TEACHING RADIATION PROCESSES IN MEDICAL HIGHER EDUCATION INSTITUTIONS: THE ROLE OF MEDICAL RADIOBIOLOGY, APPLICATION AND DEVELOPMENT OF RADIATION TECHNOLOGIES

L.Kh. Zoirova[1], K.R. Nasriddinov[2], K.T. Suyarov[3]
Navoi University of Innovations, PhD in Physics and Mathematics, Associate Professor[1]
Chirchik State Pedagogical University of Tashkent Region, Doctor of Physics and Mathematics, Professor[2]
Chirchik State Pedagogical University of Tashkent Region, PhD in Pedagogical Sciences, Associate Professor[3]
https://doi.org/10.5281/zenodo.18399117

Abstract. *This article discusses the pedagogical and technological foundations for in-depth teaching of radiation processes to students in medical higher education institutions within the framework of the medical radiobiology curriculum. In addition, the paper highlights the role and significance of medical radiobiology in modern medicine, the integration of educational processes through an integral (integrative) learning module, and perspectives for the development of radiation medicine.*

Keywords: *medical radiobiology, diagnostics, therapeutic methods, modern medicine, radiation processes, dosimetry, radiation protection, teaching technologies, radiopharmaceuticals.*

Introduction

Teaching medical radiobiology in medical higher education institutions is of great importance. This discipline not only strengthens the theoretical foundations of medicine but also serves as a basis for understanding modern diagnostic and therapeutic methods. It should be emphasized that, in the process of mastering medical radiobiology, students of medical higher education institutions gain an increasingly profound understanding — through lectures as well as practical and laboratory classes — of the growing importance of radiation in modern medicine. Many advanced technologies used in diagnostics and treatment are based on the principles of radiation physics and biophysics. Therefore, providing future physicians with an in-depth understanding of radiation processes, elucidating the role of medical radiobiology in these processes, and analyzing the development of radiation technologies constitute a globally significant direction in contemporary medical education.

The role of medical radiobiology in teaching radiation processes. Medical radiobiology is a discipline that applies the principles of physics to the understanding of biological systems and processes. Radiation biophysics, in particular, studies the effects of ionizing radiation on biological objects, including changes at the cellular and tissue levels. For students specializing in medicine, an in-depth study of medical radiobiology is crucial for understanding the mechanisms of radiation processes (Table 1).

Understanding the molecular and cellular effects of radiation. The fundamentals of medical radiobiology help elucidate how radiation affects DNA, proteins, and other biological

macromolecules, as well as the mechanisms of cellular damage, mutations, and cell death. This knowledge provides a foundation for physicians to understand the pathogenesis of radiation-induced diseases and to develop effective treatment strategies.

Table 1. The main role of medical radiobiology in radiation medicine

Key concept	**Its role in medical radiobiology**	**Importance in medicine**
Ionization	Studies nuclear reactions and ionization processes	Forms the basis of nuclear medicine and radiation therapy
Cellular-level damage	Mechanisms of damage to DNA, proteins, and other cellular components	Understanding the effectiveness of radiation therapy in oncology and treating radiation injuries
Dosimetry	Studies quantitative measurements of radiation and its equivalent dose effects on biological objects	Determining safe and effective doses in diagnostic and therapeutic procedures
Radiation protection	Principles of protection (distance, shielding, time) and the radiation absorption properties of materials	Ensuring the safe handling of medical staff and patients

Dose–response relationships. Medical radiobiology examines the relationship between radiation dose and biological effect (dose–response curves). This is essential for clinicians in selecting minimal effective doses for diagnostic procedures and determining optimal doses in radiation therapy to achieve tumor control while minimizing adverse effects.

Fundamentals of radiation protection. Radiation biophysics provides a scientific basis for the principles of radiation protection — distance, shielding, and time. By understanding how radiation propagates and how it is absorbed by different materials, students learn to apply effective measures to protect both themselves and their patients from unnecessary exposure.

Application and development of radiation technologies in medicine. Radiation technologies have brought about a major revolution in medicine, a process that continues to this day. They encompass a wide range of applications, from diagnosis to treatment.

The following diagnostic technologies are widely used in modern medicine:

- **Radiography (X-ray imaging):** One of the oldest and most widespread methods, used to obtain two-dimensional images of bones, lungs, and other tissues;
- **Computed tomography (CT):** Utilizes X-rays to generate cross-sectional (three-dimensional) images of the body. New-generation systems, such as spiral CT and multislice CT (MSCT), improve diagnostic accuracy and examination speed;
- **Positron emission tomography (PET):** Uses radioactive isotopes to visualize metabolic processes in the body. It is often combined with CT (PET/CT) and is widely applied in oncology, as well as in neurology and cardiology;
- **Single-photon emission computed tomography (SPECT):** Assesses the functional state of organs based on the distribution of radioisotope tracers;
- **Radioimmunoassay (RIA):** A laboratory method used to determine the concentration of hormones, tumor markers, and other biologically active substances.

At the same time, the following types of therapeutic radiation technologies (radiation therapy) are extensively employed:

- **External beam radiation therapy:** High-energy radiation is directed at the tumor from an external source (e.g., linear accelerators). Modern techniques such as intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) enable more precise dose delivery to tumors while sparing healthy tissues;
- **Brachytherapy:** Involves placing radioactive sources directly within or near the tumor. It is widely used in the treatment of prostate cancer, cervical cancer, and other malignancies;
- **Proton therapy:** An advanced form of radiation therapy that uses protons instead of photons. Protons deposit their energy at a specific depth (the Bragg peak), allowing maximal damage to the tumor while minimizing exposure to surrounding healthy tissues. This method is particularly effective in pediatric oncology and in the treatment of brain tumors;
- **Radiopharmaceutical therapy:** Delivers radioisotopes directly to tumor cells using carrier agents (e.g., monoclonal antibodies). Therapies such as **Lu-177-PSMA** are emerging as promising approaches for the treatment of prostate cancer.

Global and national research and comparative education systems. Research and educational systems in the field of radiation medicine are continuously evolving on a global scale.

Considering international experience, the following aspects deserve particular attention:

- **Research centers:** Countries such as the United States (MD Anderson Cancer Center, Mayo Clinic), Europe (Karolinska Institutet, CERN), and Japan (National Cancer Center) host major research institutions specializing in radiation biology, radiation oncology, and radiation epidemiology. These centers focus on identifying new biological effects of radiation and developing advanced methods for the diagnosis and treatment of radiation-induced injuries and diseases.
- **Educational systems:** In most developed countries, medical universities have dedicated departments or centers for radiation medicine, nuclear medicine, and medical physics. Education is structured progressively from undergraduate to master's, residency, and doctoral levels. Significant emphasis is placed on practical training and work in simulation-based learning centers. For example, in Europe, organizations such as the **European Board of Nuclear Medicine (EBNM)** and the **European Society for Radiotherapy and Oncology (ESTRO)** establish educational and professional standards for specialists in radiation medicine.
- **International collaboration:** International organizations such as the **International Atomic Energy Agency (IAEA)** and the **World Health Organization (WHO)** develop global standards for radiation safety and medical applications of radiation, support educational programs, and facilitate the exchange of specialists worldwide.

Table 2. Chronology of the development of radiation technologies in medicine

Years	**Discoveries and their applications**
1895	The discovery of X-rays
the early 1900s	The initial application of radiation therapy
the 1950s	The emergence of cobalt-60 therapy
the 1970s	The introduction of CT into clinical practice
the 1980s	The development of PET
the 1990s	IMRT and 3D-conformal radiation therapy
the 2000s	VMAT and PET/CT integration

the 2010s	The widespread adoption of proton therapy and advancements in radiopharmaceutical therapy

The situation in Uzbekistan and prospects for development. In medical higher education institutions in Uzbekistan, the fundamentals of radiation medicine are taught; however, their depth and level of integration have not yet fully reached those of leading developed countries.

- **Current status:** In medical universities under the Ministry of Health of the Republic of Uzbekistan, topics related to radiation diagnostics and radiation therapy are delivered by relevant departments. Courses on radiation safety are also included in the curriculum. Nevertheless, there is a need to place greater emphasis on the role of biophysics in understanding radiation processes and to increase the number and quality of practical training sessions (Figure 1).

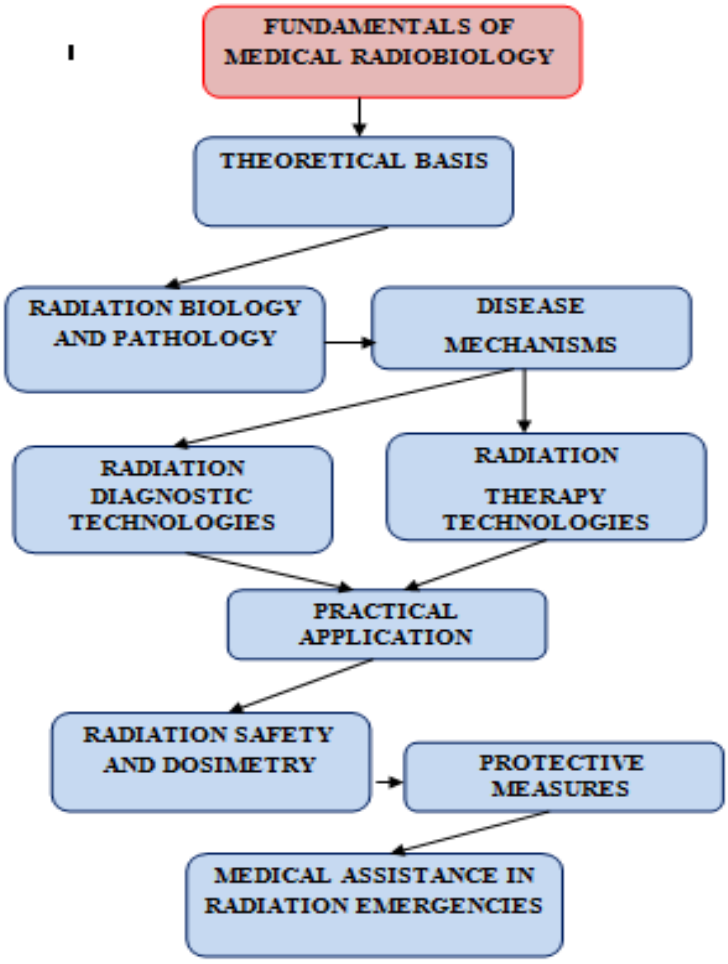


Figure 1. Model of integrating educational modules in teaching radiation processes.

Prospects for the Development of Radiation Education in Medicine

- **Modernization of curricula:** Introducing specialized, in-depth courses in radiation biophysics, radiation pathology, and radiation safety is a requirement of the times. These courses should include new methods of radiation therapy (such as proton therapy), advanced diagnostic techniques (PET/CT), and sections on radiopharmaceuticals.
- **Establishment of modern laboratories and simulation centers:** There is a need to create conditions for developing students' practical skills in working with radiation equipment, radiation dosimetry, and actions in radiation emergency situations.

- **Strengthening research capacity:** Supporting scientific projects in radiation medicine, radiation oncology, and radiation safety is essential. It is also necessary to develop systems of grants and scholarships to attract young scientists to this field.
- **Expansion of international cooperation:** It is advisable to establish joint educational programs, research projects, and faculty exchange with leading foreign universities and research centers.

Conclusion. In-depth teaching of radiation processes in medical universities, with an emphasis on the fundamental role of medical radiobiology, is an urgent requirement of modern medicine. The rapid development of radiation technologies necessitates continuous updating and the implementation of advanced practices in this field. The healthcare system of Uzbekistan should also prioritize the training of highly qualified specialists in radiation medicine in accordance with international standards. This will not only enhance patient safety and treatment effectiveness but also contribute to strengthening the country's scientific and technological potential.

REFERENCES

1. Kudryashov Yu.B. *Radiation Biophysics: Radiofrequency and Microwave Electromagnetic Radiation.* Textbook for universities. Moscow: Fizmatlit, 2008. 184 p.
2. Andrianov V.T. et al. *Radiation Biophysics of Chromatin DNP.* Moscow: Atomizdat, 1976. 220 p.
3. Kudryashov Yu.B. *Radiation Biophysics.* Moscow: Fizmatlit, 2004. 448 p.
4. Rubin A.B. *Biophysics.*, Vol. 1. Moscow: Moscow University Press, 2004. 464 p.
5. Rubin A.B. *Biophysics.*, Vol. 2. Moscow: Moscow University Press, 2004. 469 p.
6. Remizov A.N. *Medical and Biological Physics.* Textbook. Tashkent: National Encyclopedia of Uzbekistan, 2005. 588 p.
7. Bazarbaev M.I., Mullajonov I. et al. *Biophysics.* Textbook. Tashkent: Fan va Texnologiya, 2018. 212 p.
8. Zoirova L.X., Tukhtamishova M.Sh., Sultonova N.N. Teaching physics at a medical university: problems and approaches to solution. *Current Research Journal of Pedagogics*, Vol. II, 2(06), 2021, pp. 171–173. ISSN 2767-3278.
9. Zoirova L.Kh., Bozorov E.Kh., Khusanov Z.J., Sattorova Sh.G., Kuvvatova M.A. Use of various innovative-interactive methods in teaching the science of "Radiation Medicine and Technologies" in higher education. *Journal of Pharmaceutical Negative Results*, Vol. 13, Special Issue 7, 2022 (Scopus Q4), pp. 3248–3252. DOI: 10.47750/pnr.2022.13.S07.423.
10. Zoirova L.Kh., Bozorov E.Kh., Khusanov Z.J., Rakhimova M.Yu., Togaev O.Sh. Training of high-level specialists in radiation medicine and its relevance. *XXX International Scientific and Practical Conference "Modern Science: Topical Issues, Achievements and Innovations"*, Russia, Anapa, October 24, 2020, pp. 6–10.
11. Zoirova L.Kh. Effective application of innovative methods during practical lessons on the discipline "Radiation Technologies". In: *Republican Scientific Conference of Young Scientists "New Technologies in Digital Medicine"*. Tashkent, Tashkent Medical Academy, September 10, 2024, pp. 315–317.
12. Zoirova L.X. Specific training of medical physicists as an important aspect of the health of future generations. *NamDU Scientific Bulletin*, Namangan, 2021, No. 12, pp. 601–605.