Medical Physics - the science of the XXI century

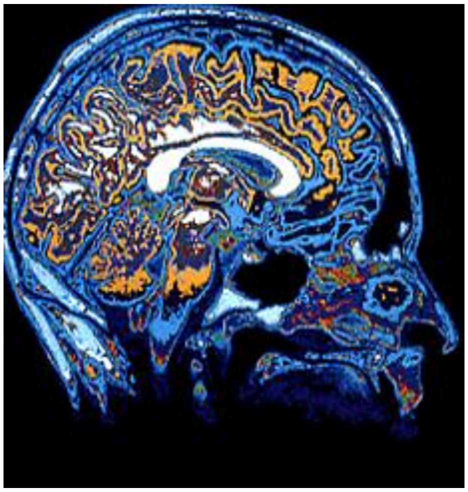
Prof. Ketevan Kotetishvili

Georgian Technical University. August 2012

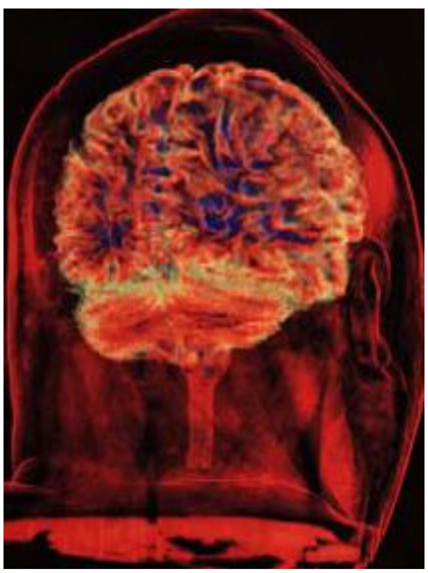
Medical physics and related areas research today is deservedly regarded as one of the most promising in the field of natural sciences, as they represent a logical and natural result of their development and implementation of the latest achievements of science, and, above all, physics, medical practice.

Medical Physics - is the use of complex physical facilities and physical and mathematical methods the study of human development and introduction of new diagnostic and therapeutic impact. Today the most widely used in medicine is a huge number of physical methods and devices that served as the basis for a variety of medical procedures Surgery, therapy and noninvasive diagnosis. For example, the appearance of an ultrasonic diagnostic imaging (ultrasound) made possible by the advances of modern acoustics, including the achievement of non-linear and ultrasonic Doppler imaging. Suffice it became commonplace in the world the use of electron and proton accelerators sterilization of medical equipment. Moreover, the synchrotron radiation of charged particles in accelerators begins to be used for high-quality X-ray transmission tomography, which has successfully complements the X-ray computed tomography (CT) and conventional radiography automatic transmission.

In Fig. we see visualization of human organs by means of different methods physical imaging

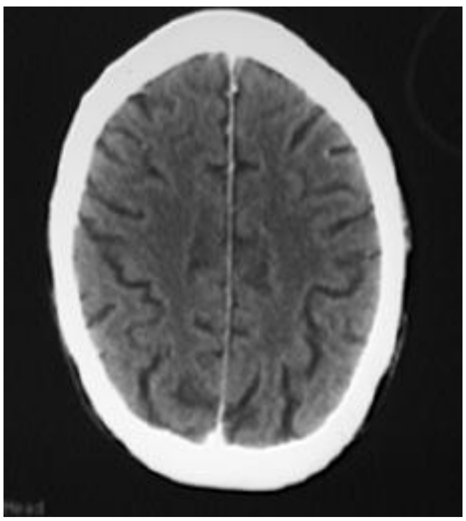


Emission Tomography - PET



Diffraction tomography NMR

Transmission Tomography X-ray



CT

Reflective tomography   ultrasound

Safe and effective use of medical radiation physics of radionuclides radiodiagnostic gamma cameras and various apparatuses of radiotherapy, including the so-called "cyberknife", was made possible by achievements of the radiation physics. To this list can be add methods for single-photon and positron emission tomography (PET), nuclear magnetic resonance imaging (NMR), high frequency EEG, lasers, variety of radiation sources, and much more, which was possible due to medical physics. For the successful promotion of these and many other directions of development of modern medicine to address a number of fundamental problems. The fundamental problems of medical physics are primarily creation of physical and mathematical models of various organs and systems of the person on the basis of physical studies research fields and processes in man under normal and pathology and to study the interaction of the human body with natural radiation. It is sufficient to recall that the double helix structure of DNA was discovered it is by physicists using such a fundamental physical methods like X-ray structural analysis, which in his time laid the foundations of physical crystallography.

The examples of achievements - this is the result solutions are very small part of the fundamental and applications of medical physics, even in medical diagnostics. And there is, for example, a developed area of radiological studies and the associated problem of radiation safety, the new therapies and surgery with ionizing radiation, medical materials and creating new transplants, the methods of physiological monitoring, medical technology and computer modeling, telemedicine, and quality control of diagnosis and treatment, etc.

Detailed and very interesting information about the medical radiation physics and dosimetry can be found, in particular, online http://www-naweb.iaea.org/nahu/dmrp/faq.shtm International Atomic Energy Agency (IAEA), which places great emphasis on safety various physical methods used in medicine.

The technical progress made possible the insertion of changes into technologies of the reception of images. It is related to the perfection of detector-piezo-crystals in the indicators of ultra-sound devices, radio-frequency channels and coils in magneto-resonance tomography (MRT), detector systems of X-ray apparatuses and computer tomography (CT) as well, as to the wide utilization of computers and micro-processors. As a result, greatly increased the diagnostic possibilities of the modern devices and arise the new diagnostic methods and technologies. Within the area of the diagnostic radiology there are – ultra-sound, CT, MRT and radio-nuclei method – the positron-emission tomography (PET). In most cases the investigations are carried out with utilization of the ultra-sound as well, as of CT and MRT.

As to PET, this method is based on the registration of couple γ-quanta, appearing at annihilation of positrons. Positron itself appears at the positron β-discharge of radio-nuclei, taking part in the composition of the radio-farm-preparations which should be inserted into the investtigated organism.

Now in PET are utilized the isotopes, listed below:

- *carbon-11 (C-11) (*$T_{1/2} = 20.4$ *min);*
- *natrium-13 (N-13) (*$T_{1/2} = 9.96$ *min);*
- *oxygen-15 (O-15) (*$T_{1/2} = 2.03$ *min);*
- *fluorine-18 (F-18) (*$T_{1/2} = 109.8$ *min).*

Due to rather small semi-discharge period of these isotopes the clinical application of PET is still rather restricted.

Wide insertion of digital technologies into the ray-diagnostic methods had been qualitatively changed the images of investigated organs. The methods of the reception and imagination of 3-D (volume) data of the medical visualization became widespread. CT turned to become the first method of creation of the 3-D reconstruction of the internal organs. Now the 3-D visualization is possible with the application of ultra-sound, MRT, X-rays, angiography, PET etc. In future all investigations will be visualized in 3-D imaging that is greatly important for doctors.

At present days this is realized by the radio-nuclei methods, such as single-photon emission computer tomography (SPECT) and positron-emission tomography (PET). But now it is also possible the utilization of the modern methods of MRT. The molecular diagnostic is by no means the future of the radiology.

Single-photon emission computed tomography (SPECT, or less commonly, SPET) is a nuclear medicine tomographic imaging technique using gamma rays. It is very similar to conventional nuclear medicine planar imaging using a gamma camera. However, it is able to provide true 3D information. This information is typically presented as cross-sectional slices through the patient, but can be freely reformatted or manipulated as required.

SPECT is similar to PET in its use of radioactive tracer material and detection of gamma rays. In contrast with PET, however, the tracer used in SPECT emits gamma radiation that is measured directly, whereas PET tracer emits positrons that annihilate with electrons up to a few millimeters away, causing two gamma photons to be emitted in opposite directions. A PET scanner detects these emissions "coincident" in time, which provides more radiation event localization information and, thus, higher resolution images than SPECT (which has about 1 cm resolution). SPECT scans, however, are significantly less expensive than PET scans, in part because they are able to use longer-lived more easily-obtained radioisotopes than PET.

Because SPECT acquisition is very similar to planar gamma camera imaging, the same radiopharmaceuticals may be used. If a patient is examined in another type of nuclear medicine scan but the images are non-diagnostic, it may be possible to proceed straight to SPECT by moving the patient to a SPECT instrument, or even by simply reconfiguring the camera for SPECT image acquisition while the patient remains on the table.

To acquire SPECT images, the gamma camera is rotated around the patient. Projections are acquired at defined points during the rotation, typically every 3–6 degrees. In most cases, a full 360-degree rotation is used to obtain an optimal reconstruction. The time taken to obtain each projection is also variable, but 15–20 seconds is typical. This gives a total scan time of 15–20 minutes.

In some cases a SPECT gamma scanner may be built to operate with a conventional CT scanner, with coregistration of images. As in PET/CT, this allows location of tumors or tissues which may be seen on SPECT scintigraphy, but are difficult to precisely locate with regard to other anatomical structures. Such scans are most useful for tissues outside the brain, where location of tissues may be far more variable. For example, SPECT/CT may be used in sestamibi parathyroid scan applications, where the technique is useful in locating ectopic parahyroid ademomas which may not be in their usual locations in the thyroid.

Combination of PET with CT or MRI

PET scans are increasingly read alongside CT or MRI scans, with the combination (called "co-registration") giving both anatomic and metabolic information (i.e., what the structure is, and what it is doing biochemically). Because PET imaging is most useful in combination with anatomical imaging, such as CT, modern PET scanners are now available with integrated high-end multi-detector-row CT scanners (so-called "PET/CT"). Because the two scans can be performed in immediate sequence during the same session, with the patient not changing position between the two types of scans, the two sets of images are more-precisely registered, so that areas of abnormality on the PET imaging can be more perfectly correlated with anatomy on the CT images. This is very useful in showing detailed views of moving organs or structures with higher anatomical variation, which is more common outside the brain.

At the Jülich Institute of Neurosciences and Biophysics, the world's largest PET/MRI device began operation in April 2009: a 9.4-tesla magnetic resonance tomograph (MRT) combined with a positron emission tomograph (PET).

Of all these examples it is clear that improved diagnostic and treatment process using modern physical methods, as well as competent maintenance of the new high-tech medical equipment and its development is impossible without a professional fundamentally new knowledge, which are on the intersection of physics, biology and medicine. Medical physics - it is unique in the degree of erudition specialist with thorough knowledge of physics, mathematics, biology and medicine, is capable of generate new ideas in medicine, based on physics, medicine and biology.

That's why medical physicists find their place: 1) institutions and research institutes medical profile, which work together with physicians, provide his scientific and technical advisory expert assessment and conduct joint research, 2) in the universities and scientific research institutions of the physical profile where research is carried out the physical foundations of new high-tech methods of medical diagnostics, therapy and surgery, 3) in industrial firms and enterprises, where they spent the scientific and technological research aimed at creating a direct modern medical equipment, its improvement and implementation. To date, no medical physicists can not fully operational no medical research institution or clinic in the U.S., Europe and other highly countries. Comprehensive information about medical physics and medical physicists can be found, in particular, sites of the American Association of Medical Physicists http://www.aapm.org/ and the International Organization medical physicists http://www.iomp.org/

EDUCATION OF MEDICAL PHYSICS IN GEORGIA

Association of Medical Physicists of Georgia was founded in 1994 on the basis of the Radiation Therapy Planning of the National Cancer Centre of Georgia. AMPG was the first who gave rise to the question of Medical Physicists Education at the University level several years ago. They had already elaborated a study programme and a system to implement it in Universities in the Physics Departments, but despite of their endeavours Universities could not adopt the new direction.

In 2005 at Bergen Summit Georgia joined Bologna Process and today Higher Education System of Georgia consists of three cycles:

First cycle – Bachelor’s Degree (240 credits);

Second cycle – Master’s Degree (120 credits);

Third cycle – Doctor’s Degree (180 credits)

Bachelor’s degree at the Physics faculty gives qualification of a secondary school teacher; only after finishing master studies student attain a professional Physicists qualification.

After the major reform procedure, the Georgian ministry of Education and Science granted a permission to establish medical physics and radiation safety department in the Technical university of Georgia. Knowledge of IT and computing is essential in order to have an understanding of modern technology in medical diagnoses, which is essential for health in contemporary world. The department of Medical Physics was created on the basis of the faculty of physics in the Georgian technical university, which will approximately have 10 to 15 graduates in that area. The reason for creating this department was that, currently no other university in Georgia offers a degree neither in Medical physics nor in the Radiation Safety. Currently students are on their 2nd year doing BA Physics and are lectured by the fully qualified professors in the physics department. According to the European standards, students have to undertake 240 credits during their 4 year of studies.

The main courses are:

N	subjects	credits
1	General Physics	20
2	Mathematics	15
3	IT	25
4	Essential Medical Physics	10
5	Medical Radiation Physics	5
6	Optics in Medicines	10
7	Mammalian Physiology	5
8	Physiological Monitoring	20
9	Medical Electronics	10
10	Medical Imaging with Ionizing Radiation	10
11	Medical Imaging with Non-ionizing Radiation	10
12	Treatment using ionizing radiation	7
13	Mathematical Methods in Medical Physics	10
14	English Language	24

In addition students must complete a project in medical physics and radiation safety (20 credits)

Graduates of this program can work according to their specialty in radiation biology, ecology, health (clinics, hospitals), social affairs and environmental sectors as well as in the Ministry of Internal Affairs and in the Ministry of Defence.