Overview of JSPS Core-to-Core Program Integrated Action Initiatives -Forming Research and Educational Hubs of Medical Physics

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JSPS Core-to-Core Program

From FY2003, the Japan Society for the Promotion of Science (JSPS) has conducted this Core-to Core Program Integrated Action Initiatives for the purpose of building and expanding a cooperative international framework in leading-edge fields of science among universities and research institutions in Japan and the following 15 western nations: The US, Canada, Austria, Belgium, Finland, France, Germany, the Netherlands, Italy, Spain, Sweden, Switzerland, the UK, Australia, and New Zealand (**slide #2**).

The program is implemented in two types: The first is called "Integrated Action Initiatives," and the second "Strategic Research Networks". JSPS issues a call for proposals for "Integrated Action Initiatives". Based on the screening of the results, projects conducted under the first type may be elevated to the second "Strategic Research Networks" (**slide #3**). Our proposal was approved as type B initiatives. After 2 years, we want to move forward to type A. The objective of the first is to support short-term collaborations among researchers in Japan and in other scientifically advanced nations that will lay the foundations for establishing cooperative research networks (**slide #4**). No matching funds from overseas are required in this Type B. Joint Research Activities, Scientific Meetings, and Researcher Exchanges will be implemented under this program.

The objective of the second is to expand and strengthen research networks that will sustain from a relatively long-term perspective and advance cooperative relations among such researchers and research institutions (**slide #5**). On this type A, matching funds from partner agencies and excellent accomplishments of type B are required. Therefore, we would like to discuss this goal with you from the beginning. We expect advancing joint research leads to the ripple effect on other research fields and spawning new research by securing more sources of competitive funding. By promoting research exchange, expanding research networks and fostering talented young researchers across multiple disciplines can be achieved. Furthermore, through international seminars, we can share research results with other institutions and researchers and can build international networks for all researchers participating in this program.

Background of Medical Physics in Japan

In Japan, one of two Japanese will get cancer. One of three Japanese will die from cancer, i.e. No. 1 killer. Therefore, to overcome cancer is an important issue for Japanese people. Cancer death rate is increasing rapidly over the years (**slide #6**). The number of new patents who require radiation is also increasing accordingly. However, the application rate of radiation therapy for newly diagnosed cancer patients remains in only 27 %, compared with 50-70% in western countries. That means, in Japan, there may be 30-40% potential patients with cancer who can be treated with radiation therapy, but actually not treated.

As you all know, radiotherapy achieves good treatment outcome as well as excellent quality of life. The patient with left huge maxillary cancer as shown in **slide #7** is a good example. MRI shows huge mass occupies the left half of her face. If she underwent surgery, she would have lost her left eye and face. Using recent carbon therapy, she was cured with good cosmetic results and sparing of her eye. To deliver such high tech radiation to patients optimally and safely, specialized knowledge of radiation, QA/QC of a complicated accelerator, and R&D capability are required. The medical professionals who have such talent are medical physicists and they are required in the clinic and research field of radiation oncology. Structural comparison between Japan and US shows the number of medical physicist is extremely smaller in Japan. Therefore, to establish the education system for them is very important in Japan.

Forming Research and Educational Hubs of Medical Physics

Japanese government is aware of their importance. Fortunately, Ministry of Education, Technology and Science, so called MEXT, initiated an educational program for professions of cancer care, so called “Gan pro: Gan means cancer in Japanese and pro means professionals” and has supported us, as shown in **slide #8.** In Osaka University, we have been collaborating with RCNP, Research Center of Nuclear Physics, Graduate School of Science for boosting basic knowledge of physics and mathematics. For clinical education, we have been collaborating with Departments of Radiation Oncology and Nuclear Medicine at Graduate School of Medicine and with Oncology Center at Osaka University Hospital. Furthermore, we collaborate with Hyogo Ion Beam Medical Center and Osaka Medical Center for Cancer as affiliate graduate schools on particle therapy and high precision radiotherapy, respectively. By this program, we could establish medical physics educational system fostering professionals with specialized knowledge and techniques domestically. We are not satisfied with current educational system. We believe fostering researchers with Research and Development (R&D) capability and global view is essential for radiation oncology community in Japan. In this proposal, we want to exchange researches and education on medical physics with your University and University of Groningen in the Netherland. Especially, we want to focus on "particle therapy research", because these three Universities have excellent achievement in development and research of accelerators.

In this "Gan-Pro", our accomplishment of Medical Physics educational program is excellent domestically (**slide #9**). The pass rate of certification exam of Medical Physicist is 100%, compared with Japanese average of nearly 30%. In the next step, using this JSPS Core to Core Program, we encourage our students to participate in both international and advanced research, especially on particle therapy. As a result, we want to foster researchers who have enough physics knowledge in medicine and can flourish in the world. Finally, we expect they will lead the research on particle therapy in the world.

In this JSPS Core to Core Program, we made 6 research topics as shown in **slide #10**, because radiotherapy process includes the following steps.

1. Beam Delivery to treat cancer.
2. Biology to verify its effect.
3. Imaging to focus on the target accurately.
4. Simulation for accurate dose calculation.
5. Treatment concept to organize these 4 steps and others for actual treatment.
6. Informatics to analyze final outcome of patients treated with radiation and give feedback to these 5 steps.

For example, as <u>beam delivery system</u>, we are developing a particle therapy device using high-temperature superconducting magnets. This magnet will dramatically reduce the size of treatment unit, and electric and construction cost.

We have already made 3T dipole magnet and scanning magnet (slide #11). Detailed information will be presented by Professor Hatanaka.

As for simulation, we are using PHITS, particle and heavy ion transport cord system as Monte Carlo simulation code. This topic will be presented by Dr. Takashina and Dr. Horaguchi (slide #12).

As for imaging, we are developing nuclear spin imaging using Pemeranchuk cooling that leads hyper polarized MRI. Sensitivity was markedly improved. However, this time, its researcher does not participate in our team. Then, as a substitute, Dr. Takashina will present diagnostic imaging with a photon counting CdTe line detector which is on going at our school (slide #13).

As treatment concept, we are studying CBCT-based dose calculation with Monte Carlo simulation that will be presented by Mr. Takegawa (slide #14). We hope to collaborate with you based on different particles and image-guide modalities.

As for cancer information system, we are in charge of managing Patterns of Care Study (PCS) and Japanese National Cancer Database (JNCDB) (slide #15). Clinical data of patients and radiation treatment planning data nationwide are coming into our data center. We are also developing Quality Assurance Center of Radiation Treatment Planning like ATC in your country. In the near future, we want to develop online data acquisition and feedback system. This will be presented by Dr. Numasaki.

As for biology, we found particle beam, especially carbon, inhibits metastatic potential significantly both in vitro and in vivo (slide #16). We want to propose biological data that radiotherapy with photon and/or particle should take into account. Mr. Akino will present the interesting data.

We introduced your university to JSPS as shown in slide#17. Please correct the mistakes, if any. Your University has enough experience of medical physics for proton therapy and precedes us in the development of proton therapy devices, and can supplement the lack of treatment accelerator development at Osaka University. Our students can participate in CAMPEP at IUSM and IUHPTC for clinical training. We would like to conclude the agreement between universities. To advance this program to type A, we hope you would kindly apply Partnerships for International Research and Education (PIRE) program by NSF as matching fund.

We also introduced the University of Groningen in the Netherland to JSPS as shown in **slide #18**. They are setting up the Particle Therapy Research Center (PARTEC), the first particle therapy center in the Netherlands. They developed the first PET camera at KVI and are leading development of innovative imaging technology in the world. . Our students can participate in FANTOM international research school, which has educational program for scientific trainee researchers of nuclear and atomic physics. We had already official tie between both Universities. To advance this program to type A, we hope them to apply ESF and NWO.

To support students and collaborate with you all, we are preparing to use information technology (IT) fully as shown in **slide #19**. Within a limited time window, we can set Web Conference to discuss about joint research, to report its progress, and to give mental care to students. Furthermore, we can use SNS to make students report their research progress and provide these information simultaneously to the next candidate students who will soon study abroad to get a virtual experience.

Our ultimate goal of this program is fostering young researchers by such brain circulation as shown in **slide #20**. To achieve this goal, we have made educational system for medical physics and receiving system of young candidates at Osaka University. In the first step of this JSPS program, we believe building mutual trust between faculties is essential to establish new research environment.
In future, we aim to elevate "Integrated Action Initiatives" type B to the next stage "Strategic Research Networks," type A or to acquire other budgets, for example JSPS Global COE program. Meantime, we want to establish the International Research Center of Medical Physics that includes not only Graduate Schools of Medicine, Science, RCNP, and University Hospital but also Graduate Schools of Engineering and Information Science and Technology at Osaka University.

The draft of time schedule of this program is shown in **slide #21**. We want to start sending our students from this August as 1st term and from November as 2nd term. At this time Drs. Takegawa or Takasina will join them. We would like to invite Dr. Das in late November or early December to Osaka as guest speaker for Osaka University Medical Physics Seminar. In FY 2012, we want to send our students as 3rd term from

June and as 4th term from September. Drs. Takegawa or Takashina will join them in August and September. We want to invite some of you in late November or early December to Osaka for the seminar.

Appendix Information

Medical Physics Certification in Japan

The pathway to become a clinical Medical Physicist in Japan is shown in **slide #22**. Background of Medical Physicist is broad in Japan. Most are coming from Health Science BS and the others are from Physics or Engineering BS. Master course and Doctor course for Medical Physics are now open in Divisions of Physics, Medicine, or Health Science. In our case, it's open in Division of Health Science. Research Medical Physicists do not necessarily require clinical training or didactic course. Most of them are involved in the research of particle therapy in Japan. For Physics students without basic courses about medicine, biology, and medical technology, we have special course to enhance their knowledge in Medicine. On the other hand, for Health Science students without basic courses about physics and mathematics, we have also provided special course to educate them for Physics and Mathematics.

Current Medical Physics Education at Osaka University

Current educational systems by didactic courses and clinical training for medical physicist as "Ganpro" at Osaka University are shown from **slide # 23 to # 27**.

Overview of JSPS Core-to-Core Program
Integrated Action Initiatives (Type B)
Forming Research and Educational Hubs of Medical Physics

Co-chair

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Professor and Chairman
Dept. of Medical Physics and Engineering
Osaka University Graduate School of Medicine

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JSPS Core-to-Core Program

- The purpose of the JSPS Core-to-Core program is to build and expand a cooperative international framework in leading-edge fields of science.

* Only universities and research institutions of the above 15 countries are allowed as a core institution.

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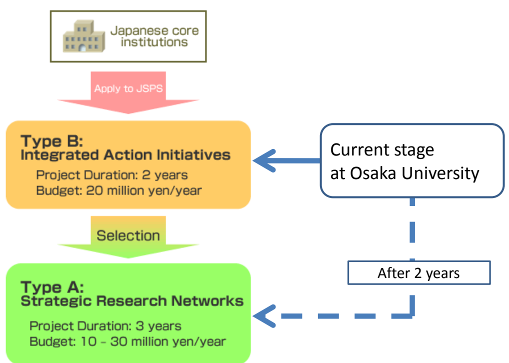
JSPS Core-to-Core Program Scheme



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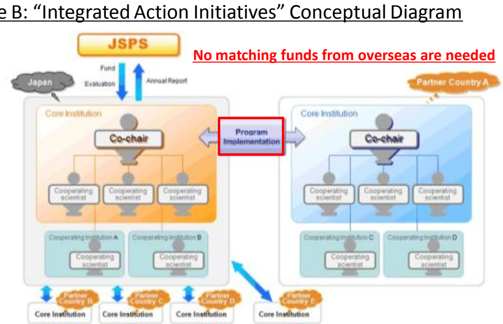
Type B: "Integrated Action Initiatives" Conceptual Diagram



Program Implementation
1. Joint Research Activities
2. Scientific Meetings
3. Researcher Exchanges

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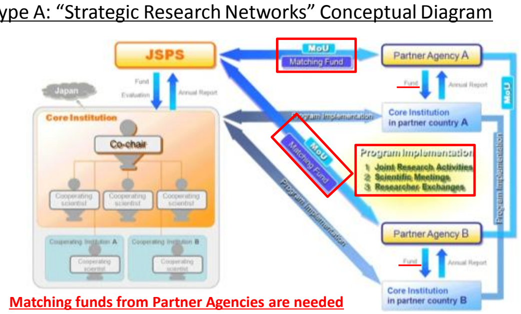
Type A: "Strategic Research Networks" Conceptual Diagram



Objectives
1. Build strategic interdisciplinary research
2. Establish sustainable research partnerships
3. Contribute to fostering young researchers

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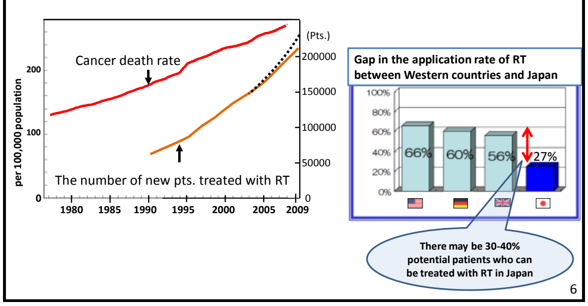
One of two Japanese will get cancer.
One of three Japanese will die from cancer.

➡ To overcome cancer is an important issue for Japanese people.



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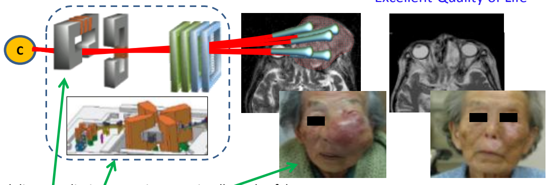
Radiotherapy

* Good treatment outcome
* Excellent Quality of Life



To delivery radiation to patients optimally and safely

- Specialized knowledge of radiation
- QA/QC of a complicated accelerator
- R&D capability

are required ⇨ Medical Physicists are essential!

Structure comparison between Japan and US	Japan (2009)	US (2004)
Population (× 10^6)	127.8	293.9
Radiation Oncologist	~900	~4,000
Medical Physicist	~150	~4,000

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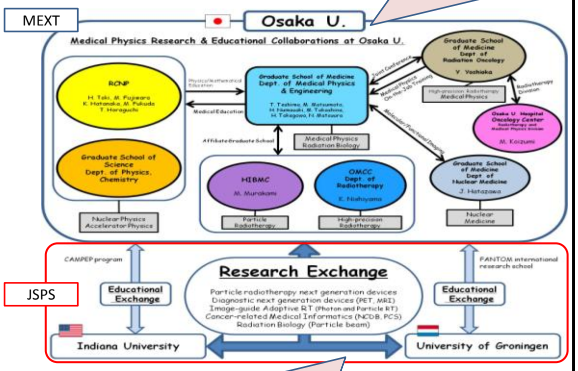

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Educational program for professionals of cancer care at Osaka U. "Gan pro"

Accomplishment of our Medical Physics educational program

Certification exam of Medical Physicist	Osaka U.	Japan
Pass rate	100% (8/8)	~30%

Next step

JSPS Core-to-Core Program

- International research
- Advanced research (especially particle therapy)

⇨ Fostering researchers who have enough physics knowledge in medicine and can flourish globally.

Lead the research on particle therapy in the world

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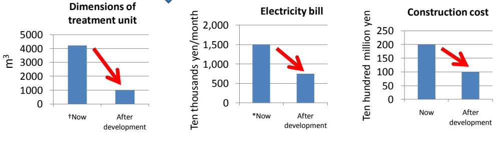
Radiotherapy

Informatics Cancer information system

Concept Image-guided radiotherapy/Adaptive radiotherapy

Simulation	Delivery	Biology	Imaging
Accurate estimation of dose distribution	Next generation particle therapy device	Particle beam radiation biology	Next generation diagnostic device

Development of a particle therapy device using high-temperature superconducting magnets



†Heidelberg Ion Therapy Center *Hyogo Ion Beam Medical Center

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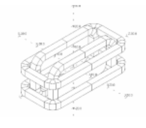
The next generation particle radiotherapy device

✓ Downsizing of devices
using high-temperature superconducting magnet

- Scanning magnet



- 3T dipole magnet

⇨ Apply to gantry

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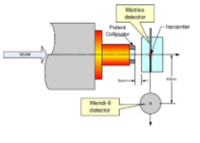
Dose calculation for high-accuracy radiotherapy

✓ Particle simulation
Using Monte Carlo simulation code PHITS *Particle and Heavy Ion Transport code System*

INDIANA UNIVERSITY

✓ Measurement by the MPRI group *D. Heckel et al., Med. Phys. 37 (2010) 2910.*

✓ Secondary neutron dose from patient collimator



Simulation with PHITS

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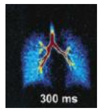
The next generation diagnostic devices

✓Development of nuclear spin imaging

➢**Pomeranchuk Cooling**

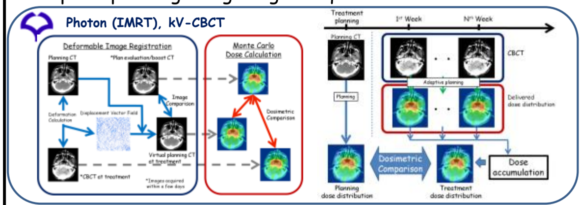


Hyper polarized MRI

（sensitivity is higher than the ordinary MRI by $10^{5\text{-}6}$ ）

Image-Guided Adaptive Radiotherapy

Adaptive planning using images acquired at treatment



Collaborations based on different particles and image-guide modalities

INDIANA UNIVERSITY — Proton (IMPT), MVCT

Research activity at IUSM & MPRI

Zhao L, Das IJ, et. al., Feasibility Study of MVCT Imaging Guided Adaptive Proton Therapy for Head and Neck Cancers. (AAPM 2010)

Cancer Information System

Japan
Osaka University
・Radiation Treatment Planning Data
・Clinical Data of Radiation Treatment

USA
Indiana University
・Radiation Treatment Planning Data
・Clinical Data of Radiation Treatment

Online Data Acquisition / Feedback System

Data Center

・Quality Assurance Center of Radiation Treatment Planning

Planning Data → Monte Carlo Verification System (developed) → International Comparison

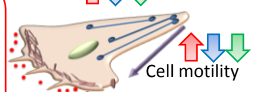
・Quality Assessment Center of Cancer Care

Clinical Data → Data analysis → Interaction Analysis: Structure, Process, Outcome; International Comparison

Particle beam radiation biology

Japan Osaka University — analyzing

EGFR → PI3K → Akt ⇧⇩?
ANLN ⇧⇩?
MLC ← ROCK ← GTP-RhoA ⇧⇩?
→ integrin αvβ3 ⇧⇩⇩
MMP-2 ⇧⇩⇩

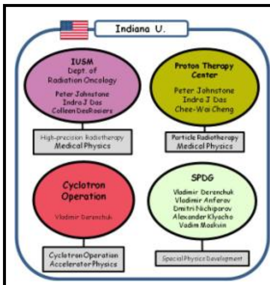


⇧ Enhance on low dose X-ray
⇩ Suppress on carbon ion beam
⇩ Suppress on proton beam
? Analysis on proton beam

USA Indiana University
・Proton and Carbon ion beam irradiation device
・Radiation Biological data

We accumulate data of gene or protein for cancer metastasis

On analyzing the data, influence of radiation on cancer metastasis will be clear.
This study will propose indicator for metastasis that RT should take into account.



➢ IU has enough experience of medical physics for proton therapy. (IUHPTC is 3rd in the US)

➢ IU precede the development of proton therapy devices, and can supplement lack of treatment accelerator development at Osaka U.

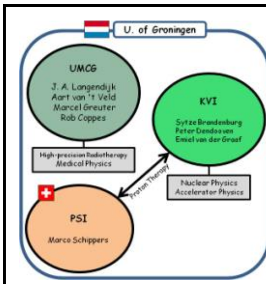
➢ CAMPEP: Certificated Medical Physics Education Program
→ Clinical training at IUSM and IUHPTC

➢ Agreement

We would like to conclude the agreement between universities.

➢ Expected Matching Fund

NSF: Partnerships for International Research and Education (PIRE) program



➢ The UMCG and KVI are setting up the Particle Therapy Research Center (PARTEC).
The first particle therapy center in the Netherlands

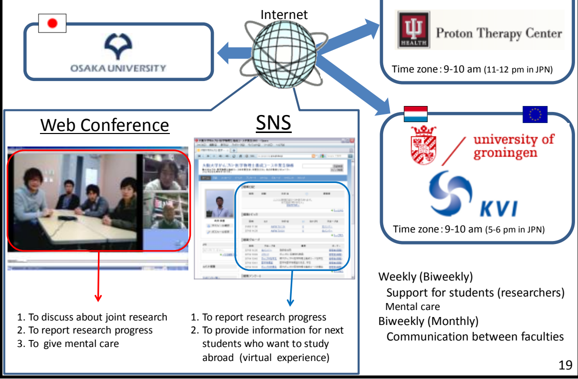
➢ The first PET camera was developed at KVI in the world.
(leading institution of the development of innovative imaging technology in the world)

➢ FANTOM International Research School
→ Educational program for scientific trainee researchers of nuclear and atomic physics

➢ Agreement
between universities (2002-), and between departments (RCNP and School of Medicine)
Osaka U. Groningen Center has been established since 2005.

➢ Expected Matching Fund
ESF: Research Networking Programes
NWO: Cooperation Japan

Support for students & Collaboration using Information Technology



Weekly (Biweekly)
Support for students (researchers)
Mental care
Biweekly (Monthly)
Communication between faculties

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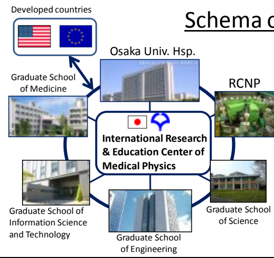
Fostering young researchers (Brain Circulation)

- Receiving environment ☺
- Mutual trust between faculties

Early visit and meeting
Information Technology

Establishment of research environment

Schema of future plan



We aim to acquire large budgets
Type A: "Strategic Research Networks"
JSPS Global COE program

Establishment of the International Research and Education Center of Medical Physics

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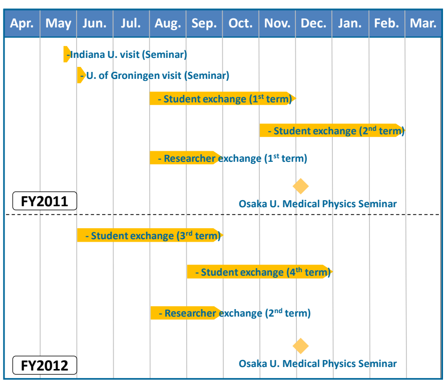
Time Schedule (Proposal)



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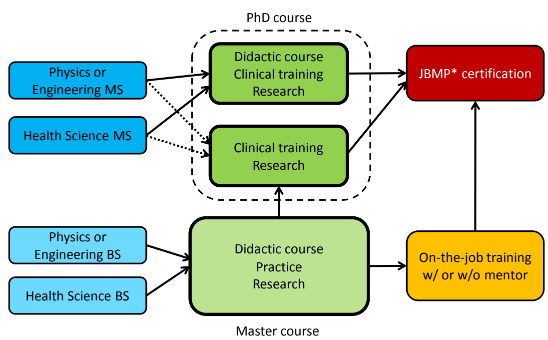
Pathways to become a Clinical Medical Physicist in Japan



* Japanese Board of Medical Physicist

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"Gan pro" Didactic courses -1

- Medical Physics-related advanced courses
  - Radiation Physics
  - Radiation Diagnostic Physics
  - Radiotherapy Physics
  - High precision radiotherapy
  - Brachytherapy
  - Particle therapy

- Oncology-related courses (electives)
  - Oncological pathophysiology
  - Regional health care and cancer screening
  - Oncological Pharmacology
  - Palliative Medicine
  - Introduction to Clinical Oncology
  - etc...

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"Gan pro" Didactic courses -2

- Basic courses for Physics or Engineering students
  - Physiology
  - Imaging Anatomy
  - Radiation Measurement
  - Radiation Oncology
  - Clinical Radiology

- Basic courses for Health Science students
  - Mechanics
  - Electromagnetism
  - Quantum Mechanics
  - Mathematical Physics

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"Gan pro" Practices

- Radiation Physics @ RCNP
- Radiotherapy Treatment Planning @ Osaka Univ. Hsp.
- Radiation Dosimetry & Quality Assurance

  @ Osaka Univ. Hsp. and Department of Medical Physics & Engineering

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"Gan pro" Clinical Training

Equipment

- Linac
  - Siemens ONCOR ×2
  - Accuray CyberKnfie
- CT-simulator
  - GE Brightspeed (16-slice)
- RALS (HDR)
  - Nucletron microSelectron (^{192}Ir)
- Treatment planning system
  - CMS(ELEKTA) Xio ×4
  - Phillips Pinnacle^3 ×2

  etc…

Treatment

- IMRT (Prostate cancer)
- Intraranial SRS/SRT
- Extracranial SRT (Lung cancer)
- Intracavity Brachytherapy
- Interstitial Brachytherapy
- ^{125}I permanent implant
- TBI

  etc...

@ Osaka Univ. Hosp.

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DTT (Dosimetry training tool)

- Dosimetry Training Tool
  - 01. Fundamentals of Cancer Management
  - 02. Anatomy for Medical Dosimetrists
  - 03. Radiobiology for Medical Dosimetrists
  - 04. Fundamentals of Radiation Safety
  - 05. Physics Fundamentals for Radiation Therapy
  - 06. Production of Teletherapy Radiation
  - 07. Radiation Sources for Brachytherapy
  - 08. Radiological Imaging
  - 09. Introduction to Dosimetry Instrumentation
  - 10. Measurement of Dose in Radiation Oncology
  - 11. Introduction to Teletherapy Dose Calculations
  - 12. Brachytherapy Dose Calculations
  - 13. Teletherapy Treatment Planning
  - 15. Practice Dosimetry Problems
  - 16. Radiographic and Virtual Simulation
  - 17. Three-Dimensional Conformal Radiotherapy
  - 18. High Dose-Rate Brachytherapy
  - 19. Introduction to Radiotherapy by Permanent Seed Implants
  - 20. Treatment Planning for Stereotactic Radiosurgery
  - 21. Treatment Planning for Intensity-Modulated Radiotherapy
  - 22. Dosimetric Quality Assurance for Radiation Oncology
  - 23. Professional Issues for Medical Dosimetrists
  - 24. Math skills

- We have provided students with this e-learning system for their self-study.

STANFORD SCHOOL OF MEDICINE

http://www.dosimetrytrainingtool.com/dtt/portal/portal

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