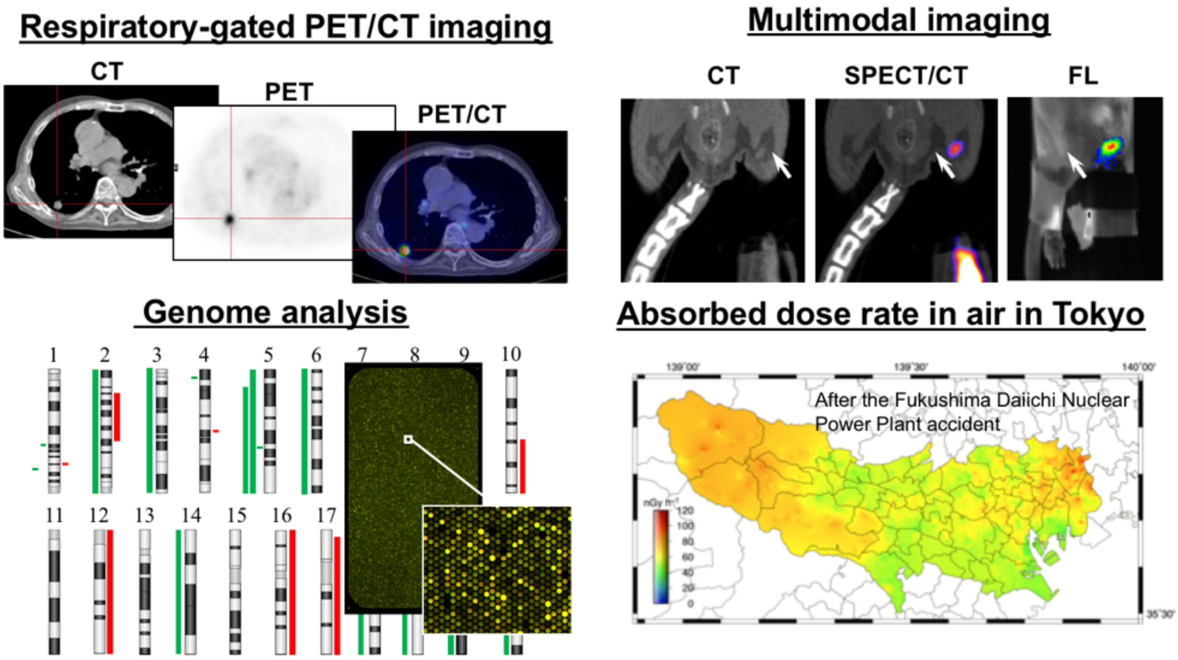
Nuclear Medicine Physics and Health Physics

Supervisors: Professor Masahiro FUKUSHI, Associate Professor Kazumasa INOUE

The Nuclear Medicine Physics and Health Physics Field at Tokyo Metropolitan University focuses on the development of novel nuclear medicine imaging techniques in clinical and small animal SPECT and PET, including SPECT/CT, PET/CT and PET/MRI multimodal imaging techniques, and development of clinical image assessment techniques. Our field also focuses on identifying environmental radiation from natural and artificial radionuclides including naturally occurring high level environmental radiation areas and areas contaminated from the nuclear accident of the Fukushima Daiichi Nuclear Power Plant; development of novel radiation dosimeters using artificial intelligence (AI); and identification of the mechanisms of health effects due to chronic low dose rate radiation exposure by using genome analysis. Besides these research activities, our main activities include conducting clinical training and educating radiological technologists and medical physicists at major hospitals in Japan.

We have had about 80 publications appear in academic journals including the *Journal of Nuclear Medicine*, *Radiation research, Marine Pollution Bulletin* and *PLOS ONE*, and we have received over 22 honors from professional societies for our contributions to nuclear medicine and health physics. More detailed information about supervisors are: "https://researchmap.jp/hana_3321125?lang=en" and "https://researchmap.jp/kzminoue". Our supervised students have received 22 doctoral degrees and 46 master's degrees, and all of them are active in the field of clinical research and education as of FY 2019. We also have attracted outstanding foreign students from Thailand, Vietnam, India, Sri Lanka and Egypt over the years. We are always recruiting highly motivated research students.

Major collaborative research and education institutes: National Institutes for Quantum and Radiological Science and Technology (Japan), Institute for Environmental Sciences (Japan), National Cancer Center Hospital and Hospital East (Japan), Tokushima University (Japan), Kagawa University (Japan), Harvard Medical School (USA), Georgetown University (USA), Pondicherry University (India) and Cho Ray Hospital (Vietnam).



Radiation Oncology Physics A

Supervised by Hidetoshi Saitoh (Prof., Ph. D.)

We conduct education and research on the latest issues on physics, engineering, technology for radiation therapy. Especially, interesting are latest radiation theory, patient information, properties of therapeutic beam, algorithm of treatment planning, dosimetry, quality assurance related cutting edge radiation therapy.

By taking recommended subjects in the field of Radiation Oncology Physics, you can acquire most credits required for completing the medical physicist education course accredited by the Japan Board for Medical Physicist Qualification (JBMP).

Example of research theme

- High speed and accuracy calculation algorithm of absorbed dose distribution
- Improvement of dosimetry using various detectors
- Imaging for high precision radiation therapy
- Activation of medical accelerator
- Development of e-learning materials for education on Medical Physics
- etc.

Apparatus and equipment can be used for your research

- Electron linear accelerator (Varian Clinac 21EX, Fig. 2)
- Radiation therapy planning system (Elekta XiO, Varian Eclipse)
- Various kind of ionization chambers and electrometers
- Radio-photoluminecent glass dosimeter
- Various kind of phantoms, etc.

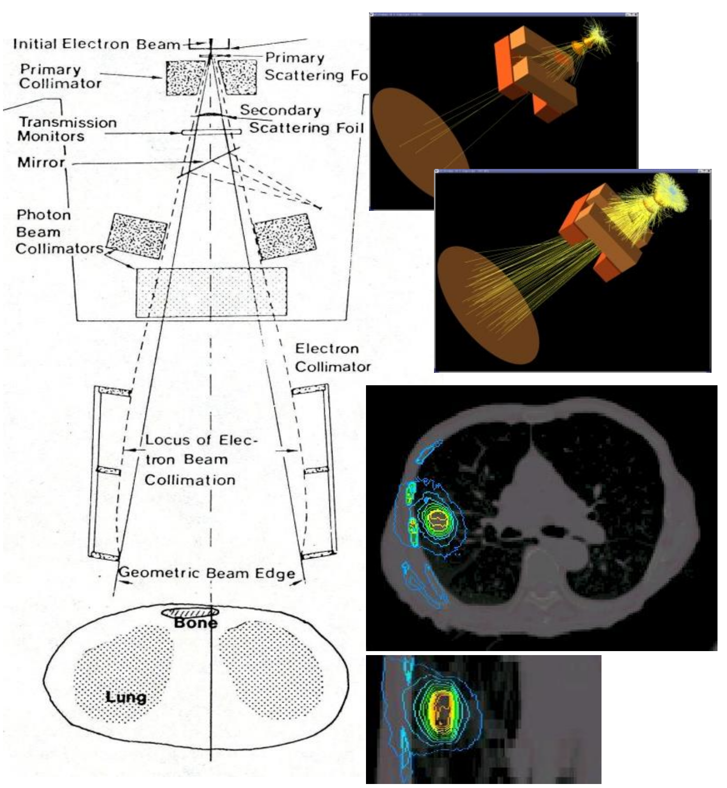


Fig. 1 Examples of Monte Carlo simulation on research field

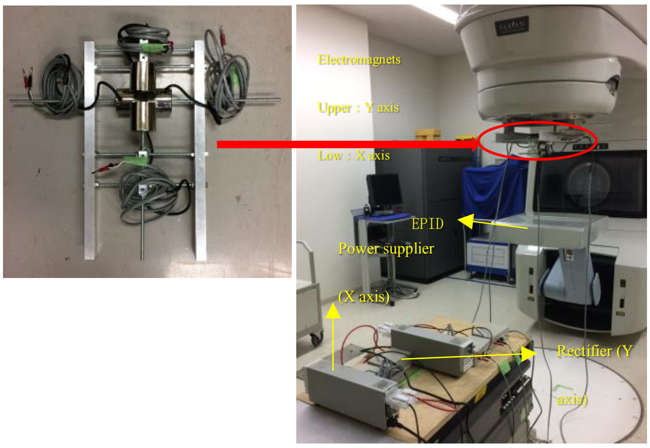
Fig. 2 Electron linear accelerator available for education and research not for clinical use

Radiation Oncology Physics

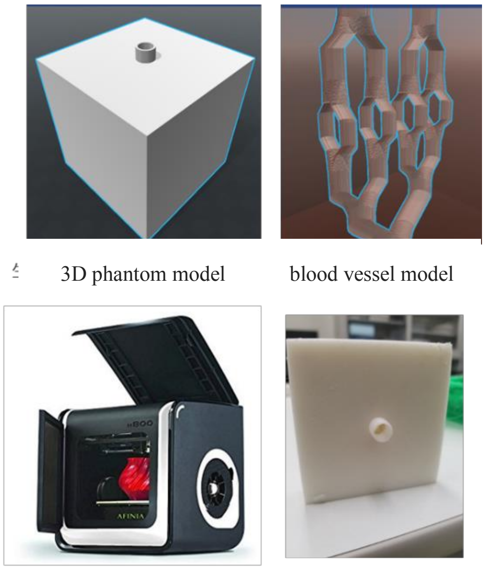
Faculty in charge: Atsushi Myojoyama

As research related to radiation therapy, we research and develop new devices for high-precision radiation therapy, high-energy imaging by X-rays and electron beams, automatic patient authentication for safe radiation therapy. We accomplish those themes with knowledge of radiation physics and programming.

- High-quality MV CBCT image reconstruction
- New imaging method using linear accelerator
- Development of new blood vessel phantom for multi-modality
- Improvement of quality of portal images using high-energy X-rays
- Development of fast Monte Carlo simulations to calculate dose distribution



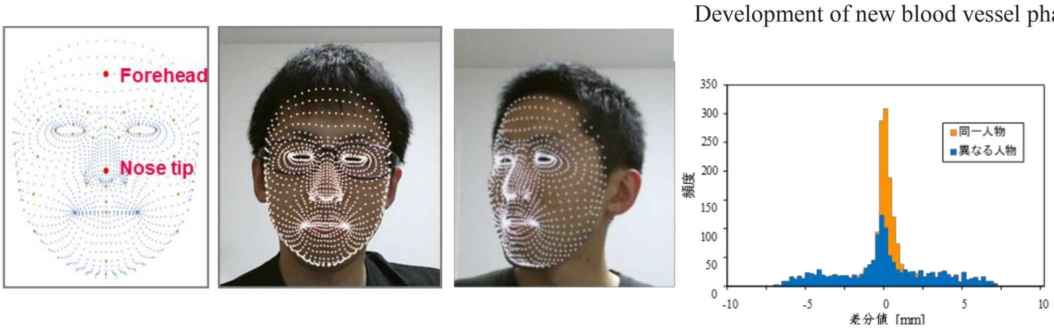
Development of image acquisition device by bending of electron beam using electromagnets



3D phantom model

blood vessel model

Development of new blood vessel phantom



Automated patient authentication by face authentication using Kinect

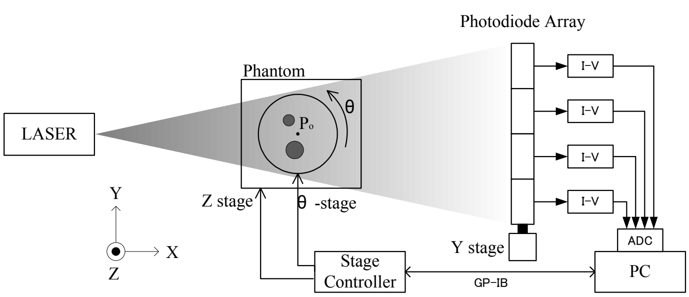
Medical Measurement Systems

Izumi Ogura

[Research]

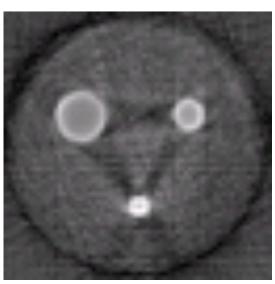
1. Consideration of simulated X-ray CT system for education using Laser Beam

We will construct an optical CT system using laser beam and consider the educational simulator system for deepening understanding of the operation principle and image reconstruction of X-ray CT system. Currently, a single helical simulation CT apparatus is completed and we will consider transition to multi slice method.

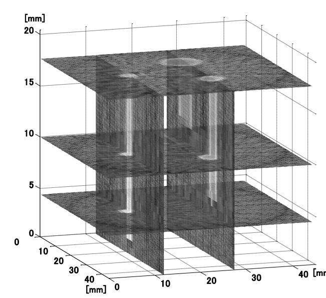


Construction of simulated CT apparatus

Appearance of single helical simulated CT device



Simulated CT image of phantom



3D reconstruction image of phantom

2. Development of a simple measuring instrument for daily management of X-ray equipment

In order to disseminate the daily management of X-ray equipment, we develop simple measuring instruments such as X-ray power meters and tube ammeters that are inexpensive in material cost and satisfy the required performance.

Simple measuring instrument system for daily management

[Education]

In the special theory, we will give lectures on measurement of minute current and characteristics of signal cable. In exercise, we will exercise about basic measurement method using microprocessor.

Medical Measurement Systems

Faculty in charge: Kiyomitsu Shinsho

Research laboratory policies: We place importance on developing the ability to independently solve problems (individual problem-solving skills). You should try to tackle questions that no one can answer. In our research laboratory, you can gain experience in the synthesis of phosphors that are sensitive to radiation, chemical analysis, optical measurement, analysis, and even the development of measurement systems.

Research details: We develop new radiation measurement devices, making use of a classical phenomenon called “thermoluminescence,” and conduct research on its mechanism.

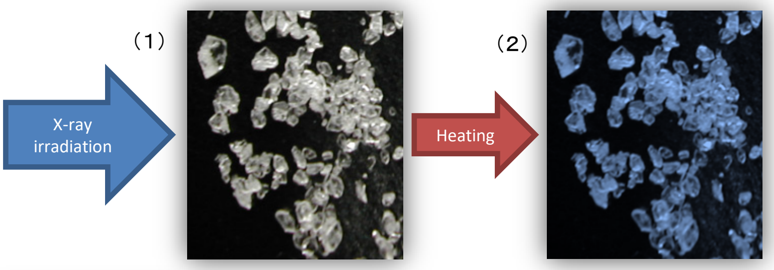
Current major research projects

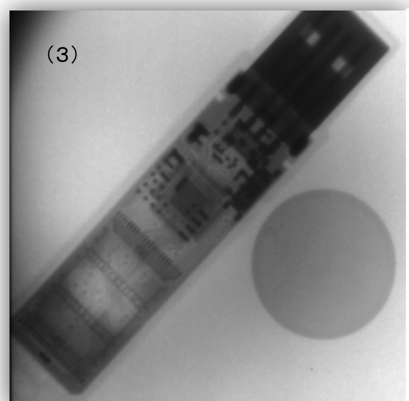
1. Studies on the development of imaging devices for charged particle radiation using thermoluminescent phosphors

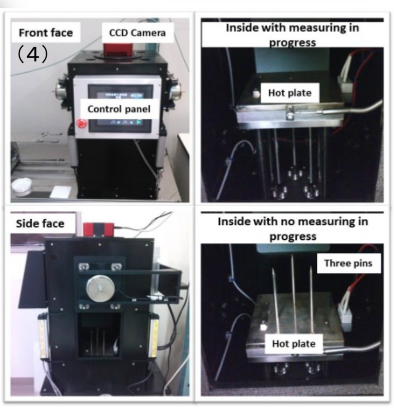
(Research collaborator: National Institute of Radiological Sciences)

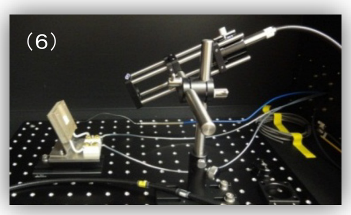
2. Research on the development of verification systems for high-precision radiation therapy plans
3. Studies on the development of neutron imaging devices using thermoluminescent phosphors

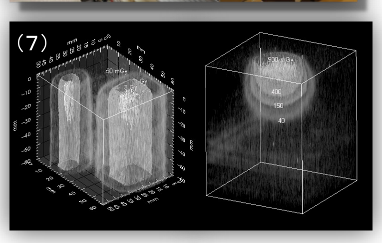
(Research collaborators: Kindai University and Kyoto University)











Thermoluminescence: When heat is applied to crystals irradiated with X-rays and so on (1), they can produce luminescence (2). This emission is called “thermoluminescence,” and it is correlated with the radiation dose. Taking advantage of this property, thermoluminescence has been used for personal radiation dosimeters and so on.

Two-dimensional analyses: When crystals exhibiting thermoluminescence are distributed in two dimensions, they can be used as a radiation imaging device. Photo (3) is an X-ray image of a USB stick and a one-yen coin taken with a thermoluminescent dosimeter developed by our research laboratory, and (4) shows the measuring instrument. (Six patents applied for) Images with a very high resolution can be obtained. The instrument can be used as an imaging device for verification of high-precision radiation therapy plans, boron-neutron capture therapy, and the measurement of environmental radiation. This is anticipated to be a new dosimeter that can obtain different information from that provided by existing dosimeters, and it has also been featured in newspapers and journals.

Increase in precision and three-dimensional analyses: In studies utilizing the heavy particle radiotherapy equipment for cancer at the National Institute of Radiological Sciences (5), the nuclear reactors at Kindai University and Kyoto University, work is underway to develop methods to measure radiation quality and dose distribution using thermoluminescence. In order to achieve this, it will be important to precisely measure thermoluminescence (6) and unravel its mechanism.

In addition, work is being done to measure three-dimensional dose distributions (7) and to develop a system that can measure the distribution of radiation in living trees over time without felling them (8). This is effective in identifying flow pathways and useful for decontamination measures and the like.

Diagnostic Medical Imaging

Akira Furukawa, MD, PhD, Takako Shirakawa, MD, PhD

In our research laboratory, we; diagnostic and interventional radiologist radiologists mainly conduct clinical studies on abdominal diagnostic imaging focusing on CT scans, MRI and ultrasound, and interventional radiology. Firstly, targeting the early detection of emergent diseases by advancement of diagnostic imaging that can lead to appropriate treatment options, we collect and analyze images of patients with various diseases causing acute abdominal conditions. We also disclose typical and characteristic imaging findings of these diseases, as well as, the diagnostic performance of various imaging tests for better understanding of values and limitations of each method. Secondary, we will develop morphofunctional imaging on gastrointestinal contractions, as well as related evaluation methods. Thirdly, diagnostic utility of ultrasonography using state-of-the-art machine for subcutaneous, joint, thyroid and breast diseases are investigated for further progress in diagnosis.

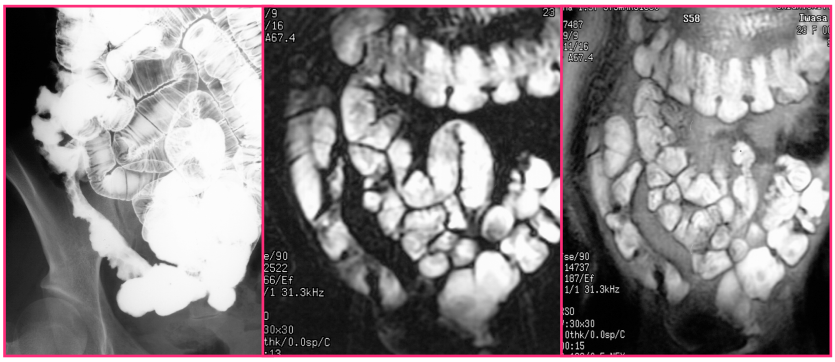
【Main Topics】

- # Performance and indication of MDCT for GI bleeding and bowel ischemia
- # Imaging Diagnosis for acute abdomen and various intestinal disorders
- # Analysis of bowel contraction using MRI
- # Morphological analysis of the liver in liver cirrhosis
- # Ultrasound assessment of disorders of the superficial organs

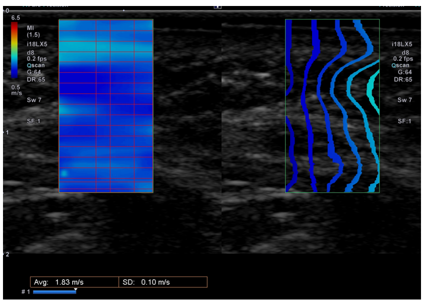
【Diverticular hemorrhage】

Angiogram Contrast –enhanced CT

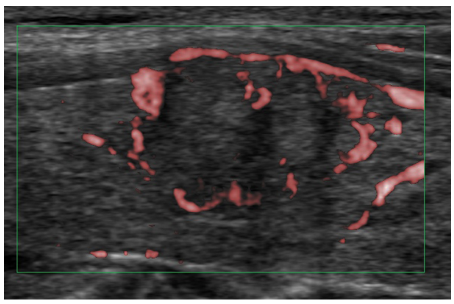
【Crohn Disease】



Barium study MR (SSFSE with fat saturation) MR (SSFSE)



【Ultrasound elastography of buccinator】



【Power-Doppler ultrasonography of thyroid gland】

Radiation Dosimetry

Supervised by Yoh Katoh (Prof., Ph. D.)

We apply nuclear methods to analyze the concentration distributions of trace elements in living organisms for elemental analysis. We have applied nuclear methods including neutron activation analysis, particle-induced X-ray emission analysis, and so on, and quantity values of the order of ppm and ppb have been obtained.

We evaluate the physical properties, protection abilities, and so on of lead-free radiological protection materials against the energy in X-ray diagnosis. We employ effective energy as a benchmark in our evaluation, but we discuss this in depth, since variations in radiation quality, including the structures of X-ray sources, added filters, and the like, can produce different evaluation results.

Example of research theme

- Actual measurement and calculation method of air kerma rate of diagnostic X-ray apparatus
- Application of MC Simulation to photon attenuation ratio of radiation protective material
- Verification of shielding ability of lead-free board and estimation by calculation
- Development of a filter dosimeter not accompanied by change of line quality
- Simple calculation method of intrinsic filtration of X-ray tube device
- Dose intensity distribution by target / filter combination
- Lead concentration in hair of X-ray laboratory workers
- Enrichment of tritium in environmental sample water
- Implementation of breast fluoroscopy, etc.

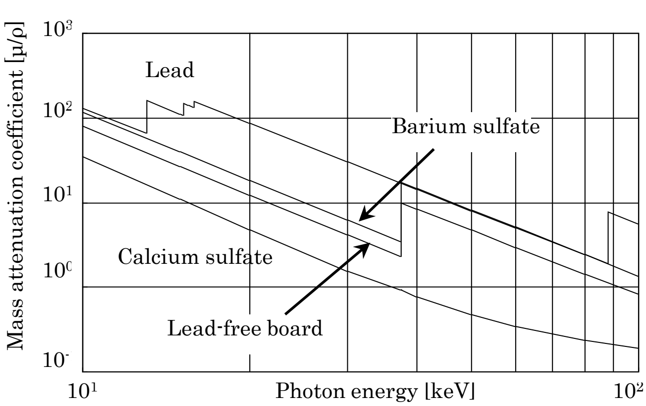


Fig.1 Mass energy attenuation coefficient of lead-free board

Fig.2 Industrial X-ray equipment

Diagnostic Imaging Systems Engineering

Faculty in charge: Atsushi Senoo

1. Research: My research projects are useful for medical technicians working in clinical settings, as well as patients or people suffering from diseases or disabilities and their family members.

1. Analysis of brain functions using MRI (functional MRI and diffusion tensor analysis)

We clarify the process of recovery from brain diseases and develop new diagnostic methods by using an MRI system to identify activated sites in the brain and detecting anomalies of the cranial nerve fibers. In addition, we also work on new image processing techniques for analyses and programming of MR imaging procedures (fMRI and diffusion).

2. Development of new MRI imaging procedures

In this research laboratory, we are developing various new imaging sequences and image reconstruction methods for clinical MR devices. We use PHILIPS GOLC for programing imaging sequences, and the C language, ITT Corporation's IDL and Mathwoks Corporation's MATLAB to develop image reconstruction methods.

3. Computer assisted diagnosis (CAD) with time-varying image processing

We are studying medical applications of a time-varying image processing method that can track objects in an image, and developing computer diagnostics such as gastroenterological diagnosis with X-ray fluoroscopic images of the stomach, three-dimensional analysis of myocardial dynamics based on gated myocardial SPECT images, and so on.

4. Risk management and patient care

What are the most common mistakes health care staff make in medical practice? We also conduct a survey on how they deal with patients and so on.

Functional MRI	Diffusion tensor analysis
Is it true that language is processed only in the left brain? Although it has been said for about the last 100 years that the repetition of words ─ (1) understanding words by listening (sensory language), and (2) repetition of words aloud (motor speech) ─ involves the left brain, it had not been possible to visualize this. Last year, we succeeded in visualizing these conditions for the first time in the world, and made it clear that the right brain as well as the left brain is also involved in speaking words. This research can clarify the process of recovery from speech disorders, and will help evaluate the effectiveness of speech therapy.	Can mental disorders be diagnosed with diagnostic imaging? Obsessive-compulsive disorder and schizophrenia are said to involve an abnormal arrangement of synapses, compared with the normal structure. Therefore, we developed a system to detect abnormal neural arrangements.
Development of new MRI imaging procedures	**CAD with time-varying image processing**
Development of MR imaging procedures with no noise Although MR devices have the advantage of obtaining cross-sectional images without using radiation, they produce a lot of noise during imaging. If this research can be put to practical use, it will be possible to greatly change the environment of laboratories. For example, examinations could be performed with music in the background in an MR room. In addition, an analysis of stimuli such as voices or sounds would be possible in imaging brain functions, which could make a significant contribution to the advancement of cerebrophysiology.	Computer recreation of gastroenterological diagnosis procedures by experienced doctors X-ray fluoroscopy is performed by doctors, and the accuracy of diagnosis is considered to vary greatly depending on the proficiency of the doctor making a diagnosis. In this research, we develop a diagnosis support system aiming to make computer recreations of diagnoses by experienced doctors. So far, we have made it possible to identify sites of stenosis with time-varying image processing.

2. Education

By following a curriculum of language acquisition specially created by the research laboratory, students can learn more about medical image processing and MR imaging sequences, and everyone will be able to perform programming. We are putting our efforts into developing human resources who can play active roles as core staff members at hospitals, research institutes, and businesses.

Diagnostic Imaging systems Engineering

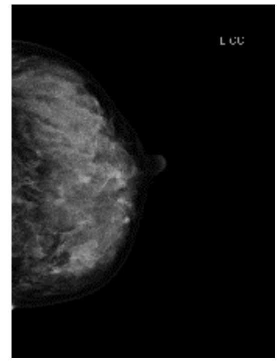
Toru Negishi

Research

We perform the measurement of each medical imaging equipment, and we examine optimization of the medical radiation exposure.

✓ Mammography

PMMA(mm)		
Breast Thickness(mm)	1	40
Air Karma(mGy)	7.667	
Breast Thickness(mm)	40	
HVL(mmAl)	0.338	
Spectrum	Mo/Mo	
Breast Glandularity(%)	50	
Average Glandular Dose(mGy)	1.747	



Currently, the examination method recommended for breast cancer screening is mammography, the breast density of the image affects cancer detection. Especially high concentration breast is considered as one of findings with high risk of carcinogenesis. Therefore, we analyze the characteristics of the device from both aspects of image quality and exposure, and consider optimization of mammography.

✓ Optimization of the medical radiation exposure (Diagnostic Reference Levels)

A diagnostic reference level of medical exposure in our country was formulated in 2015. Therefore, we examine the optimization of image quality and exposure dose.

✓ Quality Control of X-ray equipment

Based on the IEC standards, we examine the accuracy control of the diagnostic X-ray equipment's.

Education

We will lectures on X-rays diagnostic Imaging equipment, and we educate latest IEC or paper. We practice it about a measurement technology of the X-ray diagnostic equipment.

Medical Imaging and Informatics

Faculty in charge: Norio Sekine

We are working on medical image analyses and educational technology.

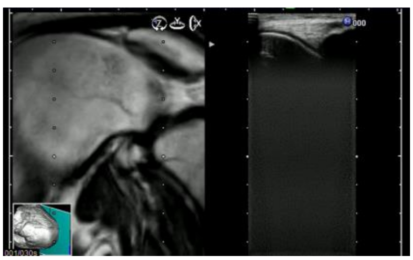
1. Evaluation of the quality of ultrasound images

○ Development of an automated screening system for breast cancer.

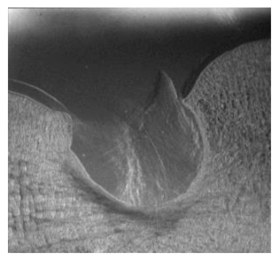
○ Development of a screening system for potential patients with osteoarthritis of the knee.

2. Radiation imaging for medical applications

○ Development of a reconstruction algorithm for tomosynthesis images with a refraction contrast technique.



Simultaneous display of MRI and ultrasound images



Depiction of ligaments and cartilage in a monochromatic X-ray

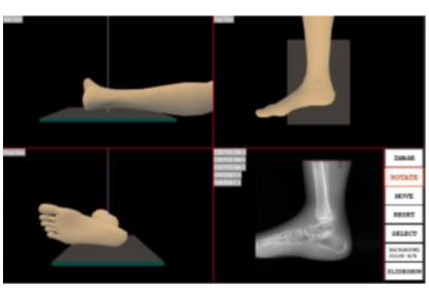
3. Development of an education support system for radiological technology

○ Research on positioning support for augmented reality (AR) technology and its applications.

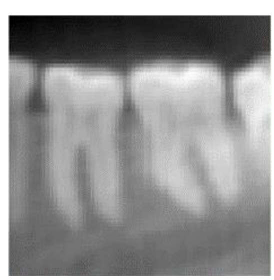
○ Simulations of X-ray images for education using CT data.

Virtual goniometer with real imaging and augmented reality

Imaging simulation consistent with information about posture



3D-CG display examples



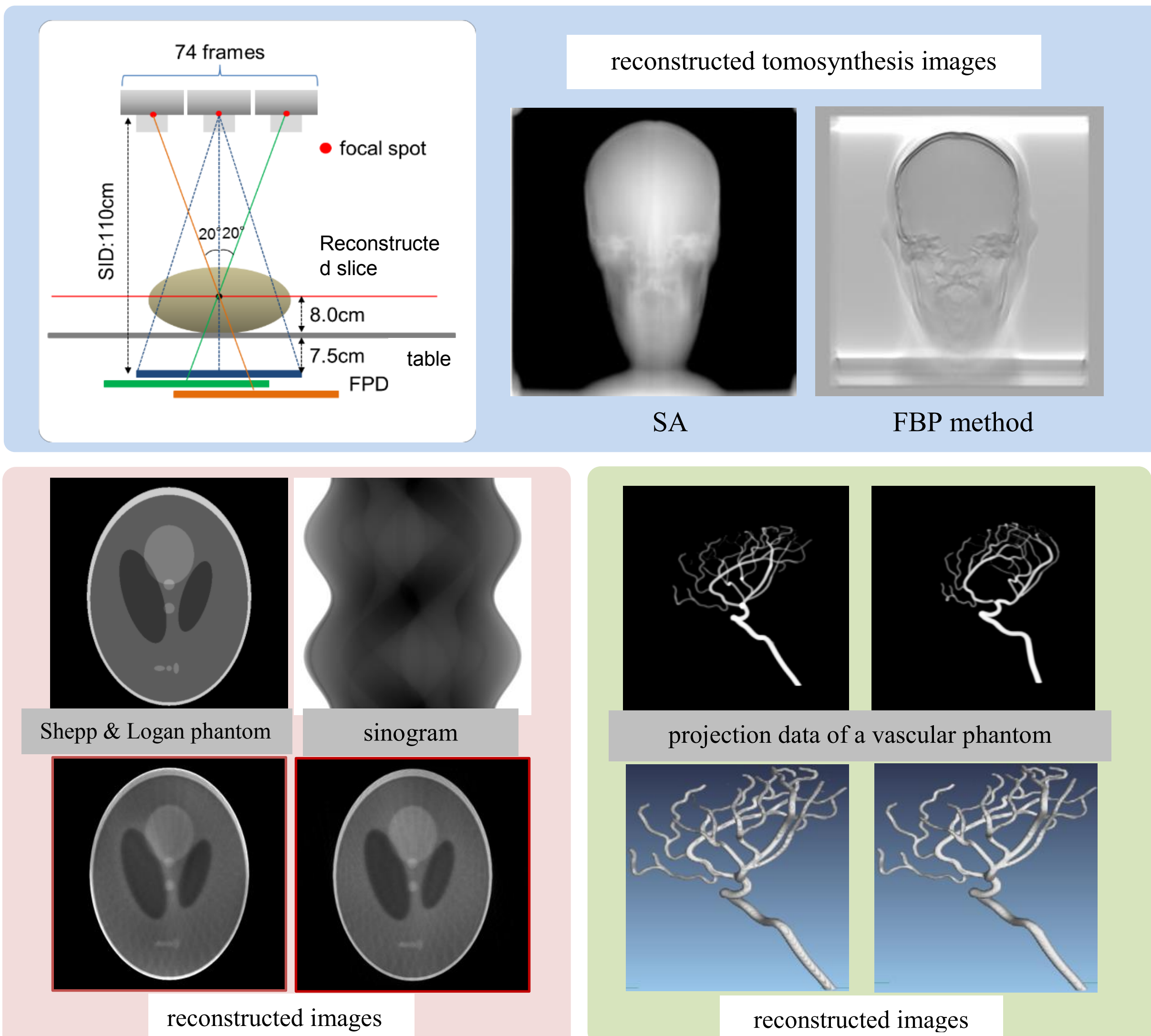
Dental X-ray simulation

Medical Imaging and Informatics

Faculty in charge: Yoshiyuki Nyui

1. [Research]

We are conducting fundamental research on medical image concerned with image reconstruction techniques. We mainly study image reconstruction of tomosynthesis. And we also study to reconstruct images from a few projection data using iterative reconstruction techniques (algebraic reconstruction technique, a maximum likelihood expectation maximization method and so on).



2. [Education]

In advanced courses on Medical Imaging and Informatics, we give lectures on the basic principles of image reconstruction methods. Furthermore, in the practical exercises of advanced courses on Medical Imaging and Informatics, students will actually create a simple image reconstruction program such as simple back-projection, filtered back-projection and iterative image reconstruction method. And further learn more about image reconstruction method by changing various parameters (such as projection angles, number of projections and so on).

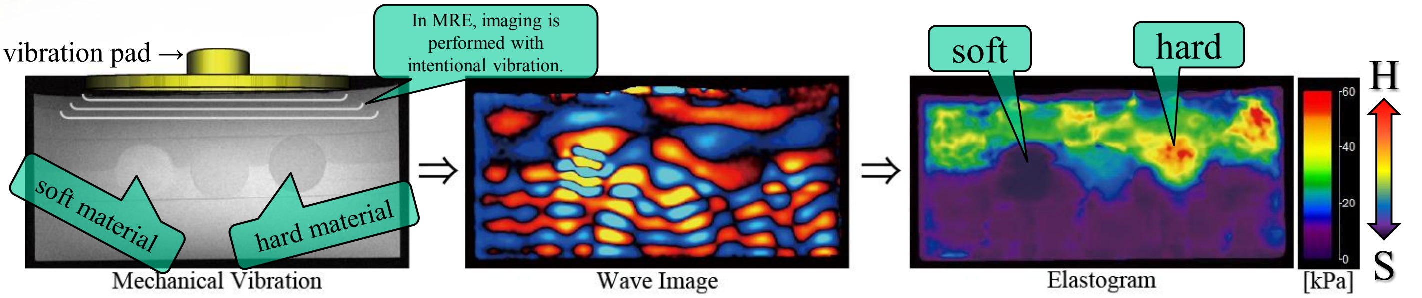
Details of research conducted in the Numano research laboratory

Research project in Numano research laboratory: MRI

We make use of MRI to carry out research on techniques to visualize *in vivo* information that has been difficult to imaging.

A technology to create an image of "hardness" *in vivo*: Elastography

We are advancing MR Elastography (MRE) that does not rely on the technology of MRI manufacturers, and have demonstrated MRE with our unique technology. MRE can create an image of "hardness" *in vivo* that had been impossible to image with traditional MRI technology. Thus, we can now obtain imaging data reflecting a distribution of hardness, which was not possible to image in the past.

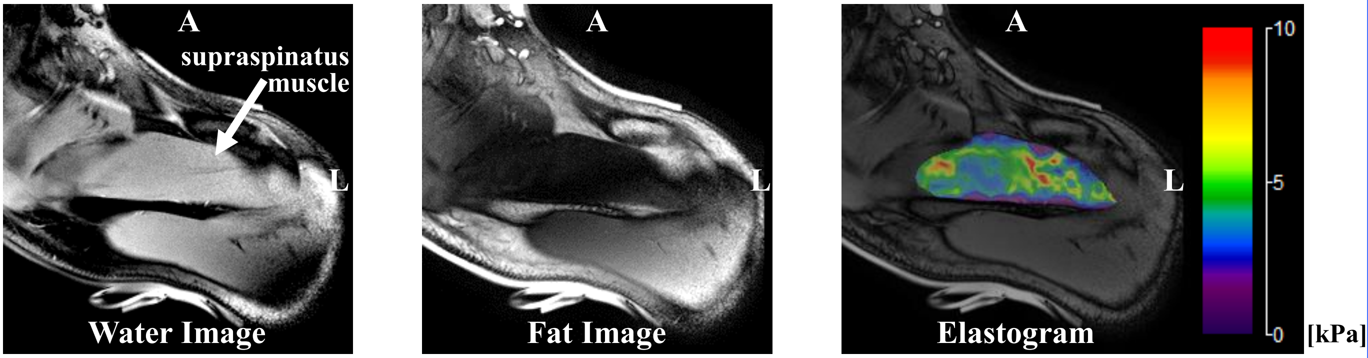


A Simple Method for MR Elastography: A Gradient-Echo Type Multi-Echo Sequence. *Magn. Reson. Imaging* 2015 33:31-7

Development of a new MRE technology

Ethics Committee for Safety and Ethics in Research, Faculty of Health Sciences, Tokyo Metropolitan University (Acceptance Nos. 10085, 13001)
Japanese Patent No. 6548257

We demonstrate a new technology which enable *shoulder* MRE and water/fat imaging simultaneously.



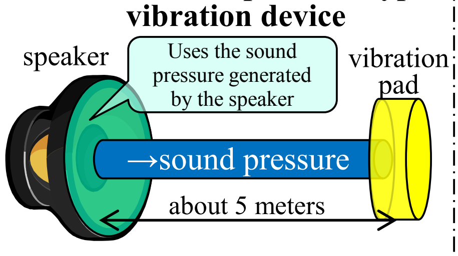
Fat is often a source of problems in MR imaging. It tends to have high signal intensity at all contrasts, which could mask image changes reflecting various tissue pathologies. We have developed a new method for simultaneous acquisition of MRE and two-point Dixon imaging (water/fat imaging) on a conventional MR imager.

Simultaneous Acquisition of MR Elastography and Two-point Dixon Imaging. *ECR 2018: ESR/EFRS Radiographer Awards*

Development of a new vibration device for MRI

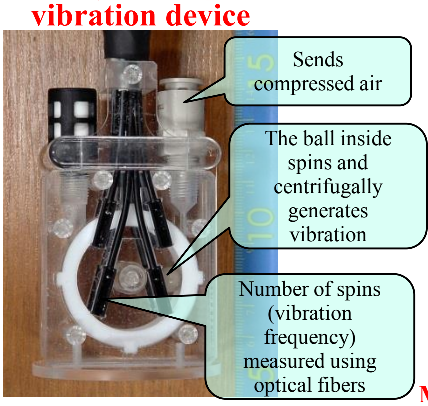
Japanese Patent No. 5376593

Current sound pressure-type vibration device



・Limited to a low vibration frequency range (the image resolution of MRE is low).
・The tube connecting the speaker to the vibration pad measures up to several meters (causing a great loss of vibrational energy)

Newly developed vibration device



There are a number of advantages compared with a sound pressure-type vibration device.

- High vibration frequency range (the image resolution of MRE is higher).
- Directly vibrate the target (resulting in little loss of vibrational energy).
- Even a small device can generate strong vibration.
- As is the case with the sound pressure type, this new device does not influence MRI since it is made of non-magnetic materials.

In this research laboratory, we are also developing devices that will play a part in next-generation MRE technologies, together with MRE techniques with a relatively high feasibility.

Magnetic Resonance Elastography using an air ball-actuator. *Magn. Reson. Imaging* 2013 31:939-46

We look forward to your questions and inquiries. TEL: 03-3819-7353, E-mail: t-numano@tmu.ac.jp, Numano research laboratory