and starting salary based on educational background.

Subsequently, we identified the number of examinees taking the national examination for RTs in the fiscal years 2006 to 2016, as well as the pass rate, to support the discussion on the supply and demand for RTs.

Based on the findings, the outcomes of various statistical surveys.

conducted by the MHLW, the Ministry of Internal Affairs and Communications, or the professional associations of physicians, nurses, and others were examined.

Facilities that did not clearly provide information on certain sections of their job postings, such as their starting salary or requirements for employment, were excluded from each analysis. Statistical processing was performed using IBM SPSS Statistics Ver.22, which included basic descriptive statistics, a homogeneity analysis, the Mann-Whitney U test, and the Kruskal-Wallis test.

3. Results

3-1 Conditions regarding the demand for RTs

3-1-1 Number of job postings

The number of monthly job postings in the fiscal year 2016 is shown in Fig.1, which also shows the number of job offers for 2013 (575 cases in total) and 2015 (707 cases in total) as a comparison [9), 13)]. In April 2016, 41 job postings were sent to the Suzuka University of Medical Science, and the number increased thereafter, peaking at 85 in July. The number of job offers in July and August decreased from 2015, but there were more job offers in Sep-

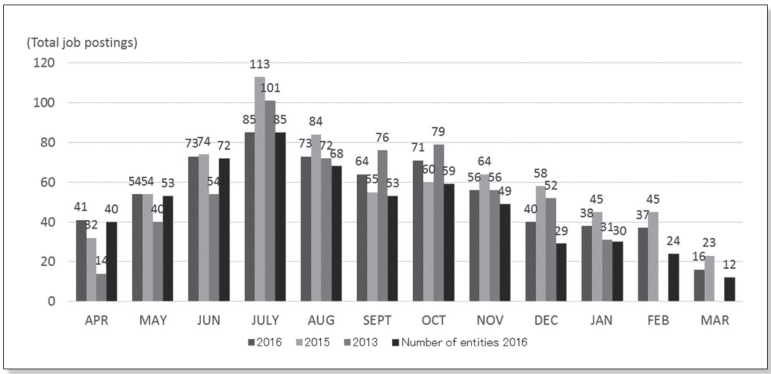


Fig.1　Total number of job postings / month

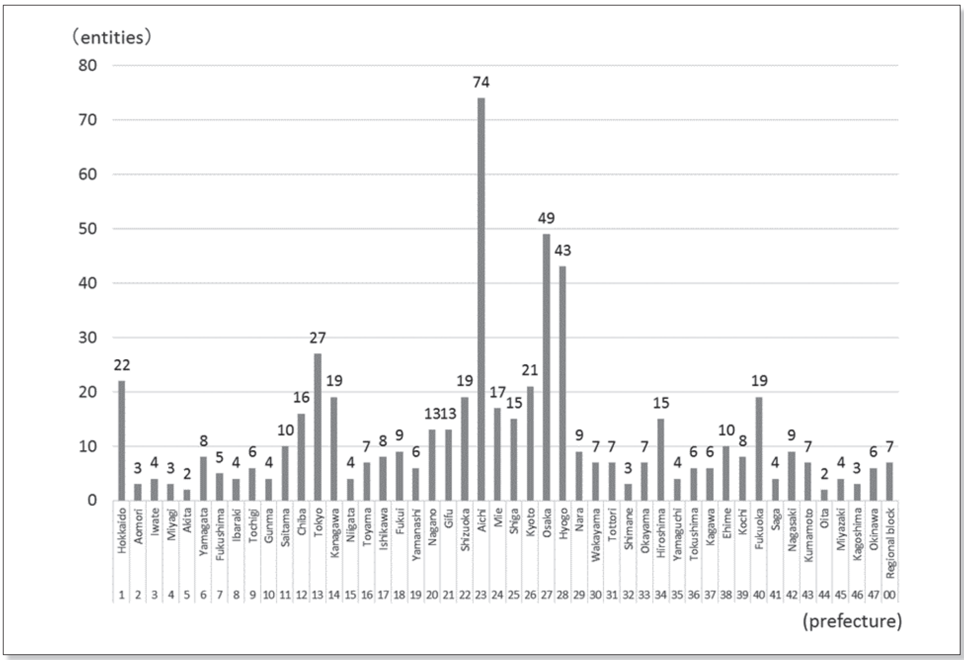


Fig.2　Number of entities of job postings

tember and October than 2015. In Fig.1, a black bar graph was added to represent the number that excluded the overlapping of job recruitment caused by recruitments from the same facilities. After the exclusion of the overlapping items, the total number of job recruitments was 574.

The job postings were then categorized by prefecture, as shown in Fig.2. In the present study, job postings were sent from all 47 prefectures in Japan and were included in the analysis.

3-1-2　Promotion of efforts to employ women

The job postings were checked for descriptions such as “recruitment of women”.

The results showed that only 42 facilities (7.3%) specified their conditions for the enhancement of female RT employment, with terms such as “women are preferred in provision of mammography services” or “women candidates preferred”. The remaining 532 facilities (92.7%) described no specific conditions for employing women. In 2013, 37 facilities (6.4%) specified conditions for employment of women, while in 2015 39 facilities (5.9%) did so. Little change was thus observed in four years from 2013 to 2016.

3-1-3 Requirements for employment based on educational background and payroll system

The job postings were checked for restrictions on employment and differentiation of the payroll system according to educational background. Conditions of employment and a salary system based on educational background were analyzed in 553 cases.

The results are shown in Table 1. A total of 49 facilities (8.9%) stated that students holding a bachelor's degree (hereafter, referred to as bachelor's graduates) or a higher qualification were eligible to apply, and three of these facilities (0.5%) specified a distinction in the payroll system between bachelor's and master's graduates. Furthermore, 247 facilities (44.7%) did not differentiate their job postings for employment but specified the differentiation of their payroll system based on educational background. Finally, 257 (46.5%) facilities specified no differentiation.

In 2015, 10.5% of these facilities indicated that they required graduated in their recruitment conditions, and 39.2% indicated salary differences according to educational background, making a total of 49.7%. In 2013, 3.0% of these facilities indicated that they graduated in the recruitment conditions, and 38.1% indicated salary differences according to educational making a total of 41.1%.

In results based on the type of facility (hospital, clinic, others), 44 (9.4%) facilities specified that they wished to employ graduates with a bachelor's degree or higher qualification, and 231 hospitals (49.4%) gave preferential treatment in the base salary. Three clinics [9.1%] and 15 health check facilities [31.9%] differed in their employment requirements or salary packages.

Table 1 Preferential treatment at the time of hiring for a degree acquirer

	hospital	clinic	medical examination center	Others	Total
Bachelor degree as a requirement	44	0	5	0	49
Different salary system depending on degree	231	3	10	3	247
No particular regulation	193	30	32	2	257
Total	468	33	47	5	553

3-1-4 Employment pattern (full-time, fixed-term, part-time, etc.)

In 2016, regarding the employment pattern of RTs, 533 (92.9%) facilities included permanent full-time staff, 31 (5.4%) included fixed-term staff, and 10 (1.7%) included part-time staff.

In 2015, permanent full-time staff comprised 95.1%, fixed-term staff comprised 3.3%, and staff providing part-time service comprised 1.6%, while in 2013, 94.6% were permanent full-time staff, 3.3% were fixed-term staff, and, 1.9% were staff providing part-time service.

3-2 Conditions regarding the supply of RTs (the number of examinees and pass rate for the national examination for RTs)

Next, the supply situation was investigated. On the MHLW's reports [15], the number of examinees, the number of candidates who passed, and the pass rate in the National Examination of Radiological Technologists since 2006 were examined, and the yearly trends are shown in Fig.3 and Fig.4. The following figures are confirmed on the website of the MHLW [15] : Until 2012, the number of examinees in the RT's national examination was around 2,500. As from 2013, the number increased, reaching 2,939 in 2016. In recent years, because the number of schools for RTs has increased, the number of RTs newly graduated from college has increased.

3-3 Conditions regarding salaries and work hours of RTs

3-3-1 Salaries by payroll system (base salary, starting salary)

Among the 574 facilities investigated, 550 (95.8%) stated the salary on their job posting. This was approximately the same as in 2013 (93.7%) of and 2015 (96.0%. In 537 [97.6%] of

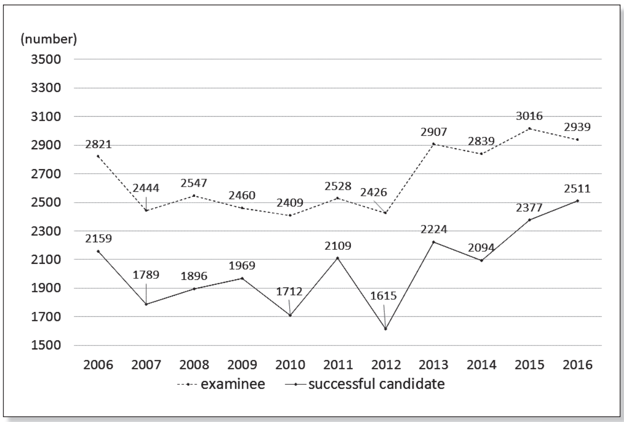


Fig.3 Number of examinees and number of successful candidate

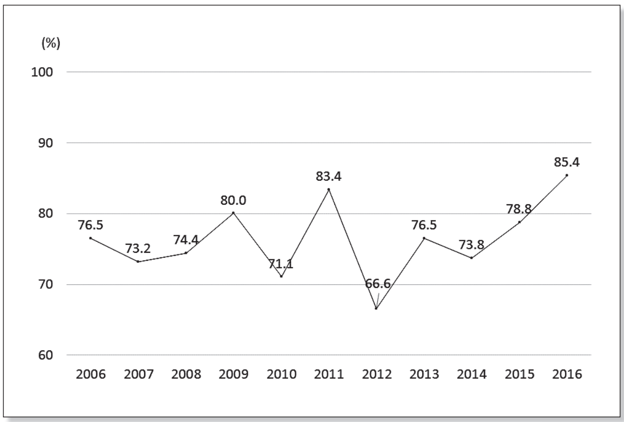


Fig.4 Pass rate for RT national examination

those facilities, the payroll system for RTs included a monthly salary, while in five [0.9%] it included an annual salary, and in five [0.9%] it included a daily salary.

A comparison of base salaries according to the payroll system (excluding qualification allowance or extra allowance) is presented in Table 2. In the case of facilities offering different salaries according to educational background, the salary for bachelor's degree graduates was utilized for the analysis.

The base salary in the facilities adopting a monthly payroll system was 190,095 yen on average, the median was 189,100 yen, the minimum was 81,650 yen, and the maximum was 265,000 yen. The base salary in the facilities adopting a daily payroll system was 9,783 yen on average, the median was 9,619 yen, the minimum was 8,581 yen, and the maximum

Table 2 Base salary for new graduates by the payroll system for 2016 versus that for 2015

payroll system		monthly		daily		annual		hourly
year		2016	2015	2016	2015	2016	2015	2016
Number of entities		537	576	5	6	5	3	3
salary	average	190,095	188,934	9,783	8,780	3,231,180	3,521,393	1,243
	median	189,100	187,075	9,619	8,807	3,243,900	3,564,180	1,130
	S.D.	19,725	19,251	1,465	701	378,210	106,644	223
	minimum	81,650	100,000	8,581	7,804	2,760,000	3,400,000	1,100
	maximum	265,000	280,000	12,180	9,600	3,600,000	3,600,000	1,500

Unit : yen
w/o qualification allowance

Table 3 Starting salary for new graduates by the payroll system for 2016 versus that for 2015

payroll system		monthly		daily		annual		hourly
year		2016	2015	2016	2015	2016	2015	2016
Number of entities		537	576	5	6	5	3	3
salary	average	198,415	201,602	9,783	8,780	3,231,180	3,521,393	1,243
	median	195,500	198,330	9,619	8,807	3,243,900	3,564,180	1,130
	S.D.	18,103	19,987	1,465	701	378,210	106,644	223
	minimum	120,000	108,300	8,581	7,804	2,760,000	3,400,000	1,100
	maximum	281,600	301,600	12,180	9,600	3,600,000	3,600,000	1,500

Unit : yen

was 12,180 yen. The base salary in those adopting an annual payroll system was 3,231,180 yen, the median was 3,243,900 yen, the minimum was 2,760,000 yen, and the maximum was 3,600,000 yen. The base salary in facilities adopting the monthly payroll system in the present study was higher than that reported in the 2015 survey results [13)] by 1,161 yen on average and by 2,025 yen according to the median, with no statistically significant differences. Moreover, the base salary in facilities adopting the monthly payroll system in the present study was higher than that reported in the 2013 survey results [9)] by 1,066 yen on average, and by 690 yen according to the median, with no statistically significant differences.

The starting salary calculated by adding the extra allowance to the base salary is shown in Table 3. The starting salary in the facilities adopting a monthly payroll system was 198,415 yen on average, the median was 195,500 yen, the minimum was 120,000 yen, and the maximum was 281,600 yen. As for the mean, 3,187 yen, the median decreased by 2,830 yen compared with 2015 with no statistically significant differences.

3-3-2 Starting salaries by educational background

A comparison of starting salary based on educational background is shown in Table 4. The starting salary for 45 facilities that stated in their application requirements that they would employ applicants holding a bachelor's degree or higher qualification was 197,417 yen on average, the median was 195,400 yen, the minimum was 176,800 yen, and the maximum was 232,645 yen. Among these facilities, three specified a differentiation in the starting salary for master's degree graduates, with an average salary of 212,067 yen for these graduates.

For the 245 facilities that did not specify the required educational background for application but differentiated the starting salary based on educational status, the starting salary for bachelor's degree graduates was 196,527 yen on average, the median was 193,600 yen, the minimum was 172,500 yen, and the maximum was 246,386 yen. The starting salary for professional school graduates was 187,412 yen on average, the median was 184,800 yen, the minimum was 166,300 yen, and the maximum was 224,419 yen. Among these facilities, 21 specified the starting salary for master's degree graduate, offering 211,549 yen on average, with a median of 209,900 yen, a minimum of 190,300 yen, and a maximum of 230,000 yen. For facilities that did not specifically limit recruitment or differentiate the base salary according to educational background, the average starting salary was 200,470 yen, the median was 196,450 yen, the minimum was 120,000 yen, and the maximum was 281,600 yen.

Table 4 Differences in starting salary for new graduates by degree for 2016 versus that for 2015

Degree required		bachelor	bachelor	non	non	non	non
Credential		master	bachelor	master	bachelor	diploma	not vary by credential
Number of entities		3 (2)	45 (64)	21 (14)	245(239)	245(239)	247 (273)
salary	average	¥212,067 (¥213,270)	¥197,417 (¥204,635)	¥211,549 (¥208,006)	¥196,527 (¥195,959)	¥187,412 (¥186,503)	¥200,470 (¥205,829)
	median	¥212,000 (¥213,270)	¥195,400 (¥204,066)	¥209,900 (¥204,250)	¥193,600 (¥194,200)	¥184,800 (¥184,500)	¥196,450 (¥202,176)
	S.D.	¥17,100 (¥20,548)	¥14,454 (¥15,249)	¥13,371 (¥14,200)	¥13,616 (¥14,902)	¥13,490 (¥13,664)	¥22,019 (¥23,414)
	minimum	¥195,000 (¥198,740)	¥176,800 (¥175,000)	¥190,300 (¥191,300)	¥172,500 (¥108,300)	¥166,300 (¥161,400)	¥120,000 (¥140,000)
	maximum	¥229,200 (¥227,800)	¥232,645 (¥245,400)	¥230,000 (¥232,800)	¥246,386 (¥268,900)	¥242,419 (¥231,300)	¥281,600 (¥301,600)

Unit : yen
Values for fiscal 2015 are shown in parentheses.

These results indicated that the starting salary for professional school graduates in facilities differentiating the payroll system by educational status was lower than that in any other group ($P < 0.05$).

The starting salary for master's degree graduates in the group of facilities differentiating the payroll system according to education was higher than that in the group of facilities that required a bachelor's degree or professional school qualification ($P < 0.05$).

We compared the starting salaries of 2015 with those of 2016. The starting salary for bachelor's degree graduates in the group of facilities that required a bachelor's degree for the application was lower than last year ($P < 0.05$). Furthermore, the result for facilities that did not specifically limit recruitment or differentiate the base salary according to educational background was lower than 2015 ($P < 0.05$). The starting salary for master's degree graduates in the group of facilities differentiating the payroll system according to education was higher than 2015 ($P < 0.1$). The results for facilities that did not specifically limit recruitment or differentiate the base salary according to educational background was lower than 2013 ($P < 0.05$).

3-3-3 Salaries by prefecture (base salary, starting salary)

The starting salary for newly graduated RTs by prefecture is shown in Table 5. In addition to the average starting salary for each of the 47 prefectures, the starting salaries in facilities employing graduates in wide area, such as the National Hospital Organization, as well as the national average, are presented. For the calculation of the average starting salary in facilities offering a different salary for bachelor's degree graduates, the starting salary for bachelor's degree graduates was used. The names of the prefectures are presented in Japanese, with the prefecture identification numbers defined by ISO 3166-2: JP (in this report, the wide-area

Table 5 Summary of the starting salary difference by area for 2016 versus that for 2015

ISO JP code	Prefecture "Japanese"	Average of RT's starting salary 2016 (2015)		Average starting salary of medical and welfare bachelor's degree 2016 (2015)	
01	Hokkaido	190,373	(198,803)	193,100	(220,100)
02	Aomori	192,100	(195,967)	177,000	(164,800)
03	Iwate	182,725	(180,050)	181,500	(158,600)
04	Miyagi	193,333	(197,220)	203,200	(211,500)
05	Akita	183,200	(189,700)	183,300	(162,600)
06	Yamagata	200,380	(209,520)	165,400	(190,500)
07	Fukushima	205,736	(222,160)	191,700	(184,600)
08	Ibaraki	209,670	(216,300)	176,000	(207,700)
09	Tochigi	203,294	(196,263)	253,000	(181,900)
10	Gunma	198,400	(193,850)	188,000	(198,700)
11	Saitama	200,948	(205,622)	197,600	(195,000)
12	Chiba	213,130	(199,656)	215,700	(207,900)
13	Tokyo	208,865	(210,898)	203,300	(205,400)
14	Kanagawa	211,305	(210,014)	205,400	(208,200)
15	Niigata	196,759	(187,051)	185,000	(166,900)
16	Toyama	176,090	(184,489)	182,800	(168,000)
17	Ishikawa	186,266	(189,475)	192,000	(192,800)
18	Fukui	190,533	(183,483)	193,000	(195,200)
19	Yamanashi	195,306	(217,265)	191,800	(165,100)
20	Nagano	194,326	(191,780)	197,400	(169,500)
21	Gifu	197,427	(190,383)	189,000	(194,300)
22	Shizuoka	199,149	(202,555)	188,800	(204,100)
23	Aichi	202,011	(210,355)	203,400	(207,000)
24	Mie	198,828	(203,327)	182,000	(196,200)
25	Shiga	198,572	(198,574)	185,800	(192,200)
26	Kyoto	196,084	(196,472)	193,500	(188,100)
27	Osaka	201,124	(202,902)	206,100	(200,100)
28	Hyogo	203,751	(207,196)	194,500	(195,200)
29	Nara	192,822	(201,429)	196,800	(191,000)
30	Wakayama	198,333	(195,543)	–	(214,200)
31	Tottori	184,383	(183,900)	172,200	(170,000)
32	Shimane	189,200	(191,201)	158,900	(185,800)
33	Okayama	192,757	(198,471)	191,300	(194,600)
34	Hiroshima	204,829	(206,647)	195,300	(202,600)
35	Yamaguchi	219,333	(198,417)	185,300	(177,700)
36	Tokushima	213,244	(234,667)	183,900	(171,100)
37	Kagawa	188,364	(202,467)	201,600	(181,600)
38	Ehime	192,202	(191,863)	194,400	(172,400)
39	Kochi	197,050	(195,656)	188,000	(215,800)
40	Fukuoka	200,205	(206,042)	190,700	(174,200)
41	Saga	188,835	(199,667)	203,300	(184,000)
42	Nagasaki	188,275	(203,702)	181,500	(207,900)
43	Kumamoto	183,157	(163,650)	186,700	(218,500)
44	Oita	189,450	(218,533)	192,300	(171,700)
45	Miyazaki	187,050	(196,200)	176,700	(160,000)
46	Kagoshima	190,483	(193,058)	171,700	(187,500)
47	Okinawa	195,950	(201,900)	179,700	(184,300)
00	Regional block	188,429	(188,060)	–	
JP	Total	199,012	(201,602)	196,700	(199,000)

Unit : yen

Values for fiscal 2015 are shown in parentheses.

blocks and the national average are 00 and JP, respectively).

In addition, the starting salaries for RTs in the present study are presented in Table 5, along with the survey results regarding the starting salaries for the various job types in the medical and welfare professions (excluding physicians and nurses) reported in the Basic Survey on Wage Structure (starting salary) [16), 17)] conducted by the MHLW. The starting salary reported in the Basic Survey on Wage Structure is calculated by subtracting commuting allowance from a given salary (consisting of base salary and other allowances without overtime compensation) for new graduates performing regular duties.

A survey by the MHLW also showed that the starting salary of RTs in 2016 was lower than in 2015, similar to our findings. In our own survey, in comparison to the previous three years, the starting salary decreased by 640 yen, while in the findings of MHLW, it increased by 6,600 yen.

In Fig.5, the shaded area represents the For 47 prefectures where the starting salary was lower in 2016 than in 2015. The base salary for newly graduated RTs by prefecture in this investigation ranged from 176,090 yen to 213,244 yen, with a difference of approximately 37,000 yen (prefectures with five or fewer job postings that met the requirements were excluded) (Table 5). In the 2015 investigation, the differ-

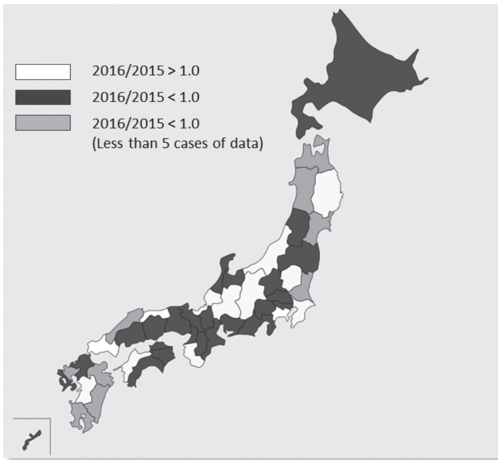


Fig.5 Summary of the starting salary difference by area

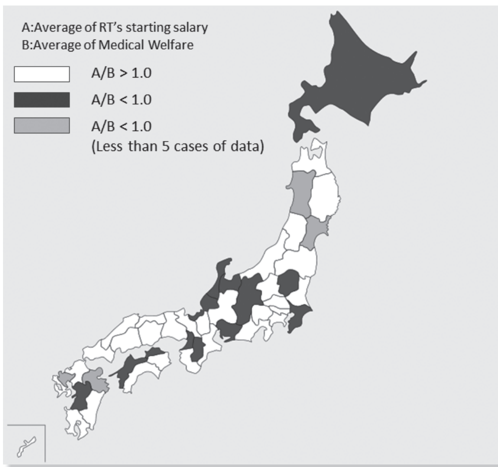


Fig.6 Summary of the starting salary difference by area in 2016

ence in the starting salary of each prefecture was about 25,000 yen. The area difference in the starting salary mean tends to have spread than in 2015. Furthermore, 16 prefectures had a starting salary above the national average.

For 47 prefectures, those with a starting salary for newly graduated RTs below the national average is represented by the shaded area in Table 5. According the results of the 2016 MHLW Wage Survey (medical and welfare,) the starting salary ranged from 158,900 yen to 253,000 yen, with a maximum difference of 94,100 yen.

A comparison of the starting salary for RTs the results of the 2016 MHLW Wage Survey (medical and welfare) revealed a higher starting salary for RTs (Fig.6).

3-4 Working conditions (holiday system)

In the 574 cases surveyed, the number of facilities where a holiday was shown clearly in an advertisement for a job was 489 (85.2%). With regard to a holiday system, 61 facilities (12.5%) adopted a five-day working week, 332 facilities (67.9%) adopted a five to six-day workweek, and 96 facilities (19.6%) adopted a system allowing for six holidays in four weeks.

We compared the number of facilities that adopted a holiday system allowing for six holidays in four week, and found that these included 76 hospital facilities (18.5%), eight clinic facilities (25.8%), and 12 medical examination centers (26.7%), as shown in Fig.7.

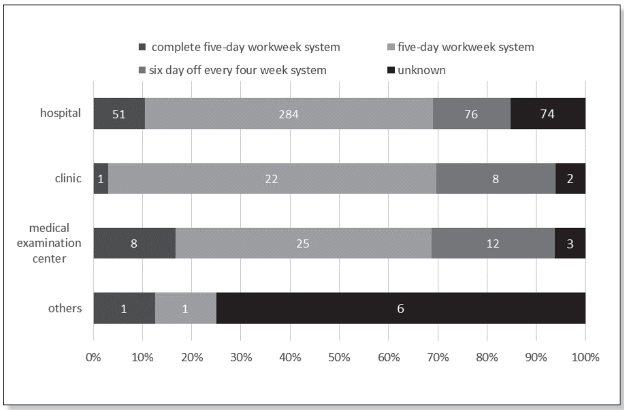


Fig.7 Summary of workweek system

4. Discussion

We aimed to investigate the current status with regard to the supply and demand and working conditions of RTs taking into account regional differences. The discussion further includes prediction of the supply and demand for RTs and the general prospects [9), 13)] for these professionals.

In the study, we conducted a continuous survey of the number of job postings, the number of employment systems, and the supply and demand trends based on starting salaries, the national examination passers of RTs, and the educational background required. In the following section, we analyze the survey results and consider measures to improve working conditions for RTs.

The number of job postings examined in the current study will be compared to those included in studies conducted in 2011 and 2013 [9)]. The last two months of the fiscal year 2011 were not investigated and were excluded from this comparison. The job postings were compared, and results showed that there were 527 job postings in 2011, 575 in 2013, 639 in 2015, and 595 in 2016.

The increase in the number of job postings is considered to have abated. The number of job openings requiring a college graduate holding a bachelor's degree was 17 in the 2013 survey but has increased to 49 in this survey, which suggests that the demand for college graduates is increasing.

Next, to evaluate the working conditions of RTs from the perspective of wages, an analysis was performed based on starting salary. In the 2016 survey, the average starting salary of facilities paying monthly salaries was indicated as 198,415 yen, a decrease of 3,187 yen from that indicated in the 2015 survey, but there was no statistically significant difference. Similarly, there was no statistically significant difference in comparison with the 2013 survey, indicating that in the past four years, there has been no significant change in the demand for newly graduated RTs, nor in salaries for these graduates.

At present, the shortage of medical staff and the uneven distribution of medical care are also pressing issues [18]. We therefore compared the average starting salary by prefecture in order to determine the status of RTs in each area with regard to employment conditions. Results indicated that in 2016, the starting salary between prefectures increased by approximately 37,000 yen from 176,090 yen to 213,244 yen, and it increased by 12,000 yen compared to 2015. In the MHLW survey, the difference between prefectures was 94,100 yen, which was 32,600 yen greater than in 2015.

Regarding the aspect of supply, the number of candidates who passed the national examination for RTs exceeded 2,500 in 2016. Also, new schools are expected to open in the next few years, and supply will increase in the long term.

Concerning demand, the results of this survey indicated that the demand for RTs was strong overall.

On the other hand, however, in the *Report on the Actual Condition of RTs in 2017* [19, 20] issued by the Japan Association of RTs, it is stated that approximately half of the facilities felt that there were "not enough" medical radiologists. The report further indicates that approximately 40% of facilities have overtime of more than 10 hours, and more than 12% of facilities have less than 5 paid days off. Therefore, it is necessary to improve the working conditions of RTs so as to increase the numbers.

In this survey, approximately 50% of the facilities clearly indicated a salary system based on educational background. Compared with the level in 2013, the number of facilities considering higher education when hiring increased by 12.5%. Moreover, the average starting salary of all RTs decreased by 3,187 yen as compared to 2015, but there was no statistically significant difference between the two years. However, the average starting salary increased slightly from 2015 in facilities that based their salary system on educational background, especially in facilities where graduates holding master's degrees were specified. There was a significant difference in wage allocation based on educational background, and for facilities where neither application conditions nor education requirements were specified, the wage allocation in 2016 was reduced compared with 2015 and 2013. In this study, the amount of the starting salary according to educational background in *the Actual Condition of RTs in 2017* [19, 20] issued by the Japan Association of Radiological Technologists (JART) [19, 20] is 170,000 yen to 179,000 yen for vocational school graduates with a four year qualification. The starting salary for those who graduated from a university increased from 180,000 to 189,000 yen, and for those who completed graduate school with a master's degree, the starting salary increased from 200,000 to 219,000 yen. As is the case in the current survey, this indicates that the higher the education, the higher the salary that is offered.

However, the report states that it is not clear whether basic salary settings will increase with education [19]. In the analysis of recruitment slips in our study, the results revealed that approximately half of all facilities and about 60% of hospitals took higher educational degrees into consideration at the time of recruitment. From the above results, it is can be concluded that the demand for degree holders is on the rise.

We further considered the future demand for RTs and considered how to improve working conditions. One factor is the employment of degree holders, as mentioned above. In consideration of the pay raise system adopted at each facility, it is vital to encourage the employment of individuals holding not only bachelor's degrees but also higher degrees such as master's and doctoral degrees.

A second factor is the promotion of affirmative action and the development of a working environment that allows for a variety of working styles to be selected according to the individual circumstances of working people. Where of different treatment of female and male workers occurs, such as few women being employed at a workplace or the majority of management positions being occupied by men, the workplace should engage in "positive action" [21]. For example, a recruitment slip should include a request for female RTs. These do not violate the Equal Employment Opportunity Law [21]. At present, the percentage of women employed in radiation departments is 24.6%, and it is reported that there is a slight increase in this number [20]. In Japan, with the number of female RTs expected to increase in the future, the needs related to different working styles, including compatibility with childcare and nursing care, are expected to diversify. Therefore, further promotion of women's employment including positive actions is expected.

Third, related to the above, there is a need to implement measures for the retention of new or young RTs. According to the *Report of the Survey of Actual Status of RTs in 2017* [19], the turnover rate for newly graduated RTs was 2.2% for men and 3.0% for women.

Therefore, measures for staff retention are necessary. Specific measures include considering the introduction of a standardized education system [19], conducting training for new staff, and improving the training environment according to the environment in which people following various work styles are placed. These measures should be implemented in the workplace, but it is assumed that it is not feasible to introduce training of new staff and a standardized education system in small-scale facilities. JART should play a central role in promoting activities in cooperation with the Japan Society of Education for Radiological Technologists (JSERT) and with universities.

In future research, a detailed survey is needed to provide evidence to support improvement in the work environment so that RTs can select various work styles according to their individual circumstances. It is thus necessary to examine the work style of RTs and their need for career support, and a fact-finding survey on career support initiatives is needed.

The limitation of this study is that it is based on job postings sent to only one facility. In order to formulate a more comprehensive supply-demand outlook, we propose that a survey be conducted in cooperation with JART, the prefectural JART, JSERT, and training institutions for RTs.

5. Conclusion

Concerning the demand for RTs holding bachelor's and master's/doctoral degrees is expected to increase.

In the future, in order to stimulate demand and improve the working conditions of RTs, the following measures are suggested: 1) employment of degree holders, 2) promotion of affirmative actions, 3) improvement of the work environment so that various working styles can be selected. In addition, we advocate the implementation of measures for the retention of young RTs.

Acknowledgements

This work was supported by a contract research grant for the fiscal year of 2016, awarded by the Japan Association of Radiological Technologists to the JSERT.

References

1) Statistics Bureau, Ministry of Internal Affairs and Communications: Population estimation (As of October 1, 2017).
http://www.stat.go.jp/data/jinsui/2017np/index.html
2) The Cabinet Office of Japan: The 2016 annual report on the aging society. 2016.
3) A notice issued by the Director, Medical Policy Office, the Ministry of Health, Labour and Welfare: Promotion of team healthcare delivery by the cooperation of medical staff. 2011.
4) Committee for the Promotion of Team Healthcare Delivery: Minutes of the committee for the promotion of team healthcare delivery. 2013.
5) Ministry of Health, Labor and Welfare Social Security Council Medical Subcommittee: About promotion of team medical care.
https://www.mhlw.go.jp/stf/shingi/2r9852000001wrcw-att/2r9852000001wri2.pdf
6) Ministry of Health, Labor and Welfare: About the issuance of a ministerial ordinance that partially revises the rules for the enforcement of radiological technologists and the laws on clinical laboratory technicians.
http://www.jart.jp/activity/lifelong_study/ib0rgt0000002bk3-att/kaiseisyourei270217.pdf
7) The Ministry of Health, Labour and Welfare: The report by the conference for the seventh projection of estimated supply and demand for nursing personnel. 2010.
8) The Japanese Nursing Association: The 2012 survey of hospital nurses demand and supply. 2018.
9) Hiroe Muto et al.: Basic statistical research on wage according to starting salary in job recruitment of radiological technologists: Study on the current status and future demand. The Japan Society of Education for Radiological Technologists, vol.6, No.1, 21-23, 2014.
10) Naoki Kodama et al.: Study on future demand for radiological technologists. The Japan Society of Education for Radiological Technologists, vol.1, No.1, 13-18, 2009.
11) Koichi Shibuya et al.: Starting salary for radiological technologists. The Journal of the Japan Association of Radiologic Technologists, vol.55, No.673, 50-53, 2008.
12) Koichi Shibuya et al.: Effect of decrease in starting salary for radiological technologists. The Journal of the Japan Association of Radiological Technologists, vol.57, No.696, 51-56, 2010.
13) Hiroe Muto et al.: The Employment Environment of Radiological Technologists. The Journal of the Japan Association of Radiologic Technologists, vol.64, No.776, 637-644, 2017.
14) The Cabinet Office of Japan: Work-Life Balance Charter, 2007.
http://wwwa.cao.go.jp/wlb/government/20barrier_html/20html/charter.html
15) The Ministry of Health, Labour and Welfare: Announcements of results of the national examination for radiological technologists (http://www.mhlw.go.jp/).
16) The Ministry of Health, Labour and Welfare: The 2015 basic survey on wage structure (starting salary). 2015.
17) The Ministry of Health, Labour and Welfare: The 2016 basic survey on wage structure (starting salary). 2016.
18) The Ministry of Health, Labour and Welfare: The 2015 basic survey on wage structure (starting salary). 2015.
19) Persons in charge of research at the Japan Association of Radiological Technologists: The 2017 report of field survey results on salary. vol.65, No.786, 414-434, 2018.
20) Persons in charge of research at the Japan Association of Radiological Technologists: The 2017 report of field survey results on salary. vol.65, No.784, 161-185, 2018.
21) The Conference for the Promotion of Working Women: "Positive action".
https://www.mhlw.go.jp/positive-action.sengen/about.html

Received July 2, 2018; accepted October 26, 2018

Optimization of radiation exposure to the eye lens in stereotactic radiosurgery

Kohei Kawasaki[1)], Osamu Nagano[2)], Kyoko Aoyagi[2)], Takahiro Kageyama[1)]

1) Department of Radiology, Chiba Cardiovascular Center
2) Gamma Knife House, Department of Neurosurgery, Chiba Cardiovascular Center

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 796: 15-20, 2019.

Key words: stereotactic radiosurgery, Gamma Knife, radiation dose, eye lens, cataract

【Abstract】

In 2012, International Commission on Radiological Protection (ICRP) published a threshold dose for cataract as 0.5 Gy. However, little evidence is available on determination of radiation dose to the eye lens in gamma knife radiosurgery (GKS). The purpose of this study was to confirm the fact of radiation exposure to the eye lens and produce an appropriate treatment plan for GKS. From January 2015 to December 2016, 57 patients (39 women; age, 27-84 years) with single lesion of meningioma were enrolled in this study. We retrospectively measured the dose to the eye lens in the treatment plans that have been performed for these patients. To investigate whether a reasonable dose distribution could be designed we modified the plans regarding the eye lens as organ at risk in the cases that the lens dose exceeded 0.5 Gy. Then we compared treatment parameters between plans before and after modification. As a result, the maximum dose to the eye lens reached the threshold level for cataract in 13 cases. In the modified treatment plans for all of these cases, the maximum dose to the eye lens was reduced to less than 0.5 Gy although the irradiation time was prolonged by 11.6 minutes on average. There was no significant difference in dose covering 95% of the lesion volume (D95). In conclusion, in 23% of patients who underwent GKS, the eye lenses were exposed beyond the ICRP threshold dose for cataract. Ophthalmological follow-up might be required in these cases. In addition, we could produce optimal treatment plan with reduced lens dose to less than the threshold dose for cataract while keeping D95 with acceptable prolongation of irradiation time.

1. Introduction

Gamma knife radiosurgery (GKS) is one of the techniques of stereotactic radiosurgery, which is specialized for intracranial lesions [1)]. The steepness of the dose distribution curve of stereotactic radiosurgery raises concern about adverse radiation effects. Thus, it is essential to be cognizant of the spatial relationship between organs at risk of developing side effects, target lesions and the dose distribution. Therefore, there have been several reports to optimize the radiation dose to organ at risk in this field [2-5)].

In International Commission on Radiological Protection (ICRP) publication 118 [6)], it was required to pay particular attention to cataract. The threshold dose for cataract of 0.5 Gy was proposed, which is drastically lower than previously considered. However, little evidence is available on dose optimization for the eye lens involving the new threshold value in GKS. The purpose of this study was to confirm the fact of radiation exposure to the eye lens in GKS and produce an appropriate treatment plan to prevent the lens dose from reaching the ICRP threshold level.

2. Materials and methods

This study was approved by institutional review board (IRB) of our hospital (IRB No. 392). We took care not to infringe on the patients' right to privacy by making the data anonymous. All patients provided written informed consent.

2-1 Patient characteristics

From January 2015 to December 2016, 57 patients with single meningioma were enrolled in the present study. Patient characteristics and the location of the lesions are presented in Table 1. GKS was performed in all the patients using the Leksell Gamma Knife Perfexion (Elekta Instruments AB, Stockholm, Sweden).

Table 1　Patient characteristics

Characteristic	Value
Total no. of patients	57
Men/women	18/39
Age (years), median (range)	64 (27-84)
Lesion location	
Right/left	29/28
Frontal lobe	21
Temporal lobe	14
Occipital lobe	2
Parietal lobe	2
Cerebellopontine angle	12
Cerebellar hemisphere	6

2-2　Confirmation of the fact of radiation exposure to the eye lens

To confirm how much the eye lens was irradiated, we retrospectively calculated the dose to the eye lens in the treatment plans that have been conducted for GKS. The peripheral dose prescribed for the lesions was 12.5-18 Gy. In the cases of the lesion adjacent to the optic nerve, staged GKS was applied and peripheral doses of 8.5-9 Gy were prescribed [7]. On treatment plan system (Leksell GammaPlan 10.1.1; Elekta Instruments AB, Stockholm, Sweden), we newly contoured the eye lens in the original plans and overlaid the dose distribution. And then, we regarded the eye lens as an organ at risk and measured following dose parameters: maximum lens dose; mean lens dose; the volume of the eye lens received beyond 0.5 Gy ($V_{0.5}$). Additionally, we analyzed following factors that might affect the dose parameters: lesion location (anterior, mid, posterior, ipsilateral and contralateral); lesion volume; peripheral dose; number of shots; existence of other organs at risk.

2-3　Optimization of the treatment plan

We further analyzed the cases in which the maximum lens dose reached the threshold level as a result of Sect. 2-2. We modified the original treatment plans to design reasonable dose distribution. We intended to make 0.5 Gy isodose line away from the eye lens without compromising lesion control by employing a hybrid isocenter technique referred to as “composite shot” with collimators of different sizes that are blocked and mixed. Then, we compared following dose parameters between before and after modification: maximum lens dose; dose covering 95% of the lesion volume (D95); irradiation time.

2-4　Statistical analysis

All statistical analyses were performed using EZR (http://www.jichi.ac.jp/saitama-sct/SaitamaHP.files/statmed.html) [8]. We evaluated the factors affecting the dose to the eye lens using multiple regression analysis. We compared the maximum lens dose, the D95 and the irradiation time between original and modified plans using the Wilcoxon signed rank test. The significant level was defined as 0.05.

3. Results

3-1　Confirmation of the fact of radiation exposure to the eye lens

The measurement results of the maximum and the mean dose to the eye lens and the $V_{0.5}$ are shown in Table 2. The maximum lens dose, the mean lens dose and The $V_{0.5}$ ranged 0-1.1 Gy, 0-0.8 Gy and 0-276.3 mm^3, respectively. Figure 1 shows the frequency distribution of

Table 2　Measurement of the dose parameters

Dose parameter	Value
Maximum lens dose (Gy)	0.1 (0-1.1)
Mean lens dose (Gy)	0.1 (0-0.8)
$V_{0.5}$ (mm^3)	30.4 (0-276.3)

Data are presented as median (range)

the maximum lens dose. In 13 cases (23%), the eye lenses were exposed beyond 0.5 Gy which is the ICRP threshold dose for cataract.

Table 3 demonstrates the result of multiple regression analysis of the factors affecting the dose parameters for the eye lens. There was a significant correlation between the lens dose and the location of the lesions. Besides, the co-existence of organs at risk significantly affected the lens dose. As for the $V_{0.5}$, there were no significant correlated factors.

Figure 2 illustrates the representative case that the lens dose was affected by the existence of the other organ at risk. This 48-year-old man had a left cavernous sinus meningioma. In the original treatment planning, we regarded the optic nerve as the organ at risk [7] and produced the dose plan without concern about radiation exposure to the eye lens. Peripheral dose for this lesion was 9 Gy. The isodose line for 0.5 Gy was unexpectedly expanded toward the right eye lens despite the lesion was on the left side. The maximum doses to the lens were 0.7 Gy in the right and 0.6 Gy in the left, respectively. The dose to the right eye lens which is the contralateral side of the lesion was greater than the left.

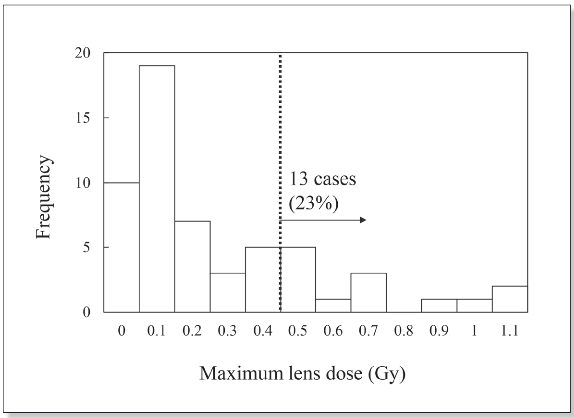
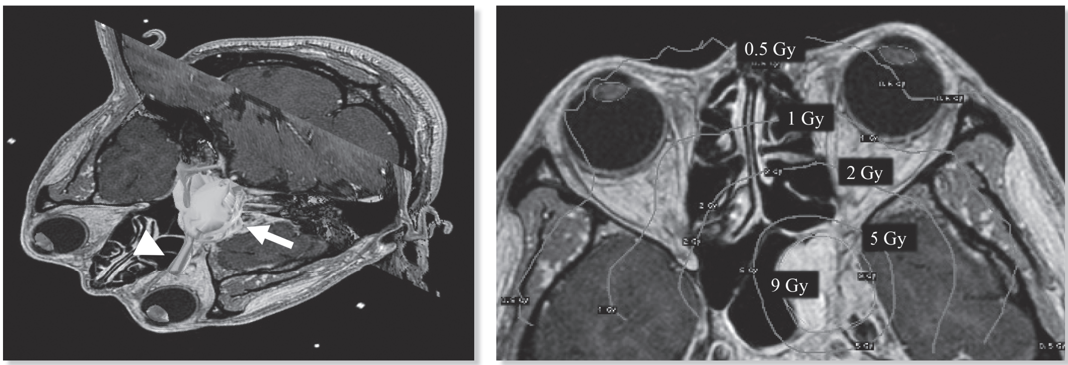


Fig.1 Frequency distribution of the maximum lens dose.

In 13 cases (23%), the maximum lens dose reached 0.5 Gy, the ICRP threshold dose for cataract.

Table 3 Multiple regression analysis regarding the factors affecting the lens dose

Factor	*P* value Max dose	Mean dose	$V_{0.5}$
Lesion location (anterior vs. mid)	<0.05	<0.05	0.236
Lesion location (anterior vs. posterior)	<0.05	<0.05	0.377
Lesion location (ipsilateral vs. contralateral)	0.218	0.268	0.380
Lesion volume	0.642	0.438	0.063
Peripheral dose	0.205	0.648	0.075
No. of shots	0.536	0.885	0.448
Other at-risk organ	<0.05	<0.05	0.232



a b

Fig.2 Unexpected expansion of the dose distribution.

a) This 48-year-old man had a left cavernous meningioma (*arrow*). We regarded the optic nerve as the organ at risk (*arrowhead*) and produced the dose plan.
b) The lesion was irradiated with 9 Gy of peripheral dose. The isodose line for 0.5 Gy was expanded toward the right lens despite lesion was on the left side. The maximum dose to the right lens was 0.7 Gy, greater than the left lens.

3-2 Optimization of the treatment plan

Figure 3 demonstrates the comparison of the maximum lens dose between before and after modification. The dose to the eye lens was significantly reduced in the modified plans. (*P*<0.05). Further, the radiation exposure to the eye lens were less than 0.5 Gy in the modified plans for all of the cases. The comparison of the D95 is shown in Fig.4. There was no significant difference in the D95. Figure 5 shows the comparison of the irradiation time. The irradiation time was prolonged by 11.6 min on average in the modified plans (*P*<0.05).

Figure 6 illustrates the representative case that a reduction in the dose to the eye lens could be achieved by modifying the treatment plan. This 62-year-old woman had a meningioma in the olfactory groove. In the original plan, both eye lenses were covered with the 0.5 Gy isodose line. The maximum lens doses were 0.7 Gy in the right and 0.9 Gy in the left, respectively. On the other hand, 0.5 Gy isodose line was away from both eye lenses when the dose distribution was modified with taking the radiation exposure to the eye lens into account. As a result, the maximum lens doses were reduced to 0.4 Gy.

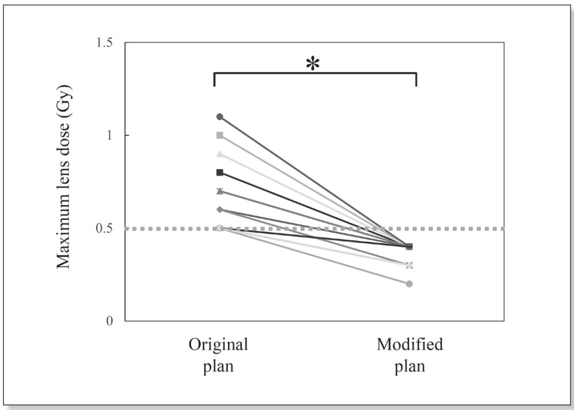


Fig.3 Comparison of the maximum dose to the lens.

The maximum lens dose was significantly reduced in the modified plans on which the eye lens was regarded as the organ at risk. Radiation exposure to the lens were less than 0.5 Gy in all of the plans after modification. *P<0.05

4. Discussion

The fact of the radiation exposure to the eye lens during stereotactic radiosurgery remains to be clarified although ICRP published the threshold dose for cataract as 0.5 Gy. Eye lens does not seem to be dealt with as organ at risk for adverse effect at low radiation dose in treatment planning for GKS. To the best of our knowledge, the present study is the first report focusing on this important issue. Our data indicates 23% of cases were exposed beyond the ICRP threshold dose in GKS for patients with meningioma (Fig.1). In multiple regression analysis of the factors affecting the lens dose, the location of the lesions and co-existence of organs at risk were significant correlated factors (Table 3). While the former seems to be reasonable because the lesions are close to the

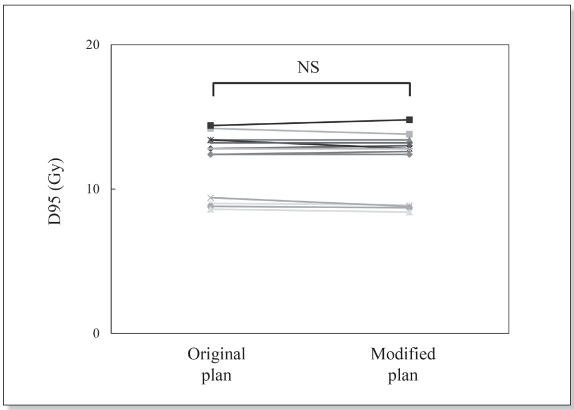


Fig.4 Comparison of the dose covering 95% of the lesion volume (D95).

There was no difference in the D95. NS not significant.

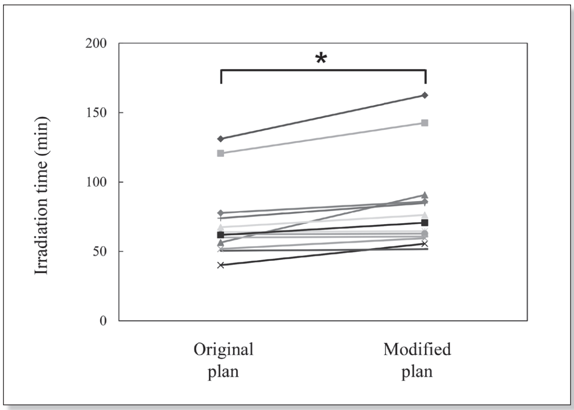


Fig.5 Comparison of the irradiation time.

The irradiation time was prolonged by 11.6 min on average in the modified plans. *P<0.05

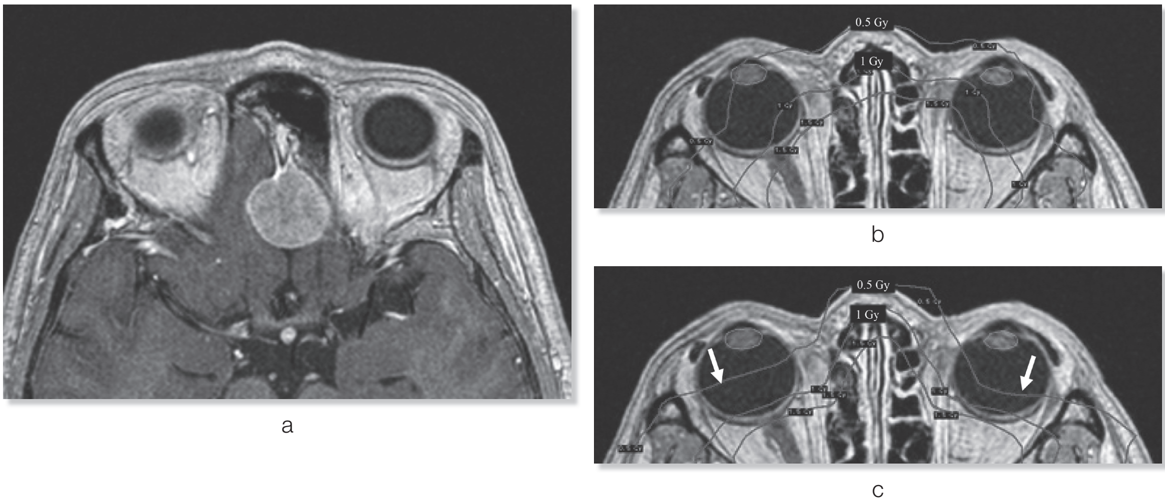


Fig.6 Dose reduction in the eye lens.

a) This 62-year-old woman had a meningioma in the olfactory groove.
b) In the original plan, both eye lenses were covered with the 0.5 Gy isodose line. The maximum lens doses were 0.7 Gy in right and 0.9 Gy in left, respectively.
c) In the modified plan, the 0.5 Gy isodose line was away from both eye lenses (*arrows*). The maximum lens doses were reduced to 0.4 Gy.

eye lens, the latter is a new finding. Careful attention might be necessary to the increase in the dose to the eye lens due to unexpected expansion of dose distribution when producing treatment plan with other organs at risk (Fig.2). In the cases that the lens dose reaches the ICRP threshold dose, ophthalmological follow-up may be recommended to check for cataract induced by stereotactic radiosurgery.

It is possible to distinguish between radiation related cataract and senile cataract [9]. Posterior subcapsular cataract that occurs at back of the lens is typical type of radiation related cataract. Young patients, 40s or less in particular, who undergoing GKS for benign lesions should be observed as long as possible since previous studies indicate radiation related cataract was detected in decades after irradiation [9, 10].

To produce appropriate dose distribution for the cases which exceeded the ICRP threshold dose level for cataract, we regarded the eye lens as organ at risk and modified the original plan. As a result, we could reduce the lens dose to less than 0.5 Gy without making any difference in D95 (Fig.3, 4). Meanwhile, the irradiation time was prolonged by 11.6 min on average in the modified plans (Fig.5). In this regard, the gamma knife model at our hospital, Perfexion is fully robotized and both the radiation beam configuration and the couch positional coordinate setting are automated, which makes patient hospitable and mitigates the workload of the operator [11]. Additionally, for patients which are considered to achieve long-term survival it is required not to raise the level of occurrence of radiation-induced complications in the rest of their life. Thus, the prolongation of irradiation time was short enough to accept clinically although there was a trade-off between a conformal dose plan and irradiation time. Our effort to optimize radiation exposure to the eye lens is meaningful in GKS.

The present study has several limitations. First, this is a single institutional study. Next, relatively small number of subjects were enrolled in this study. Third, we did not take into account the movement of the eye ball during the irradiation when calculating dose to the eye lens. The internal error due to lens motion should be defined in GKS to make dose evaluation more rationally. Finally, in our experience, there are no patients who is diagnosed with radiation related cataract. To address these issues, a long-term observational study with a larger number of subjects is necessary in the future. We believe that the treatment planning with consideration for radiation exposure to the eye lens is a way to advance GKS as minimally invasive treatment. We hope that the relationship between radiation exposure to the eye lens in stereotactic radiosurgery and the occurrence of cataract will be elucidated as further research in this field progresses.

5. Conclusions

In 23% of patients who underwent GKS, the eye lenses were exposed beyond the ICRP threshold dose for cataract. We demonstrated that the treatment plan could be modified in order to reduce the eye lens exposure below the threshold level with clinically acceptable D95 and irradiation time.

We presented this study at the 20th International Society of Radiographers and Radiological Technologists held in Port of Spain, Trinidad and Tobago in April 2018.

References

1) Lunsford LD, et al.: Stereotactic radiosurgery of the brain using the first United States 201 cobalt-60 source gamma knife. Neurosurgery, 24, 151-9, 1989.
2) Ove R, et al.: Preservation of visual fields after perisellar gamma-knife radiosurgery. Int J Cancer, 90, 343-50, 2000.
3) Gondi V, et al.: Why avoid the hippocampus? A comprehensive review. Radiother Oncol, 97, 370-6, 2010.
4) Maruyama K, et al.: Optic radiation tractography integrated into simulated treatment planning for Gamma Knife surgery. J Neurosurg, 107, 721-6, 2007.
5) Kawasaki K, et al.: Quantification of the radiation dose to the pyramidal tract using tractography in treatment planning for stereotactic radiosurgery. Radiol Phys Technol, 10, 507-14, 2017.
6) Stewart FA, et al.: ICRP Publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs-threshold doses for tissue reactions in a radiation protection context. Ann ICRP, 41, 1-322, 2012.
7) Mayo C, et al.: Radiation dose-volume effects of optic nerves and chiasm. Int J Radiat Oncol Biol Phys, 76 (3 Suppl), S28-35, 2010.
8) Kanda Y: Investigation of the freely available easy-to-use software 'EZR' for medical statistics. Bone Marrow Transplant, 48, 452-8, 2013.
9) Minamoto A, et al.: Cataract in atomic bomb survivors. Int J Radiat Biol, 80, 339-45, 2004.
10) George R. Merriam, Jr. : A Clinical Study of Radiation Cataracts. Trans Am Ophthalmol Soc, 54, 611-53, 1956.
11) Régis J, et al.: Radiosurgery with the world’s first fully robotized Leksell Gamma Knife Perfexion in clinical use: a 200-patient prospective, randomized, controlled comparison with the Gamma Knife 4C. Neurosurgery, 64, 346-55 (discussion 355-6), 2009.

Received December 25, 2017; accepted November 30, 2018

The optimal scanning method for three-dimensional T_1-weighted black-blood turbo spin-echo MRI in the aortic arch

Kenichi Nakagawa[1), Masanori Kinosada (medical doctor)[2), Takashi Tabuchi[3),
Noriyoshi Morimoto[1), Sachi Fukushima[1), Takashi Ogasahara[1), Masayuki Kumashiro[1)

1) Department of Radiological Technology, Kurashiki Central Hospital
2) Department of Neurosurgery, Kurashiki Central Hospital
3) Department of Medical Technology, Kurashiki Central Hospital

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 798: 29-33, 2019.

Key words: aortic arch, black blood, plaque, aortogenic embolism, TEE

【Abstract】

Aortic arch plaques visualized using transesophageal echocardiography (TEE) are at risk for brain embolism. However, TEE is not suitable for all patients. Therefore, we focused on scan of MRI with T_1-weighted (T_1w) black blood turbo spin-echo (TSE) imaging. This study aimed to clarify the optimal scanning method for 3D T_1w black-blood TSE imaging in the aortic arch. Five healthy volunteers (mean age, 33.8 years; range, 25.0 to 57.0 years) participated in this study. We obtained Institutional Review Board approval and the informed consent of all subjects. All experiments were acquired by volume isotropic TSE acquisition (VISTA) with anti-DRIVE using a 1.5-T magnetic resonance scanner. The study protocol was divided on the basis of two aims: 1) To evaluate the combinations of six patterns of phase direction with and without electrocardiography (ECG) and navigator echo, and 2) to compare the ECG during systole and diastole to determine the optimal trigger timing. We determined that the combination of phase direction foot-head (FH), ECG, and navigator echo was the best scanning method. Furthermore, the optimal trigger timing was during diastole, which showed lesser movement of the vessel wall than during systole. Our results suggest that 3D T_1W BB-TSE with anti-DRIVE using the diastolic trigger timing by ECG-gating and navigator echo respiratory gating in the aortic arch can provide beneficial information for clinical practice.

1. Introduction

Complex atherosclerotic plaques include irregular surface plaques, ulcerated plaques, and mobile plaques [1), 2)]. Complex plaques that are observed in the aortic arch on transesophageal echocardiography (TEE) are at high risk for aortogenic brain embolism [3)-8)]. However, TEE, which is associated with a number of complications and contraindications, is not suitable for all patients [9)].

However, in the examination of carotid plaques, magnetic resonance imaging (MRI) can be used for the diagnosis of plaque components based on MR contrast [10), 11)]. Unstable carotid plaques are characterized by a fibrous cap, atheroma, and intraplaque hemorrhage. In addition, high-intensity plaques on T_1-weighted black blood (T_1W BB) MRI are considered a useful finding in assessing unstable plaques [12)-14)].

Therefore, we focused on the black blood image of MRI as an adjunct diagnostic modality for complex plaques of the aortic arch that are difficult to observe owing to multiple artifacts. To address these problems, we devised a scanning methodology using three-dimensional T_1-weighted black-blood turbo spin-echo (3D T_1W BB-TSE) MRI in the aortic arch. The aim of this study was to clarify the optimal scanning method for 3D T_1W BB-TSE.

2. Materials and Methods

2.1 Patients

Five healthy volunteers (mean age, 33.8 years; range, 25.0 to 57.0) participated in this study. We obtained Institutional Review Board approval and informed consent from all participants.

2.2 MR imaging protocol

All scans were performed on a 1.5-Tesla MR scanner (Ingenia R5-2; Philips Healthcare, Best, The Netherlands) using a 15-channel ds Torso coil as the receiver. All experiments were acquired by volume isotropic TSE acquisition (VISTA) with anti-driven-equilibrium post-pulse (anti-DRIVE) [15), 16)]. The parameters for VISTA with anti-DRIVE were as follows: repetition time (TR), 1 beat; echo time (TE), 24 ms; field of view (FOV), 260*260*70 mm; acquisition matrix, 1.1*1.1*4 mm; reconstruction matrix, 0.55*0.55*2 mm; refocusing flip angle, 30°; TSE factor, 25; start up echo, 4; number of signals averaged (NSA), 1. The fat saturation pulse used spectral attenuated inversion recovery (SPAIR).

2.3 Study protocol and analysis

We obtained 3D T_1W BB-TSE images in volunteers who were asked to maintain a natural breathing style while undergoing oblique sagittal scans of the aortic arch. The study protocol consisted of two processes: first, to evaluate the combination of six patterns for phase direction anterior-posterior or foot-head (AP or FH), with and without electrocardiogram-gating (ECG-gating) and navigator echo; and then, to compare ECG-gating during systole and diastole to determine the optimal trigger timing.

Two radiological technologists had experience, more than 5 years in MRI division, and were involved in visually ranking of motion artifacts for six image patterns of phase direction. The results of the visual evaluation were converted into normal scores, and analysis by the least significant difference (LSD) method was performed on this result, and significant differences in ranking were examined [17)]. The P-value for significant difference was defined as $P<0.05$.

3. Results

Figure 1 shows the results of a visual evaluation performed using the normalized-rank method and the images obtained using six patterns of phase direction (AP or FH), with and without ECG-gating and navigator echo. A significant difference between ECG+navigator-FH and ECG+navigator-AP suggested that FH improved the motion artifacts (LSD, $P<0.05$). Moreover, differences of image qualities between ECG+navigator+FH and ECG+navigator-FH, or ECG+navigator+AP and ECG+navigator-AP indicated usefulness of navigator echo.

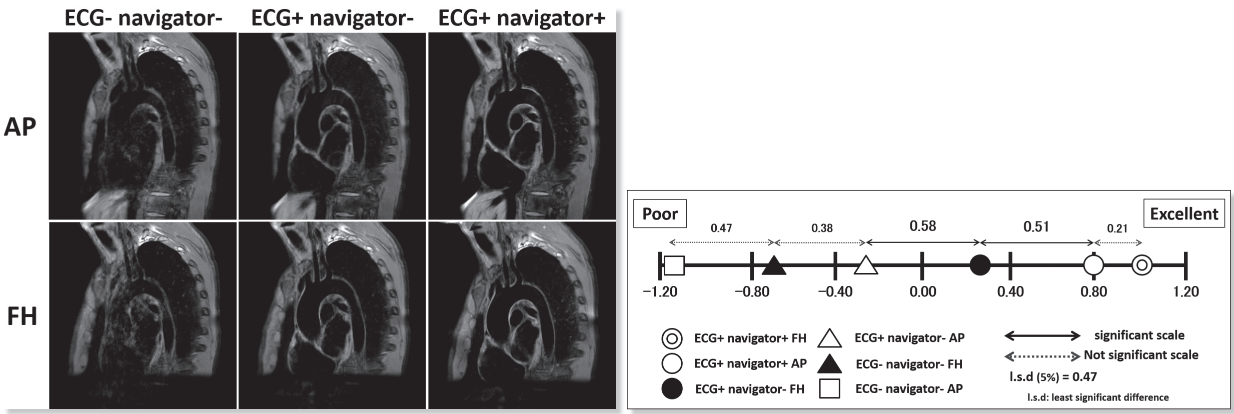


Fig.1 The anterior-posterior: AP (top row) and foot-head: FH (bottom row) phase direction. A comparison of three-dimensional T_1-weighted black-blood turbo spin-echo images obtained from the electrocardiography (ECG)- navigator-, ECG+ navigator-, and ECG+ navigator+ scans, respectively, are shown. Also shown are the results of the visual evaluation evaluated using the normalized-rank method.

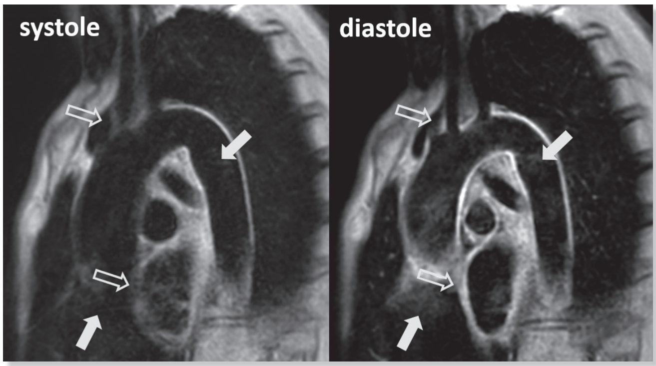


Fig.2 Comparison of the systolic images and the diastolic images obtained using navigator echo. The open arrow shows the movement of the vessel wall, and the closed arrow shows the black blood effect.

Furthermore, ECG-gating also improved the motion artifacts between ECG+navigator-FH and ECG-navigator-FH.

Further, Figure 2 shows the images obtained using ECG-gating on systole and diastole with navigator echo. ECG-gating on systole had a profound effect on both BB and motion artifacts of the ascending aorta. In contrast, low extent of flow-related signal loss was observed on ECG-gating at diastole, but motion artifacts of the vessel walls were decreased. The images from the four remaining healthy volunteers demonstrated the same results.

4. Discussion

4.1 The effect of respiration

In this study, the use of navigator echo improved the image quality by reducing the motion artifacts associated with respiration (Figure 1). Navigator echo measured the diaphragm position during free breathing, and this information allowed for triggering on the defined window within the respiratory cycle. Ample studies have demonstrated the utility of navigator echo [18]. However, it is necessary to set standards high to reduce the effect of respiration, thereby scan time is extended. In addition, oblique sagittal scanning could be problematic in image qualities because of motion artifact in the liver and the thorax. The AP and FH phase directions would reduce the motion artifact by the liver and the thorax, respectively. This study demonstrated that the FH phase direction resulted in improvement of the image quality. Setting the navigator echo around the diaphragm also improved the precision of the image of the liver without motion artifact of the liver. However, we assume that the accuracy of movement correction of the thorax was reduced due to the navigator echo directly collection at a site distant from the thorax. In other words, modifications to the setup the navigator echo would be required to decrease motion artifact of the thorax on imaging of the aortic arch.

4.2 The effect of ECG-gating

In this study, we were able to obtain good image qualities by reducing the motion artifacts associated with pulsations with ECG-gating. Furthermore, significant results were obtained for visual evaluation performed using the normalized-rank method as in Figure 1. The aortic arch generally shows severe artifacts owing to pulsations of the aortic arch [19]. However, the present results indicated that ECG-gating reduced the motion artifact of the pulsations because of synchronization with the cardiac phase. We compared the effect of setting the cardiac trigger timing to either systole or diastole. Figure 2 shows the relationship between the BB effect and the motion artifact of the ascending aorta. For the patients with reduced blood flow, the timing of ECG-gating at systole was better than diastole because of the flow void effect. In other words, regarding the BB effect, the systole is more advantageous. However, several studies have reported that mobile or ulcerated plaques and large atheromatous aortic plaques of over 4 mm in thickness on TEE can cause aortgenic brain embolism [4)-6)]. Therefore, to diagnose complex plaques in the aortic arch, a reliable method for measuring the thickness of the aortic plaques was important. Thus, the reduction of motion artifacts should be given priority over the BB effect in diagnosis of complex plaques in the aortic arch. The images in Figure 2 suggest that ECG-gating during diastole was more accurate.

4.3 Clinical images and Limitations

Figure 3 shows the clinical images of the aortic arch. We were able to obtain the high intensity plaques of the aortic arch. Furthermore, 3D T_1W BB-TSE with anti-DRIVE shows more clearly existences of multiple vulnerable plaques on the vessel wall comparing with contrast-enhanced computed tomography. However, for the patient with cardiac hypofunction or a reduced blood flow, the diastolic image might decrease the contrast of complex plaques and the BB effect, increasing possibility of incorrect diagnosis. In addition, the measurement of thickness of vessel wall in the patient with arrhythmia using this method would not shows high accuracy of images.

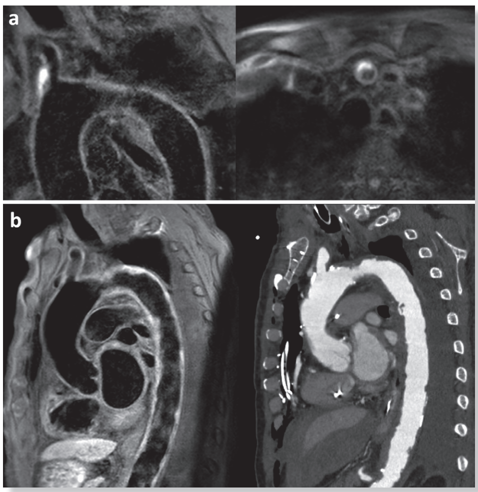


Fig.3 Clinical images of 3D T_1W black blood-TSE with anti-driven-equilibrium post-pulse (3D T_1W BB-TSE with anti-DRIVE) in the aortic arch when using the diastolic trigger timing with ECG-gating and navigator echo respiratory gating. On 3D T_1W BB-TSE with anti-DRIVE (a), the high intensity plaque of brachiocephalic artery is seen. A comparison between 3D T_1W BB-TSE with anti-DRIVE and contrast-enhanced computed tomography (CECT) (b), 3D T_1W BB-TSE with anti-DRIVE shows multiple vulnerable plaques on the vessel wall more clearly than CECT.

5. Conclusion

Our results suggest that 3D T_1W BB-TSE with anti-driven-equilibrium post-pulse in the aortic arch could provide beneficial information for clinical practice when using the diastolic trigger timing with ECG-gating and navigator echo respiratory gating.

Acknowledgements

We sincerely thank the RTs in the Department of Radiological Technology, Kurashiki Central Hospital.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1) Di Tullio MR, Sacco RL, et al.: Aortic atheromas and acute ischemic stroke: a transesophageal echocardiographic study in an ethnically mixed population. Neurology, 46, 1560-1566, 1996.
2) Di Tullio MR, et al.: Aortic atheroma morphology and the risk of ischemic stroke in a multiethnic population. Am Heart J, 139, 329-336, 2000.
3) Shimada Y, et al.: Aging, aortic arch calcification, and multiple brain infarcts are associated with aortogenic brain embolism. Cerebrovascular diseases, 35 (3), 282-290, 2013.
4) Okuzumi A, et al.: Impact of low-density lipoprotein to high-density lipoprotein ratio on aortic arch atherosclerosis in unexplained stroke. Journal of the Neurological Sciences, 326, 83-88, 2013.
5) Aortogenic embolism and paradoxical embolism due to patent foramen ovale and deep vein thrombosis. Japanese Journal of Neurosurgery, 17 (12), 901-908, 2008.

6) Amarenco P, et al.: Atherosclerotic disease of the aortic arch and the risk of ischemic stroke. N Engl J MED, 331, 1474-1479, 1994.
7) Sugioka K, et al.: Relationship between complex plaques detected by vascular ultrasound and plaque destabilization. Jpn J Med Ultrasonics, 37 (4), 455-462, 2010.
8) Kaneko K, et al.: The presence of the non-calcified plaques in the aortic arch closely contribute to the recurrence of atherothrombotic cerebral infarction. Shinzo, 40 (1), 24-33, 2008.
9) Exploration for Embolic Sources by Transesophageal Echo Cardiography. Neurosonology, 19 (3), 132-146, 2006.
10) Watanabe Y, et al.: MR plaque imaging of the carotid artery. Neuroradiology, 52, 253-274, 2010.
11) Yoshida Y, et al.: Characterization of Carotid Atherosclerosis and Detection of Soft Plaque with Use of Black-Blood MR Imaging. AJNR Am J Neuroradiol, 29, 868-874, 2008.
12) Horie T, et al.: Improved visualization of long-axis black-blood imaging of the carotid arteries using phase sensitive inversion recovery combined with 3D IR-T_1TFE. Japanese Journal of Radiological Technology, 67 (8), 888-894, 2011.
13) Nakamura M, et al.: Volumetric black blood angiography by low refocusing flip angle 3D turbo spin echo in the intracranial vertebrobasilar artery. JJMRM, 31 (4), 187-197, 2011.
14) Nakagawa K, et al.: Optimization of black blood cine for mobile plaque. Japanese Journal of Radiological Technology, 69 (11), 1274-1280, 2013.
15) Ogawa M, et al.: Fundamental study of three-dimensional fast spin-echo imaging with spoiled equilibrium pulse. Japanese Journal of Radiological Technology, 73 (1), 26-32, 2017.
16) Yoneyama M, et al.: Improvement of T_1 Contrast in Whole-brain Black-blood Imaging using Motion-sensitized Driven-equilibrium Prepared 3D Turbo Spin Echo (3D MSDE-TSE). Magn Reson Med Sci, 13 (1), 61-65, 2014.
17) Nakamae M.: Study of the Reliability of Visual Evaluation by the Ranking Method: Analysis of Ordinal Scale and Psychological Scaling Using the Normalized-rank Approach. Japanese Journal of Radiological Technology, 56 (5), 725-730, 2000.
18) Wang Y, et al.: Navigator-echo-based real-time respiratory gating and trigger for reduction of respiration effects in three-dimensional coronary MR angiography. Radiology, 198 (1), 55-60,1996.
19) Jonathan SL, et al.: Three-dimensional time-of-flight MR Angiography; Applications in the abdomen and thorax. Radiology, 179, 261-264, 1991.

Received July 17, 2018; accepted January 25, 2019

Evaluation of fat-suppression effects on ankle magnetic resonance imaging: Trial of improvement of image quality by changing the posture

Hiromi Usui[1)], Yuichi Nakai[2)], Chikara Noda[2), 3)], Hisaya Sato[1), 3)], Kyoichi Kato[3), 4)]

1) Department of Radiological Technology, Showa University Hospital
2) Department of Radiological Technology, Showa University Northern Yokohama Hospital
3) Showa University Graduate School of Health Science
4) Department of Unification Radiological Technology, Showa University

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 799: 26-31, 2019.

Key words: Fat suppression, Positioning method, Ankle

【Abstract】
Fat-suppression images are useful for imaging diagnosis. The Chemical Shift Selective saturation is susceptible to magnetic field inhomogeneities and can often be insufficient in usefulness for the feet and neck regions, which are particularly irregular in shape. The fat-suppression effect can be improved by placing a Sat Pad to correct the shape irregularities. However, there are many images of sprains and fractures in the feet, and placing a heavy Sat Pad will exert pressure on the injured part, which may interfere with healing. The aims of this study were to compare the use of Sat Pad and the method of changing the angle of feet devised in this study and to evaluate the improvement effect of fat-saturation defects.

Introduction

The most frequent form of sports injury is a sprained ankle [1)]. A sprain refers to damage to the complex ligaments or tendons of the ankle. Assessing a sprain requires differentiating it from fifth metatarsal fractures or dislocations of tendons of the peroneus muscles, which show similar symptoms as a sprain [1)]. Major factors contributing to a sprained ankle include osteochondritis dissecans, an arthrophyte, subtalar joints, and midfoot sprains, which should be assessed. Damage to the complex tendons and ligaments and early-stage osteochondritis dissecans often cannot be diagnosed using X-ray imaging alone. As the ankle is composed of muscles, fat, bone marrow, and other soft tissues, diagnostic magnetic resonance imaging (MRI), which offers excellent tissue contrast and qualitative diagnosis, is useful [2)]. Fat suppression is performed on images to identify lesions in the adipose tissue or fatty bone marrow to ascertain the spread of lesions and to mitigate chemical-shift artifacts [3)]. Methods of fat suppression include frequency subtraction, phase subtraction, and T_1 relaxation time subtraction. However, a form of frequency-selective fat suppression imaging called Chemical Shift Selective (CHESS) saturation, which can be included for all sequences, is often used [2)]. This method applies the differences in resonance frequencies between water and fat to selectively saturate fat signals, thus enabling correct suppression of the fat component of the frequency band [4)]. T_1-weighted images (T_1WIs) that are contrast-enhanced with the CHESS technique are also useful for suppressing the bone marrow fat in inflammatory lesions inside the bone or contacting bone [5)]. However, it is easily affected by an uneven magnetic field, making the fat suppression effects also likely to be uneven. In particular, because 3-T MRI devices have greater magnetization vectors compared to low-magnetic-field devices, the uneven magnetostatic field and uneven local magnetic field tend to cause uneven fat suppression effects in the foot [6] (Fig.1).

Disturbances to the local magnetostatic field during MRI can be reduced by placing a Sat Pad [7] (Sat Pad, West Chester, PA), which is a magnetic resonance device with a magnetic susceptibility close to that of the human body, in the periphery of the subject in order to reduce magnetic susceptibility artifacts caused by the uneven local magnetic field resulting from differences in the magnetic susceptibility between the subject and the surrounding air. Moriya et al. reported [8, 9] that arranging a tailor-made Sat Pad on the neck to compensate for irregularly shaped body parts yields improved fat suppression compared to commercially available Sat Pads. Applying the tailor-made pad to the ankle, which is also irregularly shaped, is expected to make magnetic susceptibility more uniform. In clinical settings, however, adding weight to an unstable sprained ankle because of ligament damage or fracture increases the risk of delayed healing or worsening of the patient's condition [10]. Therefore, it is important to investigate factors that can improve fat suppression effects with little load on the patient. Because the arrangement of the ankle relative to the magnetostatic field is thought to disturb the magnetic field, it would be useful to investigate methods of positioning the ankle so as to prevent disturbing the magnetic susceptibility. Therefore, we compared patient positions using a tailor-made pad, which is believed to improve fat suppression, and report the useful positions for improving fat suppression (Fig.1).

Fig.1 Image of poor fat suppression in the foot by Chemical Shift Selective

1. Subjects and equipment used

The device used was the MAGNETOM Trio, A Tim 3T (Siemens, Erlangen, Germany) with a head-matrix oil (12 channels) for the head as the receiving coil. A tailor-made phantom (Fig.2) was created by molding agarose (resembling the parenchymal tissue) into the L shape, imitating the ankle, and solidifying salad oil (resembling adipose tissue) around it. For the tailor-made pad, rice was placed in a plastic bag.

The subjects were ten healthy volunteers, including seven men and three women, aged 24-35 years, with a mean age of 28 years, who were approved by our hospital's ethics committee and consented to the present study (Fig.2).

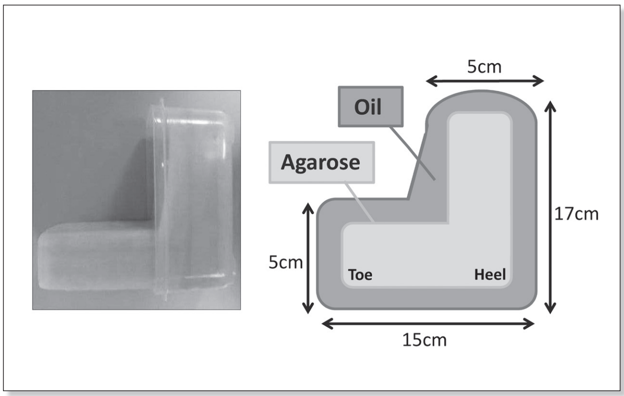


Fig.2 Appearance and composition of the tailor-made phantom

2. Imaging conditions

T_1WIs were obtained with fat suppression under high-speed spin echo (SE). The imaging parameters were: repetition time (TR), 600 ms; echo time (TE), 5.8 ms; bandwidth, 454 Hz/

pixel; turbo factor, 3; slice thickness, 5.0 mm; matrix size, 166 × 256; field of view, 190 mm; 15 sagittal slices. The fat suppression method used was the CHESS technique.

3. Methods

Visual assessment was performed by five clinical radiologists with at least 5 years of experience using MRI. The method of assessment was to divide the foot into seven segments and visually assess each segment, rating them as follows: 2 points for evenly applied fat-suppression effects, 1 point for poor fat suppression of less than 50% of the segment, and 0 point for poor fat suppression in 50% or more of the segment (Fig.3).

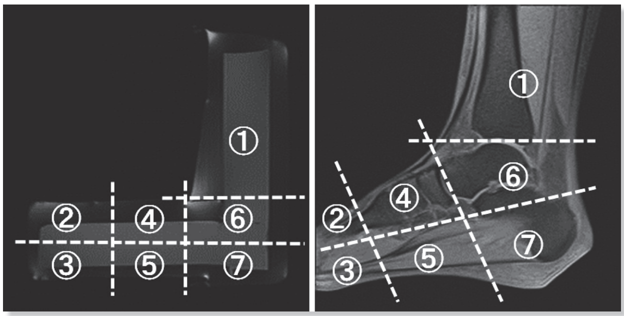


Fig.3 Segmenting of the phantom and foot in the visual assessment

3-1 Optimal arrangement of the tailor-made pad

Our standard positioning for ankle MRI is the knee joint extended and the ankle dorsiflexed at 90° (Fig.4). An L-shaped phantom was created in this position. The tailor-made pad was arranged on this phantom, and T_1WIs were acquired using CHESS to study the changes in fat-suppression effects. There was a total of 8 positions in which the tailor-made pad was placed: no pad; the pad only at the dorsum, sole, or heel; and pads in a combination of locations (Fig.5).

The resulting images were assessed visually for the optimal arrangement of the tailor-made pad. The resonance frequencies with the optimal tailor-made pad placement obtained from the visual assessment were also compared with the absence of the tailor-made pad (Figs.4, 5).

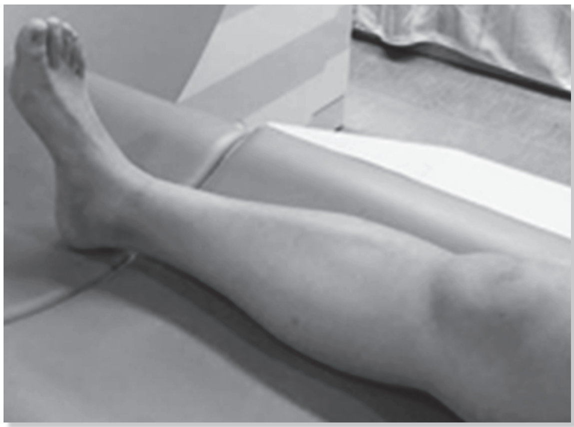


Fig.4 Conventional foot positioning on magnetic resonance imaging: knee extended, sole flexed

Combination	
i	no Pad
ii	1
iii	12
iv	123
v	4
vi	5
vii	1234
viii	12345

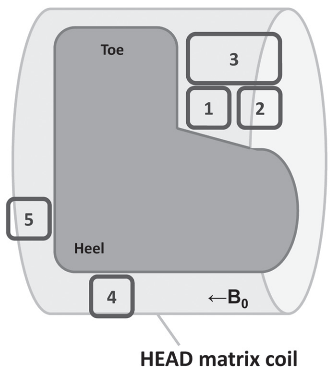


Fig.5 Combinations of pad placement methods

3-2 Considerations for the optimal position

Sagittal T_1WIs of the phantom placed at different angles were acquired using CHESS to study the changes in fat-suppression effects. The angle of arrangement of the phantom was changed to have the angle formed by the bed and lower leg move 5° at a time from 0° to 45° (Fig.6).

The resulting images were visually assessed to find the optimal angle for the angle formed by the bed and lower leg.

The resonance frequency captured with the optimal angle as obtained from the visual assessment was compared with that obtained with conventional positioning (Fig.6).

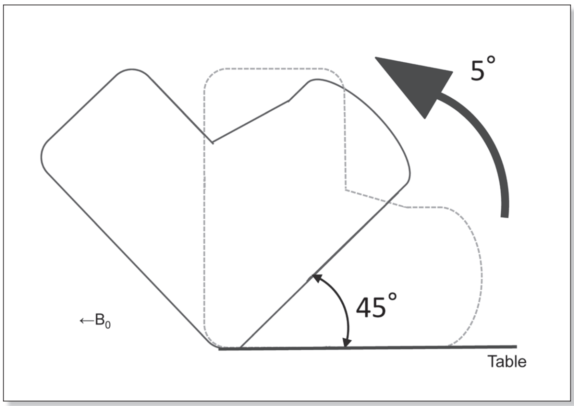


Fig.6 Changes in the angle formed by the lower leg and bed

3-3 Comparison of phantom images with tailor-made pad use and altered positioning

Images were visually assessed to compare differences between the tailor-made pad and altered positions.

3-4 Comparison of images from healthy volunteers

The ten volunteers were imaged with optimal tailor-made pad placement and optimal positioning as obtained from the results and visually assessed.

3-5 Changes in the center frequency with modified positioning

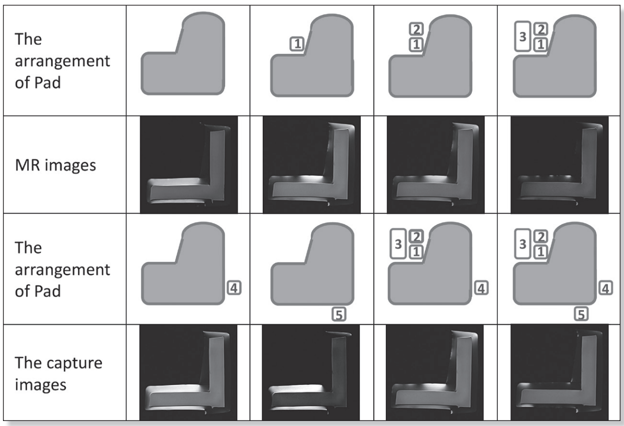
To investigate how changing the angle of the foot affects fat suppression, the set range of shimming during imaging was changed, and the center frequency at the time was measured. There were five set ranges of shimming: whole, foot, lower leg, from the foot to the heel, and from the lower leg to the heel (Fig.7).

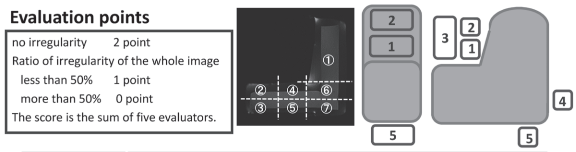
4. Results

4-1 Optimal arrangement of the tailor-made pad

Where the tailor-made pad was not used, fat-suppression effects of the dorsum-, sole-, and toe tip-like portions of the tailor-made phantom were poor (Table 1). When the tailor-made pad covered the dorsum, which is irregularly shaped, the visual assessment had a total score of 50 points, showing the greatest improve-

Table 1 Sat Pad placement methods and magnetic resonance images





Combination of pad		Degree of fat suppression effect in each segment							
		①	②	③	④	⑤	⑥	⑦	total
i	no Pad	8	0	0	0	0	7	9	24
ii	1	3	3	2	0	2	4	9	23
iii	12	4	4	2	0	2	6	7	25
iv	123	7	6	6	7	5	10	9	50
v	4	7	0	0	0	0	7	9	23
vi	5	9	0	0	0	0	9	9	27
vii	1234	4	3	3	0	3	6	9	28
viii	12345	7	4	3	8	7	8	7	44

Fig.8 Visual assessment based on pad placement

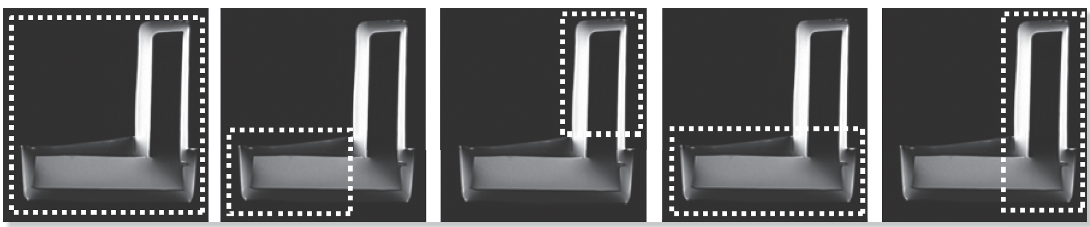


Fig.7 Seetting the range of shimming during center frequency measurement

ment in fat-suppression effects (Fig.8).

For the resonance frequency without the tailor-made pad, the water signal was separated into two halves. However, with optimal placement of the tailor-made pad as obtained from visual assessment, there was only one water signal, and the water and fat signals were separated (Figs.8, 9; Table 1).

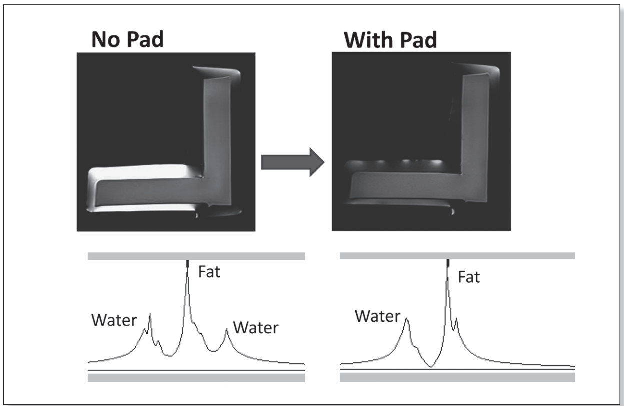


Fig.9 Comparison of captured images and resonance frequencies (with pad placement)

4-2 Considerations for the optimal position

Fat-suppression effects were poor while imaging in the conventional position for the dorsum, sole, and toe tips of the phantom, and improved when the angle formed by the lower leg and the bed was 35° to 45° (Table 2).

With conventional positioning, the water signal of the resonance frequency was separated into two halves. However, when the angle formed by the lower leg and bed was between 35° and 45°, there was one water signal, and the water and fat signals were separated (Fig.10; Table 2).

Table 2 Comparison of images with changes in the foot angle

The angle of phantom	0°	5°	10°	15°	20°
MR images					
The angle of phantom	25°	30°	35°	40°	45°
MR images					

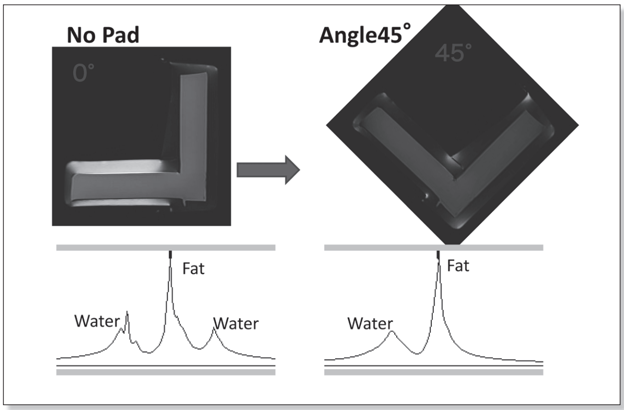


Fig.10 Comparison of images and resonance frequencies with changes in the angle formed by the lower leg and bed

4-3 Comparison of phantom images with tailor-made pad use and with altered positioning

Overall fat-suppression effects on the foot were uniform with the tailor-made pad and the positioning angle was 45° (Fig.11).

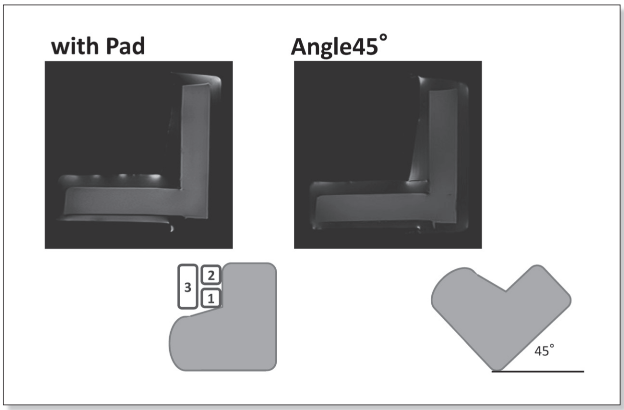
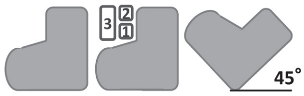


Fig.11 Image comparison with pad use and changes in the angle formed by the lower leg and bed

4-4 Comparison of images of healthy volunteers

Among the healthy volunteers, when the positioning was changed, the visual assessment score was a total of 33 points, which was the highest score (Fig.12). Fat suppression was uniformly applied to the foot as a whole when the positioning changed, but when the tailor-made pad was placed, there were poor fat suppression effects applied from the top of the foot to the sole (Fig.13).



		no Pad	with Pad	leg angle
i	volunteer1	0	2	3
ii	2	0	3	4
iii	3	0	3	4
iv	4	0	2	2
v	5	0	1	3
vi	6	0	3	3
vii	7	0	3	3
viii	8	0	2	4
ix	9	2	4	4
x	10	0	1	3
	Total	2	24	33

Evaluation points

no irregularity 2 point
Ratio of irregularity of the whole image
less than 50% 1 point
more than 50% 0 point

Fig.12 Visual assessment of volunteer images without pad, with pad, and with changes in the angle formed by the lower leg and bed

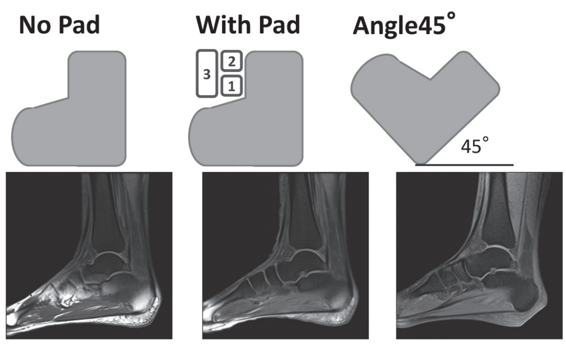


Fig.13 Image comparison with pad, without pad, and with changes to the angle formed by the lower leg and bed

4-5 Changes in the center frequency with modified positioning

From 35° to 45°, when the fat-suppression effects had improved, the results showed less variance in the center frequency from the range of shimming (Fig.14).

5. Discussion

As the foot has an irregular shape, which results in poor fat suppression when placed in a magnetostatic field, correcting the shape of the

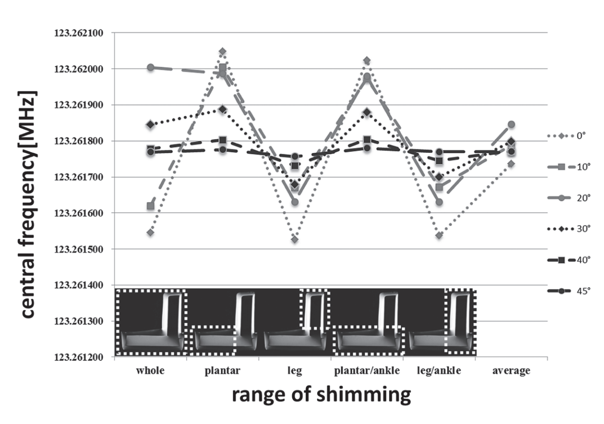


Fig.14 Trends in the center frequency with changes in the shimming range

ankle with a tailor-made pad improves fat-suppression effects. The tailor-made pad achieved a uniform magnetic field near the phantom, suggesting that the frequency distributions of water and fat changed, producing a more uniform fat-suppressed image. However, when the tailor-made pad was placed on healthy volunteers, fat-suppression effects were inadequate. This may be because the foot and tailor-made pad have different shapes, causing a separating layer of air to remain between them, rendering the magnetic susceptibility non-uniform.

We had thought that changing the patient's position with the tailor-made pad may improve the fat-suppression effects. The fat-suppression effects improved when the angle formed by the lower leg and bed was 35° to 45°. This implies that placing the foot parallel to the magnetostatic field improved the uniformity of the magnetic field.

Changing the position is believed to have stabilized the center frequency of the foot and improve the fat-suppression effects.

The method of changing the position is may have yielded a consistent improvement, regardless of individual differences in the shape of the foot, as with the placement of the tailor-made pad, because imaging was performed with overall changes to the foot.

6. Conclusion

In ankle MRI using the CHESS technique, the non-uniform magnetic field has lowered the quality of fat-suppression effects, but placing a recently recommended tailor-made pad [7] on the dorsum brought about improvement in fat-suppression effects. However, when there was a separating layer of air between the foot and the tailor-made pad, the uniformity of the magnetic field was compromised, resulting in inadequate fat-suppression effects. Introducing an angle of 35° to 45° between the lower leg and the bed in the present study yielded better fat-suppression effects compared to using a tailor-made pad, allowing for a more uniform magnetic field due to the placement of the foot pointing directly at the magnetostatic field. This suggests that changing the patient's position could enable consistent fat-suppression effects in the clinical practice, regardless of the shape of the foot and without applying the weight of a tailor-made pad to an injured foot.

Acknowledgments

We are grateful to the engineers in the radiation department of Showa University Hospital for their valuable opinions as well as their co-operation in image assessment, data collection, and more.

The Abstract of this paper was published at the autumn academic conference of the Japanese Society of Radiological Technology (October 2012, Tokyo) and at the 99th North American conference (December 2013, Chicago).

References

1) Kuzuhara, K. Shimamoto, H.: Management of Ankle Sprains. Journal of Aichi Toho University 2006; 35(2): 1-12 (in Japanese).
2) Suzuki, N.: Optimization and Clinical Application of Fat Suppression MRI Using CHESS and STIR. Japanese Society of Radiological Technology 25th autumn academic conference. 1997; 53(9): 1418 (in Japanese).
3) Obinata, K. Ozawa, K. Takahashi, Y. et al.: Fat suppression. Hitachi Medical Corporation MEDIX 2009; 50: 41-48 (in Japanese).
4) Kasai, T. Doi, T.: MR Imaging Technology, 2nd revised edition. Ohmsha Ltd. 2010; 288-289.
5) Kasai, T. Ogawa, N.: Medical Imaging Equipment, 1st edition. Ohmsha Ltd. 2008; 288-289.
6) Kanamori, I. Fujino, A. Niwa, M. et al.: MR practice: from basics to interpretation. 1st edition. Iryo Kagaku. 2011; 134 (in Japanese).
7) Miyagawa, T. Yasui, K.: Attempting to improve image quality in cervical MRI and cervical angiography: Clinical evaluation using Sat Pad. INNERVISION 1994; 9(11): 77-83 (in Japanese).
8) Moriya, S. Miki, Y. Yokobayashi, T. et al.: Rice pads: Novel devices for homogeneous fat suppression in the knee. Acta Radiol 2010; 51(2): 175-178.
9) Honda, T. Arai, K. Nishimura, F. et al.: The rice Sat Pad is useful in neck MRI. Tokyo Journal of Radiological Technology 2008; 30 (in Japanese).
10) Emergency Medicine, University of Fukui Hospital. Ankle sprain: “It looks like I sprained my ankle while playing volleyball”. Therapy 2008; 90(10): 2702-2704 (in Japanese).

Received November 7, 2018; accepted January 25, 2019

The effect of body thickness on image quality using either a semiconductor detector gamma camera or Anger-type gamma camera when performing a myocardial perfusion SPECT: A Phantom study

Koji Nakaya[1), 2)], Yoshifumi Nouno[2)], Ryota Kaku[3)], Hiroe Muto[1)], Kanae Matsuura[1)], Ryo Higashide[1)], Eisuke Yasuda[1)]

1) Department of Radiological Technology, Faculty of Health Science, Suzuka University of Medical Science
2) Department of Radiology, National Cerebral and Cardiovascular Center
3) Room of Radiation Technology, Aoyama General Hospital

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 800: 23-30, 2019.

Key words: myocardial perfusion SPECT, body thickness, semiconductor detector gamma camera

【Abstract】
The effect of body thickness on image quality was compared and examined for both semiconductor detector and anger-type gamma cameras using myocardial perfusion SPECT. A 1 cm defect was made in the anterior wall of the heart liver HL type phantom. Then, SPECT scans were acquired when either 0, 2, 4, or 6 cm of fat-equivalent material was wrapped around the phantom. Using the Plot Profile within ImageJ, we compared the contrast of the phantom defect with the half width or the visual conspicuity of the SPECT image. As the body thickness increased, the contrast and visual conspicuity of the phantom defect decreased for the semiconductor detector gamma camera, but the contrast and visual conspicuity of the phantom defect did not change for the Anger-type gamma camera. The full width at half maximum of the phantom defect did not change for both devices when the body thickness increased. Because the semiconductor detector gamma camera has higher resolution and sensitivity than the Anger-type gamma camera, the image quality depends on body thickness.

1. Introduction

Myocardial perfusion single photon emission computed tomography (MP SPECT; MPS) is affected by attenuation and scattering from fat and muscle, especially in obese patients [1). In addition, patients with thick bodies have a large distance between the site of radioisotope accumulation and the collimator, which affects the image quality. In recent years, the number of facilities where MPS is performed, not only by conventional Anger-type gamma cameras (AGC) but also by SPECT devices equipped with semiconductor detectors (semiconductor detector gamma cameras (SDGC)), has increased [2). Semiconductor detectors have higher resolution and sensitivity than scintillator detectors used in conventional AGC. In addition, the acquisition time is short, and the image quality is excellent [2-6) for SDGC. Furthermore, because the SDGC has high resolution and sensitivity, SPECT imaging can be performed using less radioisotope [7, 8). However, even SDGC image quality is deteriorated by obesity. In this study, we would like to determine which of the two devices, AGC or SDGC, is more affected by obesity. Therefore, the effect of body thickness on image quality for SDGC and AGC was compared using a phantom experiment.

2. Materials and Methods

2-1. Creating a phantom

In this study, a cardiac liver HL phantom (Kyoto Kagaku Co., Ltd., Kyoto, Japan) was used. A 1 cm defect was created in the anterior wall of the myocardium. Fig.1 shows the

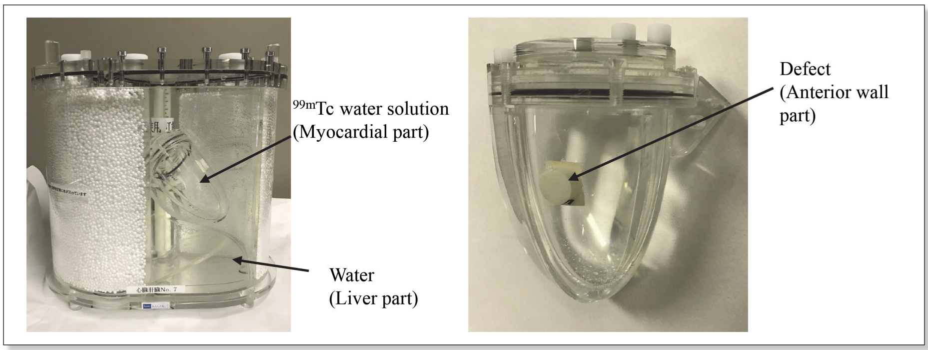


Fig.1-1 Heart liver phantom

Fig.1-2 Defect part of myocardium phantom

Fig.1 Cardiac liver phantom and defective part of the anterior wall

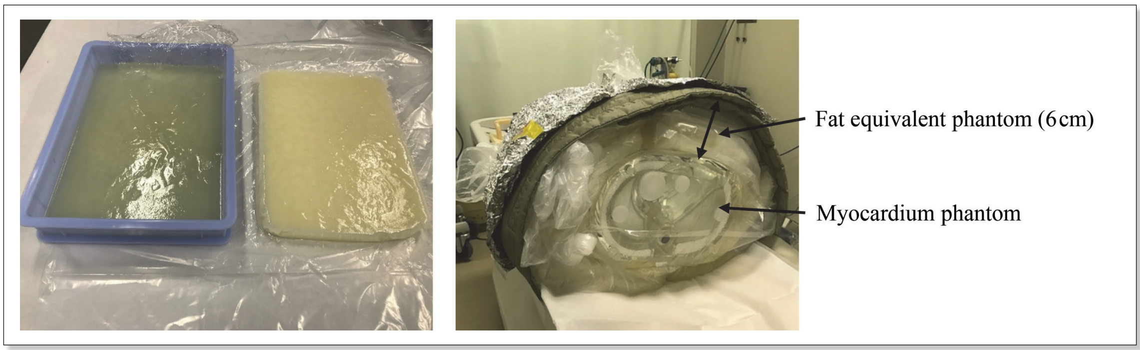


Fig.2-1 Image of fat equivalent phantom (2 cm)

Fig.2-2 Image of a myocardium phantom with a body thickness of 6 cm wrapped with a fat equivalent phantom

Fig.2 Image of body thick myocardium phantom wrapped with fat equivalent phantom and fat equivalent phantom

Description of Fig.2-1
The image on the left is an image that solidifies the oil contained in the plastic container.
The image on the right is a phantom image from which hardened oil is taken out.

cardiac liver phantom with the missing part of the anterior wall. A 120 ml aqueous solution of ^{99m}Tc with a radioactivity concentration of 0.123 MBq/mL was enclosed in the myocardium. This concentration is about 2% of the drug accumulated in the myocardium in ^{99m}Tc-methyl isobutyl isonitrile (^{99m}Tc-SESTA MIBI) used clinically[9]. Based on this, it was hypothesized that 2% accumulation in the myocardium occurs 60 minutes after administration of 740 MBq. In this study, the effect of body thickness was investigated without considering scattered radiation. Therefore, lungs, mediastinum, and liver were filled with distilled water to eliminate the potential for scattered radiation from other organs. A fat-equivalent phantom simulating different body thicknesses was prepared by hardening canola oil with an oil hardener. Heated oil was added to a plastic container (length 30 cm, width 21 cm, and height 8 cm) and solidified to create a fat-equivalent phantom simulating a body thickness of 2 cm. Four layers of fat-equivalent phantom (length 30 cm, width 21 cm, and height 2 cm) were made. Different numbers of layers were stacked and wrapped around the outer periphery of a cardiac liver HL phantom to create a body thickness of either 0, 2, 4 or 6 cm. Fig.2 shows the myocardial phantom wrapped with a fat-equivalent phantom with a body thickness of 6 cm.

2-2. SPECT acquisition

Different thicknesses of the fat-equivalent phantom, 0, 2, 4, and 6 cm, were wrapped around the myocardial phantom and SPECT

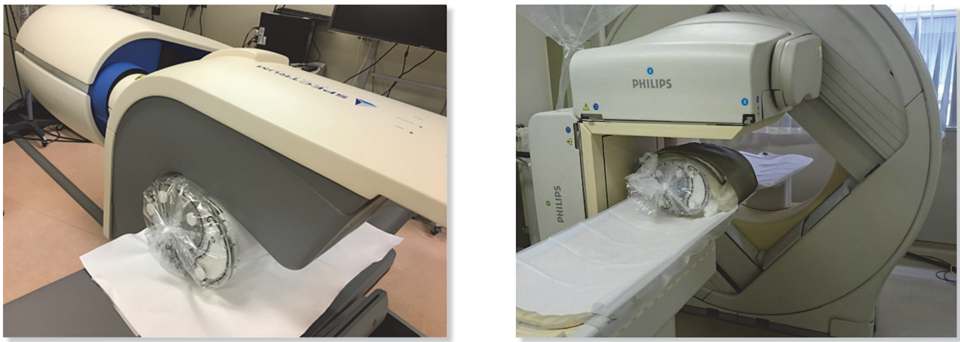


Fig.3-1 An image obtained by collecting myocardial phantom of body thickness 0 cm with D-SPECT

Fig.3-2 An image obtained by collecting myocardial phantom of body thickness 2 cm with Brightview

Fig.3 Image of appearance when phantom is collected in both devices

scanned using both a SDGC and an AGC. Fig.3 shows the experimental set-up. The SDGC used a D-SPECT (Spectrum Dynamics, Caesarea, Israel) with a wide-angle tungsten collimator (parallel hall) and cadmium-zinc-telluride (CZT) semiconductor detectors. An acquisition time of 4 minutes 5 seconds, which corresponded to 1.5 million counts in the left ventricle (LV counts) when a fat equivalent phantom was not present (0 cm), was used for all body thicknesses. The energy window was 140 keV ± 10%, the matrix size was 16 × 64/column, the field of view (FOV) was 160 mm, the magnification was 1x, and the pixel size was 2.26 mm. The projections were reconstructed using 3D ordered-subset expectation maximization (OSEM-3D) with 7 iterations and 32 subsets. Attenuation correction and scatter correction were not used.

The AGC used Brightview (Philips, Amsterdam, the Netherlands) of the two-detector type. The collimator was placed at 90° and a cardiac high-resolution collimator (CHR) was used. The data was collected in one direction for 50 seconds (50 sec/step), the rotation angle was 6°, and data in the 180° direction was collected. The energy window was 140 keV ± 10%, the matrix size was 64 × 64, the magnification was 1.85, and the pixel size was 2.26 mm. The projections were reconstructed using maximum likelihood expectation maximization method (MLEM method) using 15 subsets and 1 subset. The preprocessing filter used was a Butterworth filter (order, 10; cut-off frequency, 0.50 cycle/cm). Attenuation correction and scatter correction were not used.

The imaging protocol and reconstruction conditions for both the SDGC and AGC were consistent with those used clinically at the National Cardiovascular Center hospital.

2-3. Defect contrast ratio

A total of three cross sections were extracted: the slice centered on the defect of the short-axis SPECT image, and the slices before and after the defect. A region of interest (ROI) was drawn using ImageJ (National Institutes of Health, Bethesda, America) for the cross-section centered on the myocardial and the defect. An accumulation intensity profile curve of pixel value was created from the ROI using the Plot Profile function in ImageJ. Fig.4 shows the ROI setting and the accumulation intensity curve of pixel values created from that ROI. The contrast ratio was calculated by the following formula (1), with the minimum pixel value of the defect obtained from the profile curve as the minimum value and the maximum pixel value at the of the surrounding myocardial thickness as the maximum value.

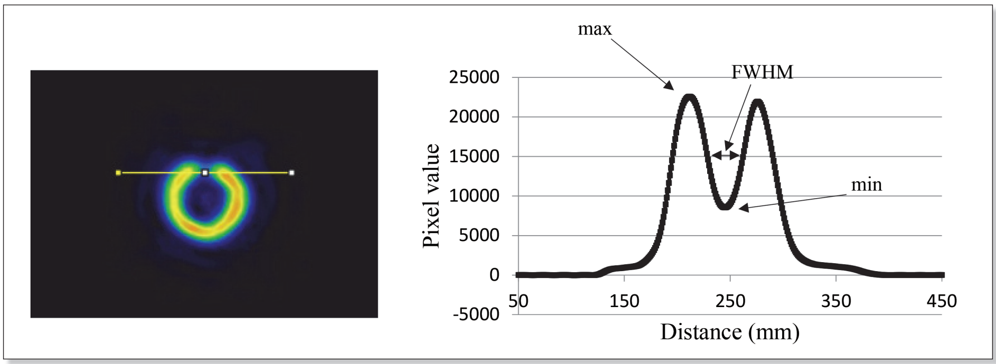


Fig.4-1　Setting of ROI　　Fig.4-2　Profile curve

Fig.4　How to set Region of Interest (ROI) centered on center part of myocardial and defect part and creation of profile curve

The profile curve in Fig.4-2 is a graph of D-SPECT collected case (thickness is 0 cm).
Max is the pixel value at the center of the myocardium. Min is the pixel value at the center of the defect. Full width at half maximum (FWHM) is the distance (mm) on the horizontal axis at the midpoint between max and min.

$$\text{Defect contrast ratio} = \frac{\textit{maximum-minimum}}{\textit{maximum+minimum}} \quad (1)$$

Pixel value of missing part: minimum
Pixel value at the center of myocardial thickness: maximum

2-4. Full width at half maximum of the defect

The full width at half maximum (FWHM) was calculated as the width of the defect portion at the intermediate value between the pixel value of the missing portion of the profile curve and the central pixel value of the myocardial thickness. The FWHM of the defect for the SDGC and AGC was compared for varying body thicknesses.

2-5. Visual evaluation of the defect

Twelve radiological technologists evaluated the defect on SPECT images (short axis, vertical long axis and horizontal long axis) of each body thickness of both devices. Defects were evaluated using a 5-point scale: 1 (poor), 2 (fair), 3 (average), 4 (good), and 5 (excellent). The values were averaged and compared for each body thickness for both devices.

2-6. Statistical analysis

One-way analysis of variance (one-way ANOVA) was used to determine whether there were any statistically significant differences in contrast ratios of the defect at each body thickness, where significance was $p<0.05$. When significant differences were determined, the post-hoc Tukey test was used. The same statistical analysis was performed for FWHM and visual evaluation for each body thickness.

3. Results

3-1. Defect contrast ratio

Fig.5 shows the defect contrast ratios for each body thickness and for both gamma cameras. The defect contrast ratios (mean ± SD) for body thicknesses of 0, 2, 4, and 6 cm in D-SPECT were 0.39 ± 0.04, 0.33 ± 0.02, 0.34, and 0.27 ± 0.01, respectively. The defect contrast ratios for the D-SPECT were significantly different between 0 cm and 2 cm, 0 cm and 4 cm, and 0 cm and 6 cm ($p<0.05$). For the Brightview, the defect contrast ratios for body thicknesses of 0, 2, 4 and 6 cm were 0.21 ± 0.02, 0.23 ± 0.01, 0.22 ± 0.02, and 0.20 ± 0.02, respectively. However, there were no significant differences in the defect contrast ratios due to body thickness (n.s.).

3-2. Full width at half maximum of the defect

Fig.6 shows the FWHM of the defect for

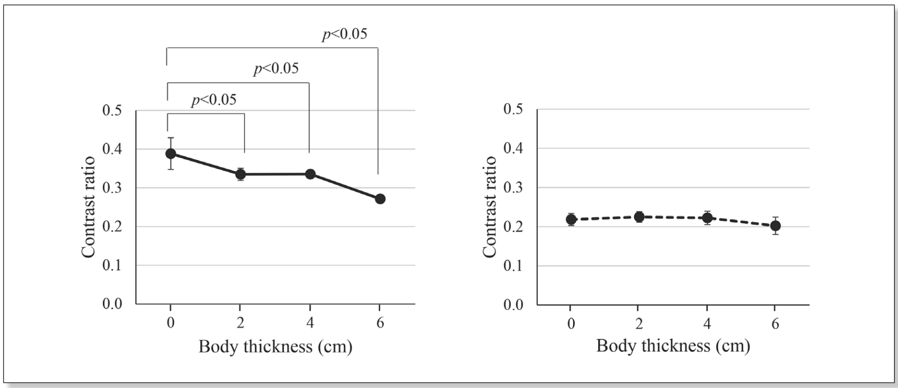


Fig.5-1 Contrast ratio of D-SPECT　　Fig.5-2 Contrast ratio of Brightview

Fig.5 Graph of the result of the contrast ratio of the defect part depending on the body thickness of both devices

One-way ANOVA was carried out for the significance test of the contrast ratio of the defect in each body thickness.
A significance level was set at p<0.05, and a significant difference was observed between body thicknesses of D-SPECT (p<0.05). In order to investigate which body thickness there is a significant difference, multiple comparison by the Tukey method was carried out.

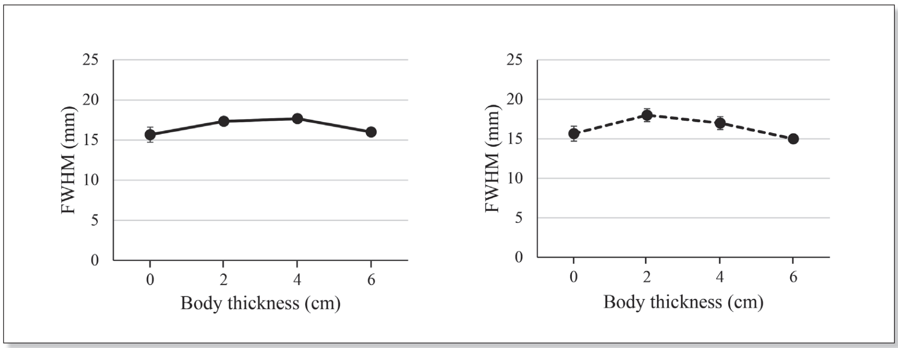


Fig.6-1 FWHM of D-SPECT　　Fig.6-2 FWHM of Brightview

Fig.6 Graph of the result of the full width at half maximum (FWHM) of the defect part depending on the body thickness of both devices

One-way ANOVA was performed for the significant difference test of FWHM of the defect part due to the difference in body thickness. The significance level was set at p<0.05, and no significant difference was observed between body thicknesses of both devices (n.s.).

varying body thicknesses for both gamma cameras. The FWHM (mean ± SD) of the defects for body thicknesses of 0, 2, 4, and 6 cm with the D-SPECT were 16 ± 0.94, 17 ± 0.47, 18 ± 0.47, and 16, respectively. However, there was no significant difference in the FWHM of the defect due to body thickness using the D-SPECT (n.s.). The FWHM of the defects with body thickness of 0, 2, 4 and 6 cm in Brightview were 16 ± 0.94, 18 ± 0.82, 17 ± 0.82, and 15 ± 0.00, respectively. However, there was no significant difference in the FWHM of the defect due to the body thickness of Brightview (n.s.).

3-3. Visual evaluation of the defect

Figs.7 and 8 show the visual evaluation results and SPECT images of the defect for each body thickness of both devices. The visual evaluations (mean ± SD) of the defects with body thickness of 0, 2, 4, and 6 cm in D-SPECT were 4.7 ± 0.42, 3.8 ± 0.60, 3.6 ± 0.69, and 3.2 ± 0.37, respectively. The visual evaluations of the defect at each body thickness on D-SPECT showed significant differences

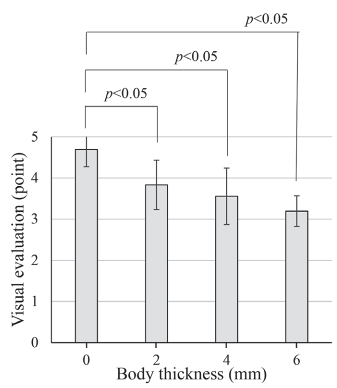


Fig.7-1 Visual evaluation of D-SPECT

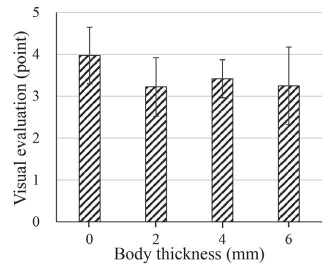


Fig.7-2 Visual evaluation of Brightview

Fig.7 Graph of visual evaluation results of defect due to body thickness of both devices

One-way ANOVA was carried out for the significance test of the visual evaluation each body thickness.
A significance level was set at $p<0.05$, and a significant difference was observed between body thicknesses of D-SPECT ($p<0.05$). In order to investigate which body thickness there is a significant difference, multiple comparison by the Tukey method was carried out.

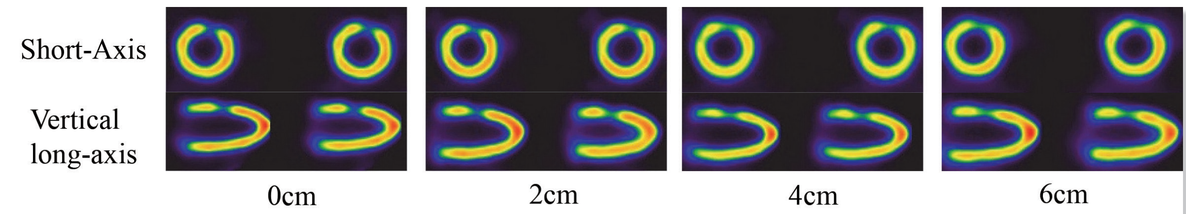


Fig.8-1 SPECT image of D-SPECT

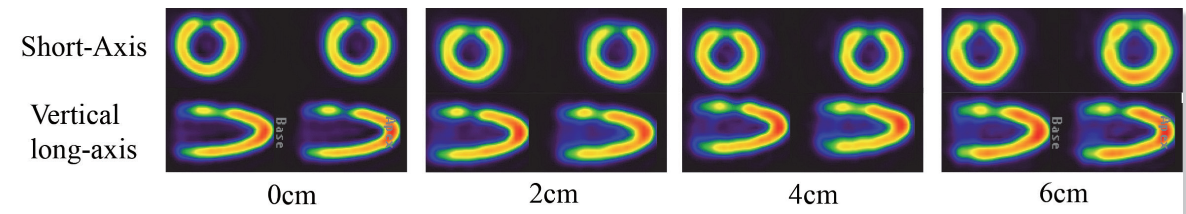


Fig.8-2 SPECT image of Brightview

Fig.8 single photon emission computed tomography (SPECT) image of the defect part due to body thickness of both devices

between 0 cm and 2 cm, 0 cm and 4 cm, and 0 cm and 6 cm ($p<0.05$). For Brightview, the visual evaluations of the defects with body thickness of 0, 2, 4, and 6 cm were 4.0 ± 0.67, 3.2 ± 0.70, 3.4 ± 0.45, and 3.3 ± 0.92, respectively. However, there were no significant differences in the visual evaluations of the defect due to the body thickness for the Brightview (n.s.).

4. Discussion

The effect of body thickness on image quality of myocardial perfusion SPECT was compared for SDGC and conventional AGC using a phantom experiment.

The defect contrast ratio for D-SPECT gradually decreased with increasing body thickness. The defect contrast ratio for a body thickness of 6 cm was significantly lower than for 0 cm

(p<0.05). In addition, the visual evaluation of defect in D-SPECT decreased with increasing body thickness, and the visual evaluation of the defect with body thicknesses of 2, 4, and 6 cm were significantly lower than that of 0 cm (p<0.05). D-SPECT's SDGC has high sensitivity and high resolution, so SPECT image was greatly attenuated and scattered by the fat equivalent phantom. Therefore, it is assumed that more attenuation and scatter lead to insufficient counts and deteriorated image quality. Hence, contrast ratio and visual evaluation decreased as the body thickness increased. For the Brightview, SPECT is collected at 50 sec/step for all body thicknesses. The acquisition time for 1.5 million LV counts was 4 minutes 5 seconds when the body thickness of D-SPECT was 0 cm. Therefore, D-SPECT was performed with this fixed acquisition time for all body thicknesses. Therefore, as the body thickness is increased, attenuation and scattering caused by the fat-equivalent phantom leads to an insufficient amount of counts. However, the acquisition of D-SPECT can be terminated either after a fixed acquisition time or after acquiring a certain amount of LV counts. Using the latter method, image quality can be improved for obese patients by increasing the acquisition time. Because the acquisition conditions used by both gamma cameras were adopted from clinical practice, both gamma cameras do not have the same counts per pixel. When acquiring with D-SPECT, the LV is placed within the dotted line as shown in Fig.9-1. This dotted line is the center of rotation during SPECT acquisition. If the LV can be placed within the dotted line, high-quality images can be acquired by taking advantage of the high-sensitivity and high-resolution characteristics of the semiconductor detector. However, as the LV deviates from the dotted line, both sensitivity and resolution decrease. When the body thickness was 6 cm, as shown in Fig.9-2, LV could not be placed within the dotted line, resulting in a contrast ratio and visual evaluation of the defect that were lower than those with a body thickness of 0 cm. However, since this device is a semiconductor detector, the average visual evaluation score of the 6 cm thick defect was 3.2 points, which is higher than average. It is possible to visually evaluate even such a thick body thickness. However, higher quality images would be provided by the semiconductor detector by placing the left ventricle within the dotted line as much as possible, especially when imaging obese patients. Since this study used a solid fat-equivalent phantom, it was not possible to collect more ideal SPECT images

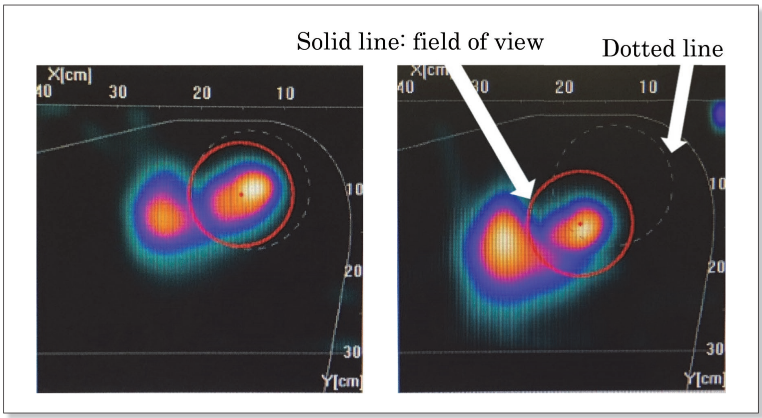


Fig.9-1 Positioning image with body thickness 0 cm

Fig.9-2 Positioning image with body thickness 6 cm

Fig.9 Positioning image of myocardium when we collected SPECT with body thickness of 0 and 6 cm in D-SPECT by moving fat to the side or to the back of the phantom. However, when SPECT is collected for obese patients in clinical examinations, positioning is performed so that the fat on the front of the chest is moved to the side and back so that the LV can be placed within the dotted line, making full use of the high image quality potential of semiconductor detectors.

Conversely for the Brightview, the contrast ratio and visual evaluation of the defect did not change with different body thicknesses (n.s.). AGCs have lower sensitivity and resolution than SDGCs, so the image quality is low even when the body thickness is 0 cm. In addition, the acquisition time was 50 sec/step, yielding enough counts even with an increase in body thickness up to 6 cm. Comparing the contrast ratio and visual evaluation of the defect in both devices, the contrast ratio of the defect was higher in the SDGC than in the AGC for all body thicknesses. Because the semiconductor detector has high sensitivity and high resolution, the image quality of the gamma camera of the semiconductor detector is better than that of the anger-type gamma camera even if the image quality decreases due to the body thickness for SDGC. To provide a high-quality image of a thick body with a SDGC, it is necessary to collect LV counts with a certain threshold value as described above.

As for the FWHM of the defect, both devices showed almost no change in the FWHM of the defect (n.s.) with increasing body thickness. In D-SPECT, as the body thickness increased, the image quality of the defect decreased; and, it was hypothesized that the FWHM would decrease as well. However, as the body thickness increased, the pixel value at the center of the myocardial thickness and the pixel value at the defect portion fluctuate as the scattering component increases. Therefore, it is assumed that the FWHM measured from the accumulation intensity profile curve did not change significantly in the 1 cm defect. For Brightview, increasing the body thickness up to 6 cm has little effect on image quality and no effect on FWHM.

In this study, a defect was created only in the anterior wall of the myocardium, and physical and visual evaluations of the defect were performed. The appearance of the defect differs depending on the location of the defect (anterior wall, lateral wall, septal wall, and inferior wall) with respect to the detector [10]. In the future, we would like to investigate the effects of image quality on each defect using both devices, depending on the body thickness. In addition to differences in defect appearance, the position of the heart may vary in patients. Such conditions as congenital heart disease may preclude placing the heart near the SPECT center of rotation. Lastly, how the degree of deviation in the X, Y, and Z-axis of the SPECT center of rotation affects image quality should also be investigated.

5. Conclusion

Our results suggest that changes in body thickness have a greater effect on image quality for the SDGC than the AGC. When performing SPECT acquisition of obese patients with SDGC, the heart must be placed in the SPECT center of rotation as much as possible so that image quality does not deteriorate. It is also necessary to acquire SPECT by setting a threshold value for LV counts.

This research was presented at the 34th Japan Conference of Radiological Technologists (Yamaguchi).

6. Acknowledgments

We would like to thank and acknowledge the following: Mr. yuto Itou, Chibune General Hospital, and Mr. Keigo Yoshimura, Aizawa Hospital.

References

1) Hansen CL, et al.: Effect of patient obesity on the accuracy of thallium-201 myocardial perfusion imaging. Am J Cardiol, 85, 749-752, 2000.
2) Koji N, et al.: Comparison Between Prone and Upright Imaging of the Inferior Wall Using ^{201}TlCl Myocardial Perfusion SPECT. J Nucl Med Technol, 45, 304-308, 2017.
3) Koji N, et al.: Breathing-related body movement from the motion of the Rib Cage in Myocardial Perfusion SPECT -Using Optical Tracking System-. The japan Society of Education for Radiological Technologists, 10, 3-11, 2018.
4) Sharir T, et al.: High-speed myocardial perfusion imaging initial clinical comparison with conventional dual detector anger camera imaging. JACC Cardiovasc Imaging, 1, 156-163, 2008.
5) Erlandsson K, et al.: Performance evaluation of D-SPECT: a novel SPECT system for nuclear cardiology. Phy Med Biol, 54, 2635-2649, 2009.
6) Ryo N, et al.: Quantitative upright-supine high-speed SPECT myocardial perfusion imaging for detection of coronary artery disease: correlation with invasive coronary angiography. J Nucl Med, 51, 1724-1731, 2010.
7) Yasuhiro S, et al.: High-speed molecular imaging D-SPECT. The Japanese Society of Nuclear Cardiology, 16, 24-25, 2014.
8) Hayato I, et al.: For image acquisition method in the CZT gamma camera -Discovery NM530c-. The Japanese Society of Nuclear Cardiology, 16, 28-29, 2014.
9) Hiroyoshi F, et al: Kakuigakugijyutusouron [Introduction to Nuclear Medicine Technology], Yamashiro Printing Co., Ltd., 251-252, 2014.
10) Akihiro K, et al.: Study of defects depiction performance in the myocardial dedicated semiconductor SPECT system. Bulletin of Hokkaido University of Science, 40, 95-99, 2016.

Received November 21, 2018; accepted February 21, 2019

Examination of education for radiological protection/staff exposure reduction by occupation that radiological technologists should conduct in team medicine

Kyoichi Kato[1), Ikuko Sakurada[2), Daisuke Kittaka[1), Miwa Ohsawa[3), Kanako Numanyu[4), Koushi Sakiyama[3), Hisaya Sato[1), Ryu Ohishi[5), Chizuko Masuda[6), Hiroshi Suzuki[7), Eiichi Geshi[8)

1) Showa University Graduate school of Health Sciences
2) Department of nursing, Aomori Prefectural Central Hospital
3) Department of Radiological technology, Showa University Fujigaoka Hospital
4) Department of Radiological technology, Showa University Hospital
5) Department of Clinical engineering, Showa University Hospital
6) Showa university, Division of Nursing
7) Department of cardiology, Showa University Fujigaoka Hospital
8) School of Health sciences, Showa University

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 801: 26-34, 2019.

Key words: Radiation protection, Exposure reduction education, team medicine

【Abstract】

In the catheterization laboratory, physicians, nurses, clinical engineers, and radiological technologists are engaged in their respective duties.

However, individuals are exposed to different learning methods and have different comprehension levels on radiation depending on their occupation.

In the present study, we clarified the knowledge on radiation protection and radiation exposure reduction for each occupation and examined future initiatives regarding radiation education.

In conclusion, as promoting team medicine, radiological technologists should form the core of radiation education. In addition, by understanding the degree of comprehension based on differences in occupation, reconstruction and continued implementation of radiation education and staff radiation reduction education system should necessarily be considered based on the expertise and specialty of each occupation.

Introduction

The angiography room is a division where multidisciplinary cooperation can be practiced. Among which, professions such as doctors, nurses, clinical engineers (CE), and radiological technologists (RT) work in the cardiac catheterization laboratory (cath lab), and as part of team medicine, the RT plays a central role in providing radiation education.

In 1994, the Food and Drug Administration (FDA) of America reported patients with radiation-induced injury to the skin. Thereafter, in 2001, the International Commission on Radiological Protection (ICRP) recommended the ICRP publication 85, and in Japan also, efforts were actively made to reduce radiation exposure.[1)] Furthermore, in August 2012, the ICRP announced that the safe equivalent radiation dose for radiation workers should be reduced from 150 mSv/year to an average of 20 mSV/year over five years (with no single year exceeding 50 mSv/year),[2)] and efforts to reduce radiation exposure of patients as well as medical professionals became more important than ever.

Therefore, in focusing on reducing radiation exposure of medical professionals, upon reflecting on education methods and the level of comprehension of radiation, it was thought that there might be a difference according to each profession cooperating in the cath lab.

To date, many studies on radiation education have been reported; [3-8] however, there are no reports including multiple professions. In the present study, we aimed to elucidate knowledge about radiation protection and reducing radiation exposure of medical professionals among each profession, and examined how to undertake radiation education in future.

Methods

The subject sample included 29 cardiologists, 34 nurses, 46 CE, and 51 RT working in the cath lab of four affiliated university hospitals. We conducted a questionnaire survey consisting of 18 items including 'awareness of radiation protection (questions 1 – 4)', 'knowledge about radiation protection (questions 5 – 9)', 'knowledge about radiation (questions 10 – 15)', 'awareness of team medicine (questions 16 – 17)', and 'opportunity for radiation education (question 18)'.

Subjects were given a choice of 'yes' or 'no' according to their self-evaluation to make responses as clear and as easy as possible. Multiple responses were permitted for 'opportunities to learn about radiation'. (Table 1)

Based on the results obtained, we examined differences according to profession, and necessary educational content for each profession from the perspective of team medicine. Furthermore, we examined the trend in individuals with qualifications, and the difference according to the presence or absence of certification for each profession.

We conducted an analysis using a chi-squared test to find a significant difference according to the presence or absence of certification ($p<0.05$).

The questionnaires were anonymous, and performed by way of leaving the questionnaire with the subjects and collected at a later date during the survey period was from October 2 – 10, 2017. Furthermore, study participation was voluntary, with questionnaire collection considered to imply consent for study cooperation.

Table 1 Questionnaire items

1	Are you concerned about radiation exposure?	Yes · No
2	Do you know your exposure dose for a month?	Yes · No
3	Do you work with consciousness of radiation reduction?	Yes · No
4	Do you want to work in a department involved in assisting radiological department?	Yes · No
5	Can you explain the three principles of external radiation protection?	Yes · No
6	Can you explain the dose limit of occupational exposure?	Yes · No
7	Can you explain how much radiation can be reduced by protective clothing?	Yes · No
8	Can you explain the standing position where there are few exposures when approaching a patient?	Yes · No
9	Can you explain the correct mounting position of the personal dosimeter?	Yes · No
10	Can you explain direct and scattered rays?	Yes · No
11	Can you explain the IVR room dose distribution?	Yes · No
12	Can you explain the difference between radiation dose during fluoroscopy and radiography?	Yes · No
13	Can you explain the difference between Sv and Gy?	Yes · No
14	Can you explain the threshold doses of deterministic effects?	Yes · No
15	Do you know diagnostic reference levels?	Yes · No
16	Do you feel a sense of unity with the radiological technologist as a team?	Yes · No
17	Will the radiological technologist explain about radiation?	Yes · No
18	Please answer the opportunity to learn about radiation. (Multiple answers allowed) In-hospital workshop · In the work · academic meeting · research meeting · internet · magazine · others ( )	

Table 2　Details of subjects who completed the questionnaire survey

Job category	Number of people	Certification number of qualified persons	Year of experience				
			0.5〜2(year)	3〜4(year)	5〜6(year)	7〜10(year)	11〜27(year)
Doctor	29	13	5	6	4	9	5
Nurse	34	4	14	15	2	3	0
Clinical engineer	46	4	11	10	5	8	12
Radiological technologist	51	12	22	9	9	7	4

Results

The collection rate was 100%. Among the 29 cardiologists, there were 13 specialists of cardiac catheterization treatment; among the 34 nurses, there were 4 certified intervention nursing experts; among the 46 CT, there were 4 certified cardiovascular intervention experts; and among the 51 RT, there were 12 experts with qualifications of the Japan Society of Angiography and interventional Radiology. The mean length of experience was 7.5 years for cardiologists, 5.2 years for nurses, 7.6 years for CE, and 6.6 years for RT. (Table 2)

The proportion of responses accounting for 'yes' and 'no' for each question according to profession is presented below. Furthermore, the proportion of individuals with qualifications is presented in brackets.

Awareness of radiation protection

To the question '1. Are you concerned about radiation exposure?', the response was 'yes' by 86.2% (48.0%) of cardiologists, 76.5% (11.5%) of nurses, 63.0% (6.9%) of CE, and 41.2% (19.0%) of RT. The response was 'no' by 13.8% (25.0%) of cardiologists, 23.5% (12.5%) of nurses, 37.0% (11.8%) of CE, and 58.8% (26.7%) of RT. (Fig.1)

To the question '2. Do you know your radiation dose for one month?', the response was 'yes' by 27.6% (37.5%) of cardiologists, 58.8% (15.0%) of nurses, 41.3% (21.1%) of CE, and 74.5% (31.6%) of RT. The response was 'no' by 72.4% (47.6%) of cardiologists, 41.2% (7.1%) of nurses, 58.7% (0.0%) of CE, and 25.5% (0.0%) of RT. (Fig.1)

To the question '3. Do you work consciously to reduce your radiation dose?', the response was 'yes' by 89.7% (50.0%) of cardiologists, 94.1% (12.5%) of nurses, 80.4% (10.8%) of CT, and 94.1% (25.0%) of RT. The response was 'no' by 10.3% (0.0%) of cardiologists, 5.9% (0.0%) of nurses, 19.6% (0.0%) of CE, and 5.9% (0.0%) of RT. (Fig.1)

To the question '4. Do you wish to work in a department involved in assisting radiation treat-

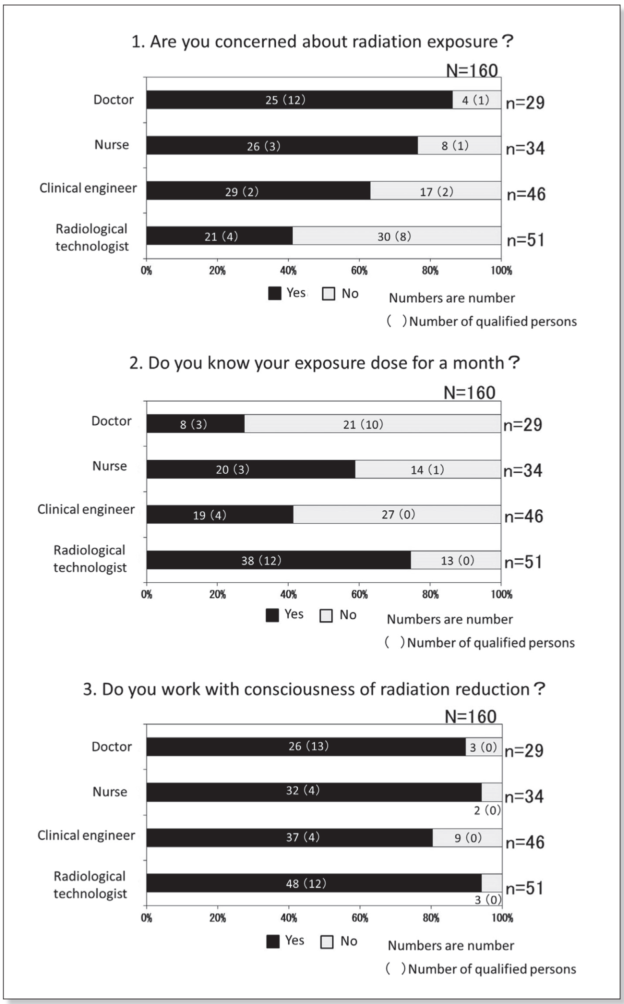


Fig.1　Questionnaire responses to 'awareness of radiation protection (questions 1-3)'

ment?', the response was 'yes' by 48.3% (42.9%) of cardiologists, 35.3% (16.7%) of nurses, 34.8% (12.5%) of CE, and 66.7% (32.4%) of RT. The response was 'no' by 51.7% (46.7%) of cardiologists, 64.7% (9.1%) of nurses, 65.2% (6.7%) of CE, and 33.3% (5.9%) of RT. (Fig.2)

Knowledge about radiation protection

To the question '5. Can you explain the three principles of external radiation protection?', the response was 'yes' by 58.6% (52.9%) of cardiologists, 79.4% (14.8%) of nurses, 37.0% (17.6%) of CE, and 98.0% (24.0%) of RT. The response was 'no' by 41.4% (33.3%) of cardiologists, 20.6% (0.0%) of nurses, 63.0% (3.4%) of CE, and 2.0% (0.0%) of RT. (Fig.2)

To the question '6. Can you explain the dose limit for workplace radiation exposure?', the response was 'yes' by 31.0% (44.4%) of cardiologists, 32.4% (36.4%) of nurses, 13.0% (33.3%) of CE, and 76.5% (28.2%) of RT. The response was 'no' by 69.0% (45.0%) of cardiologists, 67.6% (0.0%) of nurses, 87.0% (5.0%) of CE, and 23.5% (8.3%) of RT. (Fig.2)

To the question '7. Can you explain how much radiation exposure can be reduced by protective clothing?', the response was 'yes' by 37.9% (54.5%) of cardiologists, 35.3% (33.3%) of nurses, 15.2% (42.9%) of CE, and 62.7% (34.4%) of RT. The response was 'no' by 62.1% (38.9%) of cardiologists, 64.7% (0.0%) of nurses, 84.8% (2.6%) of CE, and 37.3% (5.3%) of RT. (Fig.3)

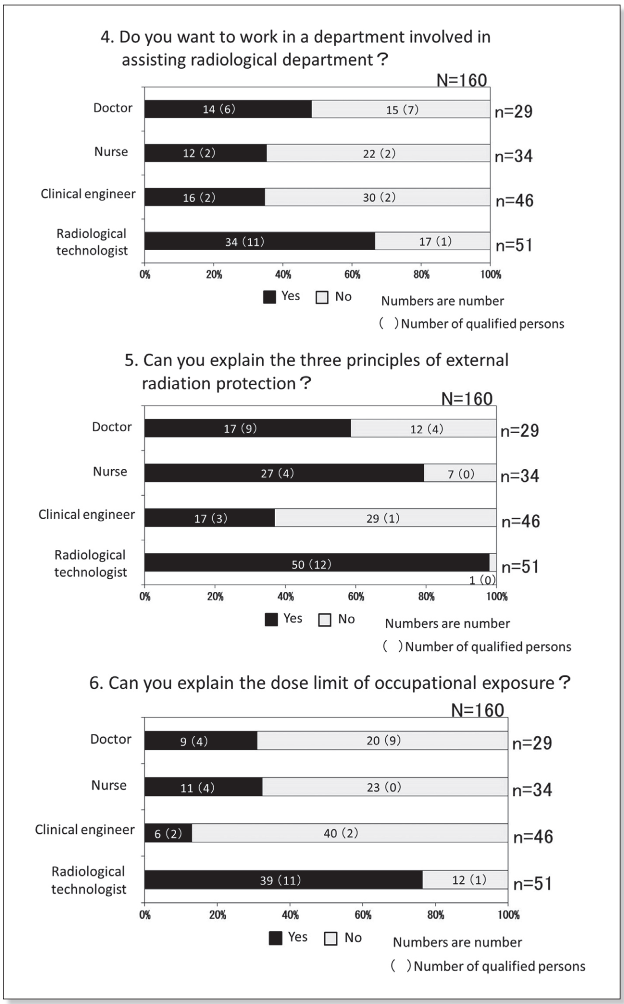


Fig.2 Questionnaire responses to 'awareness of radiation protection (question 4)', 'knowledge about radiation protection (questions 5-6)'

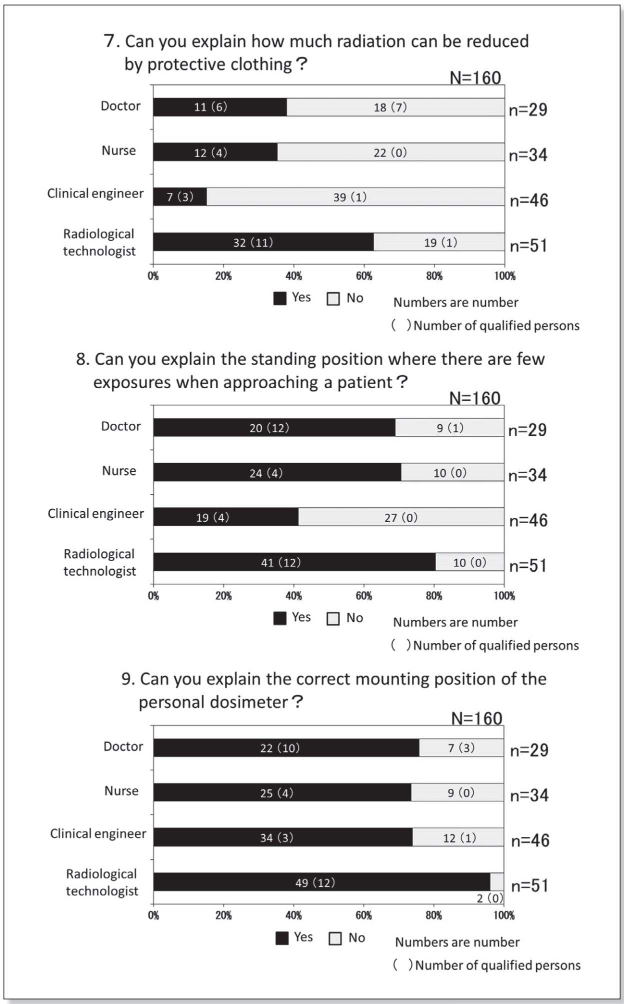


Fig.3 Questionnaire responses to 'knowledge about radiation protection (questions 7-9)'

To the question '8. Can you explain the position with little exposure when approaching the patient?', the response was 'yes' by 69.0% (60.0%) of cardiologists, 70.6% (16.7%) of nurses, 41.3% (21.1%) of CE, and 80.4% (29.3%) of RT. The response was 'no' by 31.0% (11.1%) of cardiologists, 29.4% (0.0%) of nurses, 58.7% (0.0%) of CE, and 19.6% (0.0%) of RT. (Fig.3)

To the question '9. Can you explain the correct position for wearing a personal dosimeter?', the response was 'yes' by 75.9% (45.5%) of cardiologists, 73.5% (16.0%) of nurses, 73.9% (8.8%) of CE, and 96.1% (24.5%) of RT. The response was 'no' by 24.1% (42.9%) of cardiologists, 26.5% (0.0%) of nurses, 26.1% (8.3%) of CE, and 3.9% (0.0%) of RT. (Fig.3)

Knowledge about radiation

To the question '10. Can you explain direct radiation, and scattered radiation?', the response was 'yes' by 44.8% (53.8%) of cardiologists, 50.0% (23.5%) of nurses, 28.3% (23.1%) of CE, and 90.2% (21.7%) of RT. The response was 'no' by 55.2% (37.5%) of cardiologists, 50.0% (0.0%) of nurses, 71.7% (3.0%) of CE, and 9.8% (40.0%) of RT. (Fig.4)

To the question '11. Can you explain radiation distribution in the interventional radiology (IVR) room?', the response was 'yes' by 27.6% (75.0%) of cardiologists, 29.4% (30.0%) of nurses, 26.1% (8.3%) of CE, and 52.9% (40.7%) of RT. The response was 'no' by 72.4% (33.3%) of cardiologists, 70.6% (4.2%) of nurses, 73.9% (8.8%) of CE, and 47.1% (4.2%) of RT. (Fig.4)

To the question '12. Can you explain the difference in radiation dose during fluoroscopy and x-ray imaging?', the response was 'yes' by 58.6% (70.6%) of cardiologists, 29.4% (30.0%) of nurses, 15.2% (14.3%) of CE, and 82.4% (28.6%) of RT. The response was 'no' by 41.1% (8.3%) of cardiologists, 70.6% (4.2%) of nurses, 84.8% (7.7%) of CE, and 17.6% (0.0%) of RT. (Fig.4)

To the question '13. Can you explain the difference between Sv and Gy?', the response was 'yes' by 27.6% (50.0%) of cardiologists, 29.4%

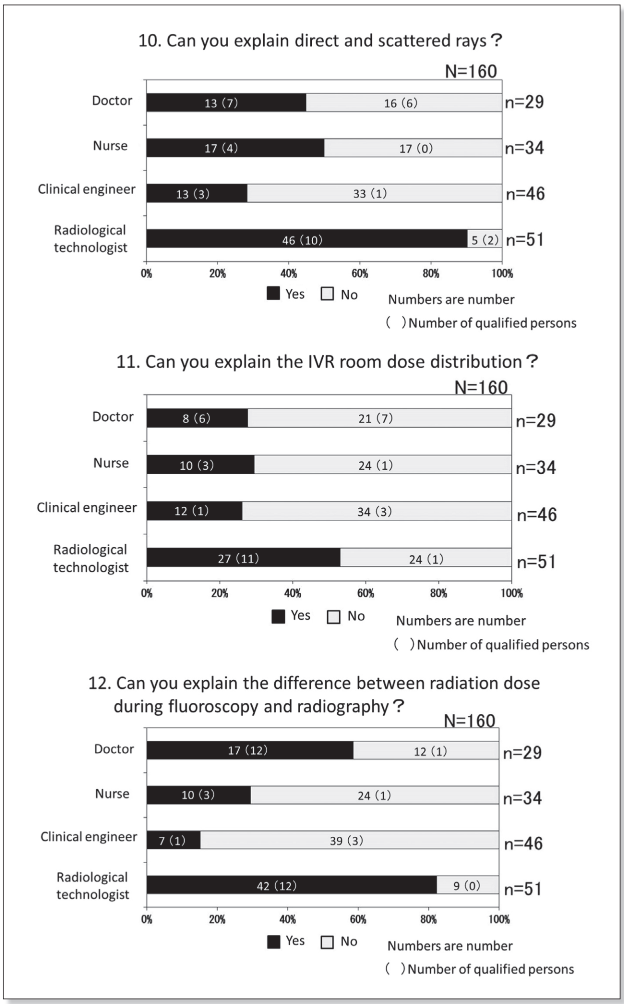


Fig.4 Questionnaire responses to 'knowledge about radiation (questions 10-12)'

(10.0%) of nurses, 26.1% (8.3%) of CE, and 82.4% (28.6%) of RT. The response was 'no' by 72.4% (42.9%) of cardiologists, 70.6% (12.5%) of nurses, 73.9% (8.8%) of CE, and 17.6% (0.0%) of RT. (Fig.5)

To the question '14. Can you explain the threshold dose of radiation for deterministic effects?', the response was 'yes' by 44.8% (46.2%) of cardiologists, 29.4% (30.0%) of nurses, 4.3% (0.0%) of CE, and 78.4% (30.0%) of RT. The response was 'no' by 55.2% (43.8%) of cardiologists, 70.6% (4.2%) of nurses, 95.7% (9.1%) of CE, and 21.6% (0.0%) of RT. (Fig.5)

To the question '15. Do you know the diagnosis reference level?', the response was 'yes' by 17.2% (40.0%) of cardiologists, 14.7% (40.0%) of nurses, 0.0% (0.0%) of CE, and 66.7% (35.3%)

of RT. The response was ‘no’ by 82.8% (45.8%) of cardiologists, of nurses 85.3% (6.9%), 100.0% (8.7%) of CE, and 33.3% (0.0%) of RT. (Fig.5)

Awareness of team medicine

To the question ‘16. Do you feel that at one as an RT and as a team?’, the response was ‘yes’ by 93.1% (48.1%) of cardiologists, 58.8% (5.0%) of nurses, 80.4% (5.4%) of CE, and 84.3% (27.9%) of RT. The response was ‘no’ by 6.9% (0.0%) of cardiologists, 41.2% (21.4%) of nurses, 19.6% (22.2%) of CE, and 15.7% (0.0%) of RT. (Fig.6)

To the question ‘17. Does the RT explain radiation to you?’, the response was ‘yes’ by of cardiologists 86.2% (48.0%), 55.9% (5.3%) of nurses, 60.9% (7.1%) of CE, and 80.4% (29.3%) of RT. The response was ‘no’ by 13.8% (25.0%) of cardiologists, 44.1% (20.0%) of nurses, 39.1% (11.1%) of CE, and 19.6% (0.0%) of RT. (Fig.6)

To the question ‘18. What opportunities do you have to learn about radiation? (multiple answers permitted)’, cardiologists, nurses, and CE responded that they had the opportunity to learn while working, whereas RT responded that they had equal opportunities at conferences and while working. Other opportunities included conferences for cardiologists, the Internet for nurses, training sessions for CE, and seminars for RT.

The results and significant differences according to the presence or absence of qualifications

The results of the test for significant differences are presented in tables 3 – 8. A significant difference ($p<0.05$) was exhibited by cardiologists for concern about radiation exposure and the difference between Sv and Gy; by nurses for the desire to be engaged in assistance of radiation treatment, knowledge of the reduction of radiation exposure from protec-

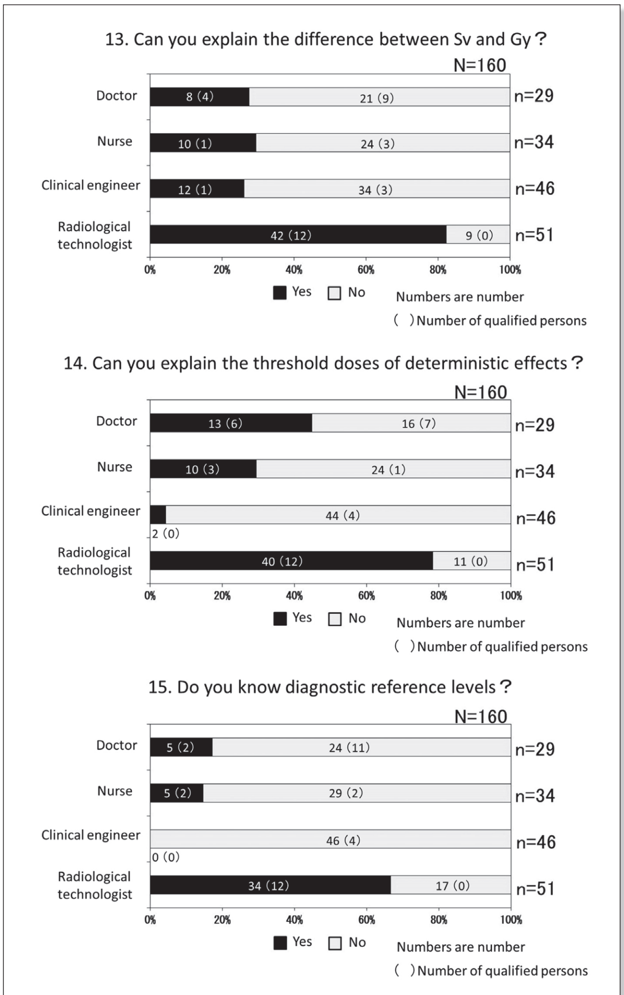


Fig.5 Questionnaire responses to ‘knowledge about radiation (questions 13-15)’

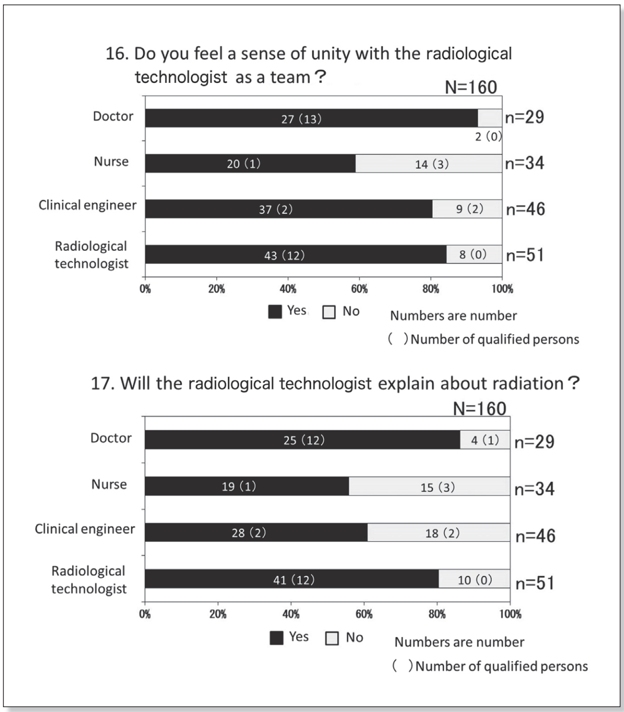


Fig.6 Questionnaire responses to ‘knowledge about team medicine (questions 16-17)’

Table 3 Significant difference according to the presence or absence of qualifications (questions 1-3)

1. Are you concerned about radiation exposure?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	12	1	13	3	P<0.05
Nurse	3	1	23	7	n.s
Clinical engineer	2	2	27	15	n.s
Radiological technologist	4	8	17	22	n.s

Chi-square test

2. Do you know your exposure dose for a month?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	3	10	5	11	n.s
Nurse	3	1	17	13	n.s
Clinical engineer	4	0	15	27	n.s
Radiological technologist	12	0	26	13	n.s

Chi-square test

3. Do you work with consciousness of radiation reduction?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	13	0	13	3	n.s
Nurse	4	0	28	2	n.s
Clinical engineer	4	0	33	9	n.s
Radiological technologist	12	0	36	3	n.s

Chi-square test

Table 4 Significant difference according to the presence or absence of qualifications (questions 4-6)

4. Do you want to work in a department involved in assisting radiological department?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	6	7	8	8	n.s
Nurse	2	2	10	20	P<0.05
Clinical engineer	2	2	14	28	n.s
Radiological technologist	11	1	23	16	n.s

Chi-square test

5. Can you explain the three principles of external radiation protection?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	9	4	8	8	n.s
Nurse	4	0	23	7	n.s
Clinical engineer	3	1	14	28	n.s
Radiological technologist	12	0	38	1	n.s

Chi-square test

6. Can you explain the dose limit of occupational exposure?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	4	9	5	11	n.s
Nurse	4	0	7	23	n.s
Clinical engineer	2	2	4	38	n.s
Radiological technologist	11	1	28	11	n.s

Chi-square test

Table 5 Significant difference according to the presence or absence of qualifications (questions 7-9)

7. Can you explain how much radiation can be reduced by protective clothing?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	6	7	5	11	n.s
Nurse	4	0	8	22	P<0.05
Clinical engineer	3	1	4	38	n.s
Radiological technologist	11	11	21	18	n.s

Chi-square test

8. Can you explain the standing position where there are few exposures when approaching a patient?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	12	1	8	8	n.s
Nurse	4	0	20	10	n.s
Clinical engineer	4	0	15	27	n.s
Radiological technologist	12	0	29	10	P<0.05

Chi-square test

9. Can you explain the correct mounting position of the personal dosimeter?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	10	3	12	4	n.s
Nurse	4	0	21	9	n.s
Clinical engineer	3	1	31	11	n.s
Radiological technologist	12	0	37	2	n.s

Chi-square test

Table 6 Significant difference according to the presence or absence of qualifications (questions 10-12)

10. Can you explain direct and scattered rays?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	7	6	6	10	n.s
Nurse	4	0	13	17	n.s
Clinical engineer	3	1	10	32	n.s
Radiological technologist	10	1	36	4	n.s

Chi-square test

11. Can you explain the IVR room dose distribution?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	6	7	2	14	n.s
Nurse	3	1	7	23	P<0.05
Clinical engineer	1	3	11	31	P<0.05
Radiological technologist	11	1	16	23	n.s

Chi-square test

12. Can you explain the difference between radiation dose during fluoroscopy and radiography?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	12	1	5	11	n.s
Nurse	3	1	7	23	P<0.05
Clinical engineer	1	3	6	36	n.s
Radiological technologist	12	0	30	9	P<0.05

Chi-square test

Table 7 Significant difference according to the presence or absence of qualifications (questions 13-15)

13. Can you explain the difference between Sv and Gy?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	4	9	4	12	P<0.05
Nurse	1	3	9	21	n.s
Clinical engineer	1	3	11	31	n.s
Radiological technologist	12	0	30	9	n.s

Chi-square test

14. Can you explain the threshold doses of deterministic effects?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	6	7	7	9	n.s
Nurse	3	1	7	23	n.s
Clinical engineer	0	4	2	40	n.s
Radiological technologist	12	0	28	11	n.s

Chi-square test

15. Do you know diagnostic reference levels?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	2	11	3	13	n.s
Nurse	2	2	3	27	P<0.05
Clinical engineer	0	4	0	42	P<0.05
Radiological technologist	12	0	22	17	n.s

Chi-square test

Table 8 Significant difference according to the presence or absence of qualifications (questions 16-17)

16. Do you feel a sense of unity with the Radiological technologist as a team?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	13	0	14	2	n.s
Nurse	1	3	19	11	n.s
Clinical engineer	2	2	35	7	n.s
Radiological technologist	12	0	31	8	n.s

Chi-square test

17. Will the Radiological technologist explain about radiation?

Job category	Certification		Non certification		significant difference
	Yes	No	Yes	No	
Doctor	12	1	13	3	n.s
Nurse	1	3	18	12	n.s
Clinical engineer	2	2	26	16	n.s
Radiological technologist	12	0	29	10	n.s

Chi-square test

tive clothing, radiation distribution in the IVR room, the difference in radiation dose between fluoroscopy and X-ray imaging, and the diagnosis reference level; by CE for radiation distribution in the IVR room, and the diagnosis reference level; and by RT for the position to approach the patient, and the difference in radiation dose between fluoroscopy and X-ray imaging.

Discussion

Cardiologists and nurses had a high level of awareness and knowledge of their own radiation protection; however, they had insufficient basic knowledge about radiation. In particular, the threshold dose for radiation-induced skin injury and crystalline lens injury was only understood by less than half of subjects, which we believe needs to be taken into due consideration, and addressed in future education as an important item.

We found that CE were aware of, but had insufficient knowledge of radiation protection. Furthermore, they had insufficient basic knowledge about radiation, and require education that enables them to obtain knowledge about radiation protection, as well as basic knowledge about radiation.

RT exhibited a high rate of understanding for all items; however, with regards to radiation education for nurses and CE (17. Does the RT explain to you about radiation?), we found that few subjects responded 'yes'. Therefore, from the perspective of team medicine, it was suggested that as radiation specialists, at present, RT do not adequately transmit the knowledge required in practical settings to other professionals. RT need to reflect back on whether, despite having expert knowledge of radiation, they inadequately shared such knowledge to other cooperating professionals. All four hospital affiliated with our university held seminars on radiation protection, and reducing radiation exposure of patients and medical professionals; however, we found that ultimately they were not made use of. While taking into account the frequency and period of seminars held, further careful investigation is needed to enable radiation education to be performed that is suited to the particularities of each profession. Moreover, the phrase 'if there is anything you don't understand, please ask' is used often in practical settings; however, it should also be understood that individuals do not know what questions to ask.[9] Therefore, as a radiation expert, it is thought that RT should step up further to help medical professions of other departments. For example, in various settings during tests, having others understand where the radiation dose is currently low, is particularly important knowledge for nurses who ask patient complaints, provide nursing care, and approach the patient often. Understanding radiation distribution will allow action to what position currently has little radiation exposure based on the arm angle and direction of the X-ray device, and from where approach should be made to the patient to reduce one's own radiation exposure. This similarly applies to CE, and is knowledge that we hope is given priority and understood better. RT should understand the expertise and behavior pattern of each professional, and accordingly should provide education suited to clinical practice.

Excluding RT, we found that other professions did not fully understand 'knowledge about radiation'. Professionals other than RT had few opportunities to learn basic knowledge of radiation in basic education, and when looking at the educational curriculum of nurse and CE training schools, [10-12] there are no classes in regard to radiation, which we believe might be one reason underlying their lack of understanding. In the future, we hope that radiation-related education will be implemented as part of team medicine.

With regards to cardiologists, we found that few responded 'yes' to being able to explain radiation distribution in the IVR room, and the difference between the radiation dose of fluoroscopy and X-ray imaging. This item is extremely important information for cardiologists performing irradiation not only in terms of their own radiation protection but also from the perspective of team medicine. Furthermore, we believe that understanding this item helps nurses and CE to show consideration such as avoiding unnecessary fluoroscopy and X-ray imaging and communicating when approaching the patient. Furthermore, although more than 80% of cardiologists responded that they were concerned about radiation exposure, less than 30% knew the dose of radiation to which they were exposed over a month. We believe that cardiologists concerned over their own personal radiation protection will lead to the reduction of radiation exposure of the patient, as well as that of the staff cooperating as a team.

Depending on the presence or absence of qualification acquisition, we found a significant difference according to different items. We believe that this is attributed to the fact that there were opportunities to receive radiation education when acquiring or continuing qualifications. However, few items showed a significant difference, and based on this result, it is thought that even after acquiring qualifications, ongoing education and training is needed.

Irrespective of the presence or absence of qualification acquisition, an environment and opportunities need to be created whereby all professionals engaged in radiation can obtain ongoing education and related knowledge about radiation. Based on the questionnaire results, most opportunities to learn radiation education were provided while on duty, and we believe that institutions should not only provide education for their staff, but that education should proceed with the RT of the institutions at the core. Moreover, it is important to examine the content of such education collectively among each profession. In future, we believe that it is important for the RT to endeavor to communicate better with other professions, and to make a greater effort in radiation education as team medicine.[13-15]

Furthermore, we believe that this will lead to the 'promotion of team medicine'[16] so-called by the team medicine promotion council.

Limitations and prospects of the present study

The present study included cardiologists, nurses, CE, and RT working in the cath lab of four hospitals affiliated with our university, which limited the survey range. As future prospects, we believe that performing a large-scale questionnaire survey with doctors of each department engaged in radiation procedures will increase the number of responses including the parameters of individuals with qualifications, and help to find detailed results.

Conclusion

In the present study, we aimed to elucidate knowledge about radiation exposure of cardiologists, nurses, CE, and RT working in the cath lab. In promoting team medicine, upon centering radiation education on the RT, and thoroughly determining the level of understanding according to different professions, it is important to reconstruct an education system taking into account the expertise and particularities of each profession, and provide ongoing education.

Ethics and conflicts of interest

The present study was conducted with the approval of the ethical review board of affiliated institutions, and there are no conflicts of interest to declare.

Acknowledgements

In proceeding with the present study, we would like to express our deepest gratitude to everyone at the Division of Cardiology Department of Medicine, Department of Nursing, Department of Clinical Engineering, and Department of Radiological Technology at Showa University for their cooperation.

An outline of this study was published at the 82nd Annual Scientific Meeting of the Japanese Circulation Society, the 8th Co-medical award lecture (March, 2018, Osaka), and the 66th Annual Scientific Session of the Japanese College of Cardiology (September 2018, Osaka).

References

1) the International Commission on Radiological Protection; ICRP: ICRP publ.85「Avoidance of Radiation Injuries from Medical Interventional Procedures」, 2001.
2) ICRP: ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs – Threshold Doses for Tissue Reactions in a Radiation Protection Context. ICRP Publication 118. Ann. ICRP 41(1/2). 2012.
3) Rie Kamishina, et al.: Clinical on-site action of the nurse who received education about the radioprotection in a course of the nursing basic education. Innervation, 21(6), 84-87. 2006.
4) Kyoichi Kato, et al.: The influence that radiation exposure reduction education gives. Cardiovascular Intervention and Therapeutics, 22(1), 74-77. 2007.
5) Reiko Kanda, et al.: About the recognition in the fundamental researches – nurse for risk communication about the medical radiation exposure –. JSRT, 64(8), 937-947. 2008.
6) Yoshiaki Morishima, et al.: Importance of the radiation education judging from the attitude survey about the radiation of the nursing student. Jpn. J. Radiat. Saf. Manage, 13(2), 173-176. 2014.
7) Tomoko Kato, et al.: Recognition of the radiologist for the role of the nurse in the radiation medical treatment and the medical treatment skiagrapher. The journal of Radiological Nursing Society of Japan, Vol.6, No.1, 3-11, 2018.
8) Yukari Masujima, et al.: Survey by about recognition and the radiation education for the occupation radiation exposure nurse engaging in IVR. The journal of

Radiological Nursing Society of Japan, Vol.6, No.1, 12-21, 2018.
9) Naomi Miyake, et al.: To Ask a Question, One Must Know Enough to Know What Is Not Known. Journal of Verbal Learning and Verbal Behavior Vol.18(3) pp357-364, 1978.
10) Showa Univercity (2018)「Department Curriculum silabus」, [online] http://www.showa-u.ac.jp/sch/pharm/curriculum.html (Reference 2019-1-5)
11) Tokyo Engineering Univ. (2018)「Health medical care department Clinical engineering department Curriculum」, [online] https://www.teu.ac.jp/gakubu/medical/clinic/curriculum2014.html (Reference 2018-11-4)
12) Kyorin University (2018)「Health department curriculum」, [online] http://www.kyorin-u.ac.jp/univ/faculty/health/ (Reference 2019-1-5)
13) Ministry of Health, Labour and Welfare: About promotion of the team medical care (Study meeting report about the promotion of the team medical care Study meeting report). March 19, 2010.
14) Ministry of Health, Labour and Welfare: Basic way of thinking for team medical care promotion and practical casebook, team medical care promotion policy examination working group, team medical care promotion meeting, June, 2011.
15) Miwako Hoshoda: It is health medical sociology essays... from the viewpoint of the healthcare worker of the each some – with “the team medical care”, No. 12, 88-101, 2001.
16) A team medical care communication meeting: About a meeting, it is an idea of the team medical care (2018) [online] https://www.team-med.jp/philosophy (Reference 2018-11-4)

Received September 1, 2017; accepted March 29, 2019

Development of the Dual Flip-Flop Angle Type T_2W-Fast Spin Echo Method

Kojiro Yamaguchi

Faculty of radiological technology, School of Health Science, Fujita Health University, Aichi, Japan
* Current affiliation : Department of Radiological Technology, Faculty of Medical Technology, Niigata University of Health and Welfare, Niigata, Japan

Note: This paper is secondary publication, the first paper was published in the JART, vol. 66 no. 804: 14-21, 2019.

Key words: Fast Spin echo, T_2W, Bloch equation, specific absorption ratio, contrast noise ratio

【Abstract】

Fast Spin echo is a major sequence used for T_2WI. The 90 (Flip) angle - 180 (Flop) angle - echo - 180 (Flop) angle - echo train sequence is the basic pattern in FSE. Major drawbacks of the technique are the increase in SAR and decrease in CNR. To overcome these problems a Flip-Flop angle type sequence, a T_2WFSE was developed. Optimal Flip and Flop angles must be selected to develop the Flip-Flop type sequence of T_2WFSE. The Bloch equation was applied in order to develop the sequence used for the evaluation of MR signal strength in numerical simulation. Optimal Flip and Flop angles were selected by numerical simulation based on the Bloch equation for the Flip-Flop angle type T_2WFSE.

1. Introduction

In the clinical setting, imaging a wide range with a thin slice thickness in a very short time period is required in Magnetic Resonance Imaging (MRI). A T_2-weighted (T_2W) sequence is a very effective scanning method for the detection of diseases. However, its efficacy is limited by the long repetition time (TR) in T_2W imaging. This consequently increases the scan time. Relaxation Enhancement (RARE) type T_2W sequence Fast Spin Echo (FSE) was proposed as a means of shortening scan times [1]. FSE is a method of shortening scan times. This technique involves the use of multi-echo spin-echo techniques that allow more data to be collected. Chunks of k-space are gathered at a time consequently reducing scan times. FSE sequence is commonly used in current clinical practice.

Despite the advantages of the FSE technique, it is limited by two major drawbacks. The first problem is the rise in specific absorption rate (SAR) [2]. The safety of radio frequency (RF) pulse exposure during clinical MRI is regulated and monitored. The RF pulse sequences used in the FSE sequence are $90°(\alpha)$ - $180°(2\alpha)$ type, based on Spin Echo sequence. The basic pattern of RF pulses for the FSE is 90°- 180° Spin Echo excitation pulse pattern followed by multiple 180° refocusing pulses. Therefore, the same number of 180° pulses are repeatedly exposed to get the required number of echoes in FSE. These 180° refocusing pulses cause the increase in SAR level which consequently increases the thermal effect [3, 4]. The second disadvantage of FSE is the decrease in soft tissue contrast in multi-slice imaging. This reduction in image quality occurs as a result of the magnetization transfer (MT) effect caused by the RF pulse, an issue frequently encountered in the FSE method [5, 6]. For the reasons discussed above the development of a new FSE sequence free of these two drawbacks has been requested.

Yamaguchi proposed a method to solve these problems. This method involves modification of the shape of the RF pulse not only to reduce the SAR, but to also improve the contrast of multi-slice imaging [7]. However, MRI scanners used in clinical settings are not equipped with the ability to use Yamaguchi's method because it requires the modification of the RF pulse. Hennig et al. Proposed a technique of reducing the angle of 180° refocusing pulses to overcome the SAR issue [8), 9)]. These methods were achieved by fixing the angle of RF either the 90° pulse or the 180° pulses [10)]. Hahn studied α° (Flip) - β° (Flop) instead of the RF pulse 90° (α) - 180° (2α) [11)]. For this study, we developed an FSE sequence with an RF pulse pattern of α° (Flip) - β° (Flop) and evaluated it in relation to SAR reduction and contrast noise ratio (CNR) improvement.

2. Method

2.1 The in-plane signal value and echo signal value.

A combination of the angles for Flip (Excitation Pulse) - Flop (Refocusing Pulse) is important if different angles are used. Echo Time (TE) in the FSE sequence is needed for the calculation of the combination of angles. Two equations were used to simulate the MRI signal values needed to obtain the optimal Flip-Flop angles. The Equation (1) is the Bloch equation. The Bloch equation enables numerical simulation of MR signals. The RF pulse profile and gradient magnetic field strength, TR, TE, T_1 and T_2 are necessary factors in numerical simulation of the Bloch equation. Mx, My, and Mz components are calculated from the Bloch equation. The Mxy component that gives the MRI signal values is then calculated from the Equation (2) accordingly [12), 13)]. The next Equation (3) gives the echo signal value as a simplified form of the Bloch equation [14)]. Although both the RF pulse profile and gradient magnetic field strength are necessary factors in numerical simulation of the Bloch equation, we used the Equation (3) to obtain an adequate calculated of the echo signal value with only TR, TE, T_1 and T_2.

$$\begin{bmatrix} \frac{dMx}{dt} \\ \frac{dMy}{dt} \\ \frac{dMz}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{T_2} & \gamma B_0 & \gamma B_1 \sin \omega t \\ -\gamma B_0 & -\frac{1}{T_2} & \gamma B_1 \cos \omega t \\ -\gamma B_1 \sin \varpi t & -\gamma B_1 \cos \varpi t & -\frac{1}{T_1} \end{bmatrix} \begin{bmatrix} Mx \\ My \\ Mz \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{M_0}{T_1} \end{bmatrix} \quad (1)$$

$$\text{In-plane signal value} = \sqrt{\left(\sum_{i=1}^{N} M_{xi}\right)^2 + \left(\sum_{i=1}^{N} M_{yi}\right)^2} \quad (2)$$

$$\text{Echo signal value} = k\rho\left\{1-\exp\left(-\frac{TR}{T_1}\right)\right\}\exp\left(-\frac{TE}{T_2}\right)\times\cos\{270-(Flip+Flop)\} \quad (3)$$

M_x, M_y, M_z : Components, γ : Gamma, gyromagnetic ratio, ω : Angular frequency in radians per second, B_0 : Static magnetic field, B_1 : Amplitude of the RF field, TR: Repetition time, TE: Echo time, ρ : Proton density, T_1: Longitudinal recovery time, T_2: Transverse relaxation time, $Flip$: Excitation Pulse, $Flop$: Refocusing Pulse.

2.2 The optimization of Flip-Flop.

Normalization maps were drawn to determine the optimal angles for the Flip-Flop sequence. First, the values from each equation were normalised to allow the comparison of the results. This was necessary given the difference in the outcome of the simulation with the Equation (2) and (3). Two maps were drawn. One was based on the result of the calculation using the Equation (2) for each signal from Flip-Flop. A Normalization map was also drawn using the result attained from the Equation (3). Next, the Equation (4) was used to obtain curves that have the same attenuation ratio of 1.0. An optimal curve was determined for each echo based on the Equation (4).

$$1.0 = \frac{\text{Normalized in - plane signal value}}{\text{Normalized echo signal value}} \quad (4)$$

2.3 Parameters for the calculation of in-plane signal value and echo signal value in numerical simulation.

The detail of the used parameters are following: TR = 4,500 ms, TE = 14.2 ms, 28.5 ms, 42.8

ms, 57.1 ms, 71.4 ms, 85.7 ms, 100 ms, 114.3 ms, 128.6 ms, 142.9 ms, 157.2 ms, 171.5 ms and 185.8 ms, Flip angle = 50°- 130° (5° step), Flop angle = 110°- 180° (5° step), Slice thickness = 5 mm, The target substance was Gray Mater of brain. Gray Matter (T_1 = 809 ms, T_2 = 101 ms [15]. The total number of the numerical simulation was 6,630. The analysis software used was Mathematic 4.0 and 6.0.

2.4 The evaluation of the optimal angles on clinical equipment.

We examined the physical evaluation for imaging by the optimum Flip-Flop angle obtained by numerical simulation in the clinical machine.

2.4.1 Analysis of Flip-Flop Angle Control

When changing the Flip-Flop angle, it is necessary to check whether the Flip-Flop angle can be accurately controlled at a specified angle. In this confirmation, the crest value of the RF waveform in the magnetic field was measured by measuring the RF waveform in the magnetic field using the search coil and changing according to the Flip-Flop angle. For the measurement range, the flip angle is 60 degrees to 120 degrees and the flop angle is 120 degrees to 180 degrees.

2.4.2 RF uniformity analysis at Flip-Flop angle

At the Flip-Flop angle, there a problem is encountered as to whether the RF pulse is uniformly applied to the substance.

To verify this problem, the RF pulse homogeneity test was conducted using a tissue equivalent phantom formed with the dielectric conductor (filler: copper sulfate solution 0.055%, conductivity: about 0.3 S/m).

The imaging conditions as follows, TR/TE = 400/15 ms, FOV = 300 mm, matrix: 256 × 256, slice thickness: 10 mm, NEX = 2, Acquire image: Sagittal, MRI unit: EXCELART/Pianissimo 1.0T (Toshiba Medical Systems).

2.4.3 Physical evaluation of images

The evaluation using the optimal Flip-Flop angles was conducted on a scanner in clinical settings. Measurements of slice thickness, Signal to Noise Ratio (SNR), and SAR were conducted as physical evaluation [16]. A 1.0 Tesla MRI (Toshiba Medical Systems) was used.

2.5 Image analysis

For the evaluation of actual images, one healthy subject's brain was scanned and the CNR of gray matter and white matter on an image from multi slice imaging was measured [17), 18)]. Informed consent was obtained from the subject prior to conducting the scan. Comparisons were made between a 90°- 180° sequence and the Flip-Flop 0 sequence regarding the drop rate of CNR in multi-slice scans. Signals from gray matter and white matter were calculated by averaging five sets of data. Each size of the region of interest (ROI) was circular, 4 × 4 (total of 16) pixels. A particular slice plane was selected so we could set the ROI on both the white and grey matter areas. The scan conditions as follows: TR = 4,500 ms, Effective TE = 100 ms, Echo Train Length = 13, Slice thickness = 5 mm, Slice gap = 1 mm, Number of slices = 22, Field of View = 300 mm × 300 mm. Matrix size = 256 × 256. A 1.5 Tesla MRI system (Philips Medical Systems) scanner was used for the CNR evaluation.

3. Results

3.1 The optimization of Flip-Flop.

Normalization maps of the in-plane signal values and echo signal values are shown in Fig.1 and Fig.2. The two maps shown have completely different patterns. Fig.1 (in-plane signal value map) shows an egg-shaped curve. The range around the maximum signal value is different to the one from 90°- 180° sequence. In contrast, the echo signal value shows a rectilinear pattern. The combination of the angle at which the signal value reaches its peak is

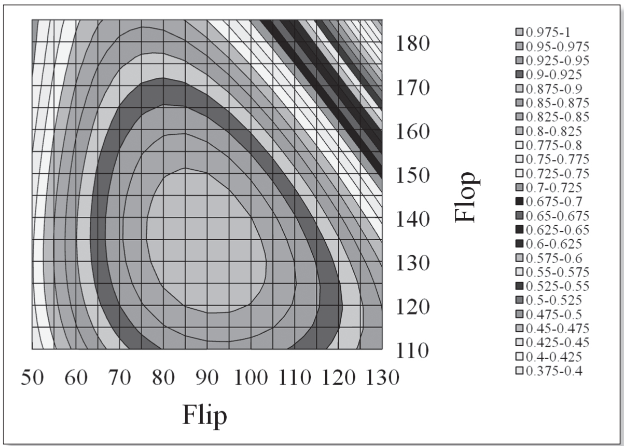


Fig.1 Normalization map of In-plane signal value

The contour diagram of the in-plane signal values obtained from the Bloch equation (Equation 1) and the in-plane signal value (Equation 2) showed an egg shape. The in-plane signal value of the center indicated.

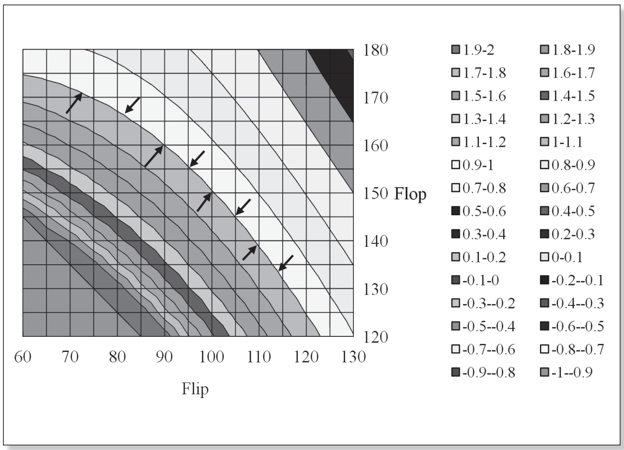


Fig.3 The optimal curve calculated from equation

The optimization curve obtained from equation 4. And a curve indicates a range showing 1.0. However, it is not possible to limit the optimum Flip-Flop angle form this curve.

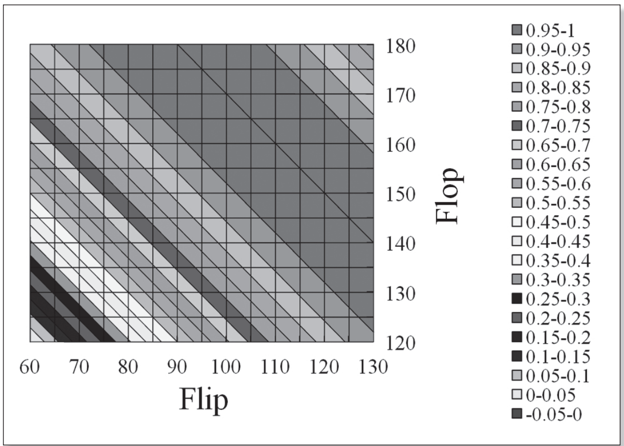


Fig.2 Normalization map of echo

Contour lines of the signal values of the Echo signal value (Equation 3) showed a linear change and showed a shape different from the Bloch equation.

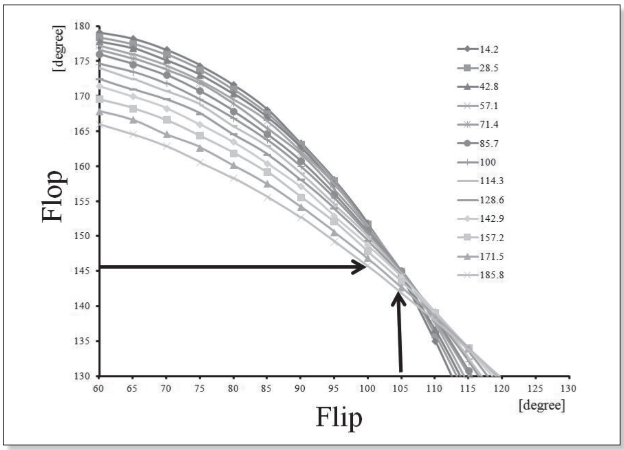


Fig.4 The curves show the optimal value when varying the TE 14.2 ms to 185.8 ms

The optimization curve shown in Figure 3 in shown for each TE. The flip-flop angle at which the optimization curve arrogates to one point wan taken as the optimum Flip-Flop angle.

at 90° - 180° sequence. The optimal curve calculated from the Equation (4) is indicated by arrows in Fig.3. The curve indicated by the arrows is at the level of 1.0 in signal strength.

3.1.1 Flip-Flop evaluation in relation to TE.

The diagram is shown below (Fig.4) describes the optimal value when shifting TE 14.2 ms to 185.8 ms. Optimal values of each curve are focused at the point of the combination near 105° (Flip) - 145° (Flop) sequence. It was determined that the angle combination is attributed to the value that has not been influenced by TE. TE 200 ms was not used as the results obtained largely deviated from 105° - 145° sequence.

3.2 Evaluation results on the clinical equipment.

3.2.1 Flip-Flop Angle Control

Fig.5 shows the peak value measurement result of the RF pulse in the magnetic field of the search coil. The correlation coefficient of the peak value with respect to the input angle

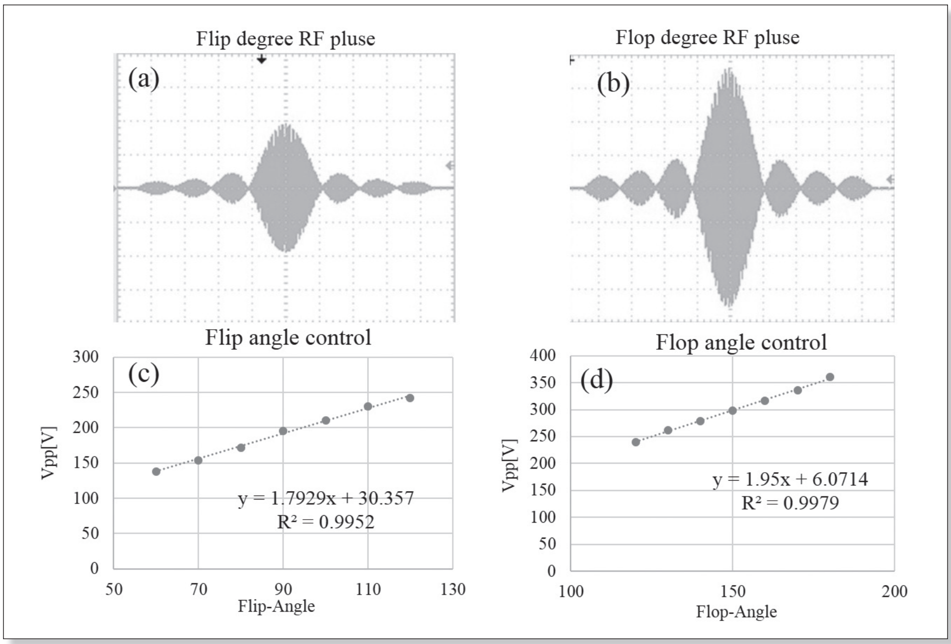
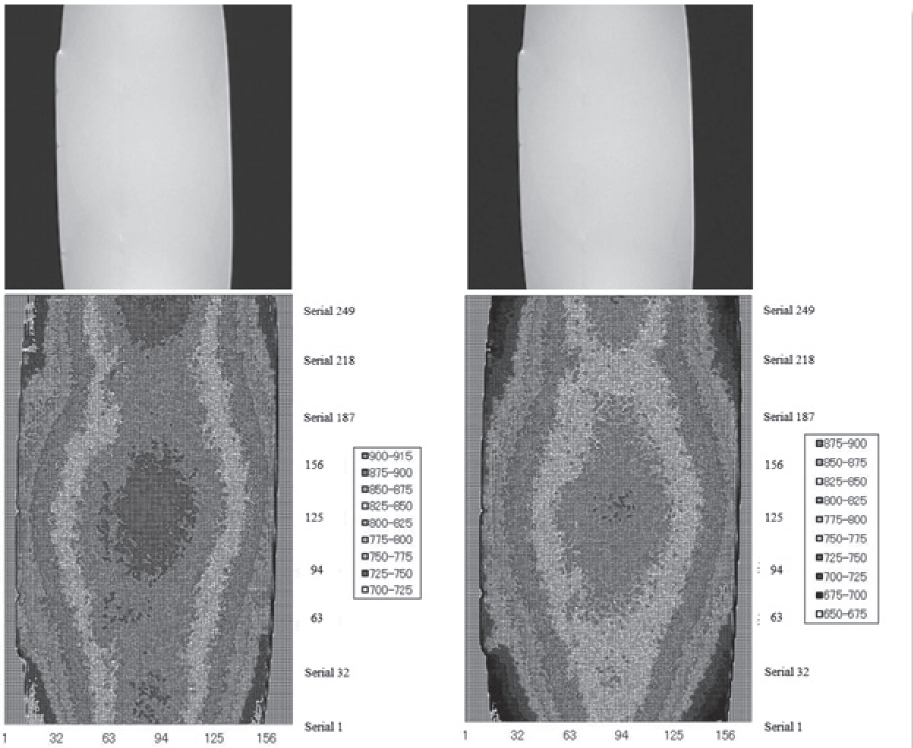


Fig.5 Accuracy of RF pulse in magnetic field

(a), (b): RF pulse waveform in magnetic field, (c): The Flip angle and the voltage of the RF pulse in the magnetic field [Vpp], (d): Flop angle and voltage of RF pulse in magnetic field [Vpp].



a) 90˚-180˚ sequence b) 105˚-145˚ sequence

Fig.6 Evaluation of uniformity of RF pulse

As for the 105˚-145˚ sequence in which the Flip-Flop was varied, like the 90˚-180˚ sequence, the signal value contour was not different in shape.

Table 1 The result of slice thickness and SNR measurements with two different combinations

Flip-Flop	Slice thickness [mm]	SNR
90°-180° sequence	5.7 ± 0.26	38.9 ± 0.1
105°-145° sequence	5.7 ± 0.27	39.7 ± 0.2

Image Acquisition Condition.
TR/TEeff = 4,500/100, 13 echo, ST/Gap = 5.0/1.0 mm, NS = 22 Slice, FOV = 300 mm, 256 × 256 matrix, NEMA Phantom.
Slice thickness and SNR is not different between 105°-145° sequence and 90°-180° sequence.

of the Flip-Flop showed high correlation and it was 0.9952 and 0.9979 at R^2.

3.2.2 RF uniformity analysis at Flip-Flop angle

Fig.6 showed the results of the RF pulse uniformity test at the optimum Flip-Flop angle. In the 90°-180° sequence, the contour plot at the center of the phantom is shown. On the other hand, even at 105°-145° sequence, contour plot showing the same shape as 90°-180° sequence was shown.

3.2.3 Physical evaluation results

The result of the physical evaluation is shown in Table 1 below. This indicates that there is no significant difference in SNR and slice thickness when using the combination of the angles of 105°-145° sequence.

3.3 The Brain imaging evaluation.

Fig.7 shows Ax T_2W images of the brain of a subject. No remarkable artifact is evident in the images. CNR of Gray Matter and White Matter for the 90°-180° sequence and the 105°-145° sequence are 37.8 and 47.8 respectively.

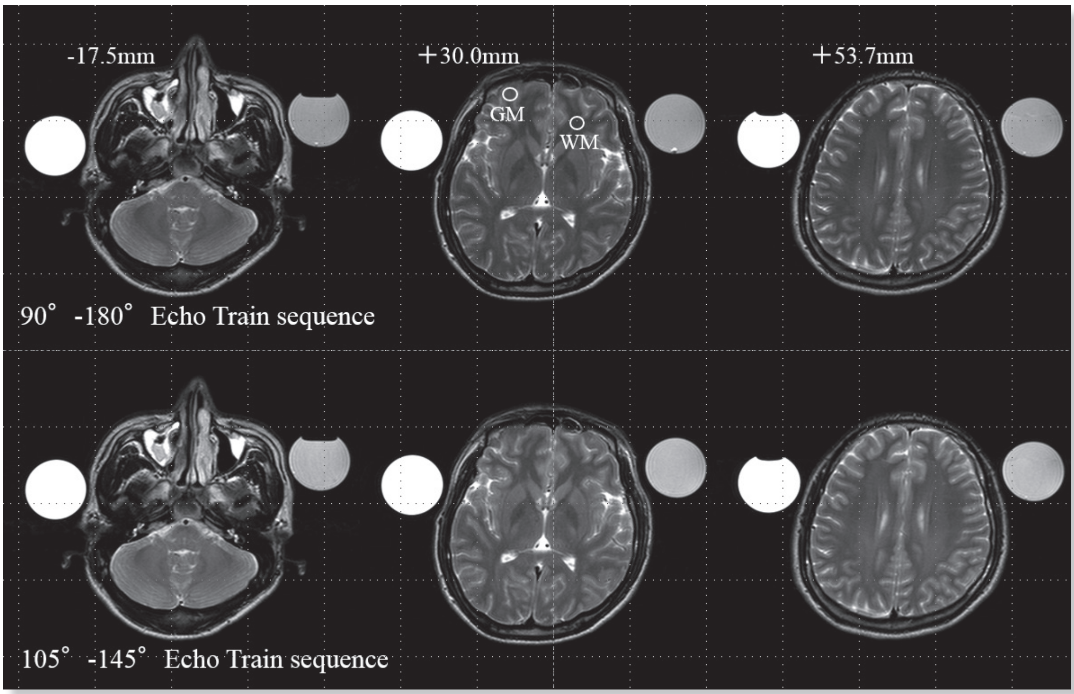


Fig.7 Images of the brain of the subject

Image Acquisition Condition.
TR/TEeff = 4,500/100, 13 echo, ST/Gap = 5.0/1.0 mm, NS = 22 Slice, FOV = 300 mm, 256 × 256 matrix, Head Coil.
Measurement points of CNR are shown. No significant artifact was obtained by 105°-145° sequenced imaging.

There is an improvement of 20.9% in the CNR when using the 105°-145° sequence. The SAR showed on the clinical machine for which CNR was obtained was 1.37 [W/Kg] and 2.06 [W/Kg] with 105-145 degree echo train and 90-180 degree echo train. We can reduce 33.6% of SAR with the 105°-145° sequence compared to the 90°-180° sequence.

4. Discussion

Factors required for diagnosis are spatial resolution or contrast resolution. The spatial resolution of multi-slice computed tomography (CT) in recent years has been superior to other medical imaging modalities. MRI maintains its advantage in contrast resolution over CT. However, low contrast resolution in FSE has been a problem in clinical practice. For this reason, minimising the degradation of contrast resolution is important for more optimal clinical practice. This article recommends the use of the Flip-Flop angle other than the angle of 90° - 180° as a viable solution to this problem.

Two equations were used in this study to calculate the MR signal values needed to obtain the Flip-Flop angle. The in-plane signal values and echo signal values are calculated from the Equations (2) and (3) The optimal value was found from the results and the optimal curve (Fig.4) was obtained to determine the Flip-Flop angle.

It is possible to obtain the Flip-Flop angle while at the same time maintaining contrast resolution. In addition, the optimal the Flip-Flop angles 105°-145° were found from each curve having different TE. Image artifact was not seen from the angles used on brain scan images using a test subject.

The study yielded some improvement in soft tissue contrast resolution, which increased by 24.3%. In addition to that, there was also a reduction of 33.6% in SAR. The above results indicate that the contrast resolution of the FSE sequence can be improved by changing the Flip-Flop angle. Further evaluation is necessary to confirm the efficacy of the Flip-Flop method on imaging in the clinical setting.

5. Conclusion

The angle of the RF pulses used in the FSE sequence is generally 90° (α) - 180° (2α). This causes the degradation of soft-tissue contrast resolution and increases the SAR. A new FSE sequence that doesn't employ 90°-180° RF pulse combination was designed. This new FSE sequence has a combination angle of 105° - 145° in relation to Flip-Flop. Using this technique enables us to improve the contrast resolution of soft tissue as well as reduce SAR.

Acknowledgements

The authors would like to thank Mr Yoshitaka Kawai RT., Mr Kenzo Nakamura RT., Mr Kenzo Baba RT., Mr Nobunari Sato RT., Mr Eiji Tanaka RT., Mr Kei Sasaki RT., and Teruhisa Ohno RT., for assisting with the study.

This work was supported by JSPS KAKENHI Grant Number JP15K01732.

References

1) Hennig J, Nauerth A. and Friedburg H: RARE imaging: A fast imaging method for clinical MR. Magn Reson Med, 3: pp.823-833, 1986.
2) Wehrli FW, MacFall JR, Shutts D, Breger R, Herfkens RJ: Mechanisms of Contrast in NMR Imaging. Journal of Computer Assisted Tomography, 8(3): pp.369-380, 1984.
3) Schaefer DJ: Safety aspects of radiofrequency power deposition in magnetic resonance. Magn Reson Imaging Clin N Am, 6: pp.775-789, 1998.
4) Shellock FG: Radiofrequency-induced heating during MR procedures: a review. J Magn Reson Imaging, 12: pp.30-36, 2000.
5) Dixon WT, Engels H, Castillo M. and Sardashti M: Incidental magnetization transfer contrast in standard multislice imaging. J Magn Reson Imaging, 8: 417-422, 1990.
6) Santyr GE: Magnetization transfer effect in multislice MR imaging. J Magn Reson Imaging, 11: pp.521-532, 1993.
7) Yamaguchi K: New RF pulse for the Improvement of MRI Images. Japan Society of Medical Electronics and Biological Engineering, 49: pp.241-244, 2011.
8) Hennig J: Multiecho sequences with low refocusing flip angle. J. Magn. Reson Image, 78: pp.397-407, 1988.
9) Hennig J and Scheffler K: Easy improvement of signal-to-noise in RARE-sequences with low refocusing flip angles. Rapid acquisition with relaxation enhancement. Magn Reson Med, 44: pp.983-985, 2000.
10) Meiboom S. and Gill D: Modified spin-echo method for measuring nuclear relaxation time. Review of Scientific Instruments, 29: pp.688-691, 1958.
11) Hahn EL: Spin-echoes. Physical review, 80: pp.580-594, 1950.
12) Bloch F: Nuclear induction. Phys. Rev, 70: pp.460-474, 1946.
13) Hinshaw WS and Lent AH: An Introduction to NMR Imaging: From the Bloch Equation to the Imaging Equation. Proc. IEEE, 71: pp.338-350, 1983.
14) Crooks L, Hoenninger J, Arakawa M, Kaufman L, McRee R, Watts J and Singer JH: Tomography of hydrogen with nuclear magnetic resonance. Radiology, 136: pp.701-706, 1980.
15) Partain CL, Price RR: Magnetic Resonance Imaging. W.B. Saunders, Philadelphia, pp.1082, 1988.
16) National Electric Manufacturers Association: Determination of slice thickness in diagnostic magnetic resonance images. NEMA Standard Publication, MS 5, 1991.
17) Wehrli FW, MacFall JR, Shutts D, Breger R and Herfkens RJ: Mechanisms of Contrast in NMR Imaging. Journal of Computer Assisted Tomography, 8(3): pp.369-380, 1984.
18) David DS, William GB: Magnetic Resonance Imaging Second Edition Volume One, Mosby-Year Book, Missouri, pp.109-144, 1992.

Regulations and Requirements for Submissions to the Journal of the Japan Association of Radiological Technologists

Submission Regulations

Revised: April 1, 2013
October 30, 2013
February 20, 2016
April 20, 2019

Objective

Article 1. These regulations are based on the operations defined in Article 4 of the articles of incorporation of the Japan Association of Radiological Technologists (hereafter “the Association”) and stipulate the criteria for submissions to the Journal and informational magazines published by the Association (hereafter “the Journal, etc.”).

Eligibility

Article 2. Only members of the Association may submit to the Journal, etc., unless the author is not a radiographer, in which case this condition does not apply.

Copyright

Article 3.

3-1. As per the copyright regulations of the Association, the copyright of published manuscripts belongs to the Association starting on the day when the decision is made to publish the manuscript.

3-2. For those who have already submitted a similar report to this or another journal, its differences from the manuscript in question must be explained separately in writing.

Obligations

Article 4.

4-1. The topic of submitted manuscripts must be in a domain relevant to technologies for prevention, diagnosis, and treatment with regard to radiation therapy, and manuscripts must be unpublished.

4-2. Submitted papers, whether for fundamental or applied research, must give sufficient consideration to bioethics, and authors must bear ultimate responsibility for their content.

4-3. Fabrication, forgery, plagiarism, violation of the law, and other forms of wrongdoing are not allowed in submissions.

4-4. Authors must disclose any information related to conflicts of interest.

4-5. If a submitted paper involves any form of wrongdoing, the onus is on the author to explain it, whether or not the paper has been adequately peer-reviewed. The Association will not be involved in any way whatsoever.

Types of submissions

Article 5. The types of accepted submissions are categorized as follows:

(1) Original works
Highly original research papers with clear objectives and conclusion.

(2) Review articles
Articles that summarize a specific research domain in a systematic way from a particular perspective.

(3) Rapid communications
Reports of original research that have to be published quickly.

(4) Reports
Surveys of significance to the study of radiological technology or reports of interesting and important cases.

(5) Notes
Articles on the development or evaluation of new equipment, techniques, products, etc.

(6) Technical material
Compilations of survey data or technical aspects or anything that can serve as a reference for research and technology.

(7) Overview articles
Summaries of techniques, principles, or fundamental aspects made with reference to other literature.

(8) Miscellaneous
Other items approved by the editorial committee for publication, such as lecture transcripts, courses published as journal articles, newspaper/magazine articles, and secondary publications, that were not published in issues no. 1–7.

How to submit

Article 6.

6-1. Manuscripts are to be submitted in duplicate, and the data for the original copy must be provided in an electronic format.

6-2. The text of the manuscript data provided is to be saved in a text format.

Formatting

Article 7. Manuscripts are to be formatted according to the submission requirements specified separately.

Receipt of submissions

Article 8.

8-1. Please submit manuscripts to the editorial committee of the Association by mail; no other method of submission will be accommodated.

8-2. The date of receipt is the date the submission arrives at the Association; the deadline for submissions is on the day the final decisions are made.

8-3. As a general rule, manuscripts will not be returned.

Review

Article 9.

9-1. Received manuscripts will be reviewed carefully and impartially by peer-reviewers chosen by the editorial committee.

9-2. Peer reviews will be conducted no more than twice unless the manuscript is an overview article or miscellaneous, which are generally not subject to peer review.

9-3. The decision to accept a manuscript is made by the editorial committee, with reference to the opinions of the peer-reviewers.

Corrections

Article 10. As a general rule, authors are allowed to submit corrections no more than twice. Corrections must be sent by the indicated date.

Printing

Article 11.

11-1. 20 copies of the papers published in the Journal, etc., will be presented to their authors as an offprint.

11-2. Authors must bear the expenses for any additional offprints. If additional offprints are required, they must be requested by the time corrections are submitted.

Revision or repeal of regulations

Article 12. These regulations may be revised or repealed subject to the approval of the Board of Directors.

Supplementary provisions

1. As secondary publication (the publication of the same paper in another journal) has the benefit of disseminating information more widely, it is allowed under the following conditions:
   (1) The source of the original paper must be cited clearly.
   (2) The title must clearly indicate that it is a secondary publication.
2. These regulations are effective as of April 1, 2012.
3. These regulations are effective as of April 1, 2016.
4. These regulations are effective as of April 20, 2019.

Requirements for Submissions to the Journal of the Japan Association of Radiological Technologists

Revised: February 20, 2016
April 20, 2019

The formatting requirements for manuscripts specified in Article 7 of the Journal of the Japan Association of Radiological Technologists submission regulations are as follows:

1. Formatting of original works, rapid communications, reports, notes, technical material, overview articles, and review articles
   1) Cover and abstract
   The first page of the manuscript must be a cover. Please provide the following information:
   ①Submitted manuscripts must clearly indicate the type of submission.
   ②The title in Japanese and English, author's name, institution name, affiliation, and occupation (please provide the member numbers of authors and co-authors who are members of the Association).

③Keywords in English (nouns; no more than five).
④Please provide abstracts in Japanese and English on a separate sheet, in 300 words/characters or less.

2) Body of the paper
①Manuscripts must be written in Japanese or English.
As a general rule, manuscripts are to be created in Word or another word processing application on A4-size paper, landscape, written horizontally in 21 lines of 24 characters per page. English-language manuscripts must be typed double-spaced in half-width characters. Please leave a margin of 5 cm at the right or bottom to insert the page number, and in the duplicate copy, the line number as well. One page of this journal is equivalent to four pages as specified above.
②The page limits for manuscripts and fees for additional pages are presented in the following table:

Type of submission	Number of pages (as published)	Fee for additional pages
Original works	8	¥10,000 per page
Review articles	8	
Rapid communications	3	
Reports	3	
Notes	8	
Technical material	8	
Overview articles	8	
Technical overview articles	4–6	None
Miscellaneous	2 (strictly enforced)	

③As a general rule, technical terms (in Japanese text) are to adhere to Cabinet Announcement no. 2 and the JIS.
④Numerical quantities are to be specified according to international (SI) units.

3) Figures and tables
①Please provide figures and tables with their numbers on a separate sheet and indicate in the body of the text where they are to be inserted.
②As a general rule, these are to be submitted in a digital format at a high enough resolution that can be processed again in production.
③For scientific papers, the titles and text within tables must be written in English.
④Figures and tables 7 cm square or smaller are counted as one manuscript page (not published page). Anything bigger will be counted as two or three pages depending on the size.
⑤Please cite the source of any figures and tables to be reprinted from elsewhere, and obtain permission for their reproduction.
⑥Please provide explanations for the figures and tables in Japanese on a separate page.

4) Bibliography
Please denote literature referred to in the body of the text at the end of the text, in a numbered list by order of appearance, set off by single right parentheses (e.g., 1), 2), 3) …).
The format for references is as follows:
①For journals and periodicals:
Author: "Title" (of paper). *Name of journal* (short form), vol. #, first–last page #, year of publication.
②For monographs:
Author: *Title*. first–last page #, publisher, year of publication.
③If an entry has more than two authors, please write only the first author's name, followed by "et al."

5) Brand names
Where brand names are necessary, please write the generic name, followed by the brand name in parentheses, and add the ® symbol.

6) Author checklist
①Please fill out and include the author checklist.

2. Address
The Japan Association of Radiological Technologists Editorial Committee
World Trade Center Bldg., 31F
Hamamatsu-chō 2－4－1, Minato-ku
Tokyo, Japan 〒105-6131
TEL: 03-5405-3612 FAX: 03-5405-3613

Journal of JART

-English edition 2020-

March 1, 2020

Issuer: Yasuo Nakazawa

Publisher: The Japan Association of Radiological Technologists

31F World Trade Center Building. 2-4-1,

Hamamatsu-cho, Minato-ku, Tokyo. 105-6131

TEL: +81-3-5405-3612　FAX: +81-3-5405-3613

http://www.jart.jp

The Japan Association of Radiological Technologists

http://www.jart.jp