I.N. Beckman

RADIATION AND NUCLEAR MEDICINE: PHYSICAL AND CHEMICAL ASPECTS

ISBN 978-5-905722-40-0

A text-book series in Postgraduate Education

About the author:

Dr. habil. Beckman Igor Nikolaevich – professor at the Department of Radiochemistry, Faculty of Chemistry of M.V. Lomonosov Moscow State University, Russia; recipient of “MSU Distinguished Professor” award.

Editors: Beckman E.M., Polonskaja-Booslaeva O.A.
The annotation and ToC were translated by: Dr. V. Deineko
Abstract

“Radiation and nuclear medicine: physical and chemical aspects” is the 7th volume in popular “Radiochemistry” text-book series, authored by prof. I. Beckman. This volume is dedicated to clinical applications of ionizing radiation and radionuclides. The author describes their usage in modern diagnostics, surgery and therapy and provides numerous practical examples to the reader. **Part I** describes the phenomenon of radioactivity, nuclear reactions, interactions of ionizing radiation with matter and biological effects of radiation. Current national and international radiation safety guidelines and sanitary standards are provided. **Part II** of the text-book is dedicated to methods of radiation diagnostics (planar X-ray imaging and CT scans) and therapy (X-ray-, γ-, and hadron therapy; radiosurgery, brachytherapy). **Part III** contains essential information on radionuclide diagnostics and therapy. The author describes the theoretical foundations, equipment and applications of scintigraphy, radioimmunoassays, single-photon emission computed tomography, positron emission tomography and kinetic methods. Methods and equipment for production of short-lived radioisotopes, as well as synthesis of radiopharmaceuticals are all outlined in the concluding chapters of present volume. The author reviews techniques which are currently employed in radiation and nuclear medicine as well as their applications in diagnostics and therapy of malignant tumors.

The volume has been written as an accompanying text-book for post-graduate students, taking advanced courses in chemistry and physics. However, it can be used a reference book by researchers working with radiation and by everyone who is interested in ionizing radiation, radioisotopes and their medical applications.
Foreword

Introduction

1. History of nuclear medicine.
2. Atomic nucleus and nuclear processes.
3. Ionizing radiation.
5. Radiation safety and radiation dose.
7. X-ray diagnostics.
8. X-ray computed tomography (CT scan).
10. Radiosurgery.
12. Particle radiotherapy.
13. Scintigraphy.
15. Single-photon emission computed tomography (SPECT).
16. Positron emission tomography (PET).
17. Therapeutic applications of radionuclides.

18. Production of radionuclides.


Conclusions

Further Reading
Table of Contents

Foreword

Introduction

1. History of nuclear medicine:
   1.1. Ionizing radiation
   1.2. Biological effects of ionizing radiation
   1.3. X-ray diagnostics
   1.4. Radiation therapy
   1.5. Radionuclide diagnostics and therapy

2. Atomic nucleus and nuclear processes:
   2.1. Atom and atomic nucleus
   2.2. Radioactivity
   2.3. Various modes of radioactive decay
   2.4. Nuclear reactions

3. Ionizing radiation:
   3.1. Types of ionizing radiation
   3.2. Interaction of ionizing radiation with matter
   3.3. Interaction of ionizing radiation with living organisms

4. Measurement of ionizing radiation:
   4.1. Detectors of ionizing radiation
   4.2. Gamma spectroscopy
   4.3. Detectors and equipment for imaging of radiation fields
4.3.1. Fluorescent screens for fluoroscopic viewing (fluoroscopy)
4.3.2. Photofilms for X-ray imaging
4.3.3. Fiber and nanocrystalline detectors
4.3.4. Detectors for digital projection X-ray imaging
4.3.5. Scintillation xenon-filled detectors with peak-sensing
4.3.6. Gamma-detectors

5. Radiation safety and radiation dose:
5.1. Physical and biological dose of ionizing radiation
5.2. External dose
5.3. Equivalent internal dose
5.4. Radiation safety standards and sanitary rules

6. Biological effects of ionizing radiation:
6.1. Radiation and biomacromolecules
6.3. Ionizing radiation and living organisms
6.4. Managing the radiobiological effect

7. X-ray diagnostics:
7.1. Modern methods of X-ray diagnostics
7.2. Projectional radiography
7.3. Equipment for X-ray diagnostics
7.4. Radiographic images
7.5. Mathematical foundations of transmission radiography
7.6. How to interpret an X-ray image
7.7. Irradiation dose during X-ray diagnostics
7.8. Applications of X-ray diagnostics
8. **X-ray computed tomography (CT scan):**
   8.1. Principles of computed tomography
   8.2. CT scan machines
   8.3. Image processing
   8.4. How to interpret results of X-ray tomography
   8.5. Contrast agents in X-ray tomography
   8.6. Medical applications of X-ray computed tomography

9. **Radiotherapy:**
   9.1. Basics of radiotherapy
   9.2. X-ray and gamma therapy
   9.3. Photon capture therapy
   9.4. Clinical applications of radiotherapy
   9.5. Irradiation dosimetry for X-ray and gamma therapy

10. **Radiosurgery.**

11. **Sealed-source radiotherapy (brachytherapy):**
    11.1. Principles of brachytherapy
    11.2. Intracavitary radiotherapy
    11.3. Interstitial radiotherapy
    11.4. Surface brachytherapy

12. **Particle radiotherapy:**
    12.1. Electron therapy
    12.2. Proton therapy
    12.3. Meson therapy
    12.4. Heavy-ion therapy
12.5. Neutron therapy
   12.5.1. Fast-neutron radiotherapy
   12.5.2. Neutron capture therapy

13. Scintigraphy:
   13.1. Key features of radionuclide diagnostic tests
   13.2. Scanning
   13.3. Static scintigraphy
   13.4. Dynamic scintigraphy
   13.5. Pharmacokinetics
   13.6. Isotopes and radiopharmaceuticals for radionuclide diagnostics
   13.7. Clinical applications of radiopharmaceuticals


15. Single-photon emission computed tomography (SPECT):
   15.1. Emission tomography
   15.2. Principles of SPECT
   15.3. Radionuclides and radiopharmaceuticals for SPECT
   15.4. Equipment and methods
   15.5. Processing and interpreting of SPECT data
   15.6. SPECT in clinical practice

16. Positron emission tomography (PET):
   16.1. Principles of two-photon emission tomography
   16.2. PET scanners
   16.3. Radionuclides and radiopharmaceuticals
   16.4. Processing and interpreting PET data
16.5. Kinetic studies
16.6. Clinical applications of positron emission tomography

17. Therapeutic applications of radionuclides:
17.1. Methods of radionuclide therapy
17.2. Radionuclides and radiopharmaceuticals
17.3. \(\alpha\)-emitting radionuclides
17.4. \(\beta\)-emitting radionuclides
17.5. Radionuclides that emit Auger electrons
17.6. Nanoparticle-immobilized radionuclides
17.7. Radioimmune therapy
17.8. Clinical applications of radiotherapy
17.9. Dosimetry and radiation safety

18. Production of radionuclides:
18.1. Production of isotopes in nuclear reactors
18.2. Laboratory-scale generators
18.3. Production of \(\alpha\)-emitting radionuclides
18.4. Production of \(\beta\)- and \(\gamma\)-emitting radionuclides

19. Synthesis of radiopharmaceuticals:
19.1. Radiopharmaceuticals for scintigraphy, SPECT and radioimmunoassay
19.2. Radiopharmaceuticals for positron emission tomography
19.3. Radiopharmaceuticals for radionuclide therapy

Conclusions.

Further reading.
Radiation and nuclear medicine: physical and chemical aspects is the seventh issue in popular Radiochemistry text-book series, authored by prof. I. Beckman. This volume is dedicated to clinical applications of ionizing radiation and radionuclides. The author describes their usage in modern diagnostics, surgery and therapy and provides numerous practical examples to the reader. Part I describes the phenomenon of radioactivity, nuclear reactions, interactions of ionizing radiation with matter and biological effects of radiation. Current national and international radiation safety guidelines. 2.6. training in radiation safety and radiation protection. 2.9. training of nurses. 2.8. Training in Radioimmunoassay. The IAEA continues to support nuclear medicine throughout the developing world and will continue to play a leading role in setting and maintaining standards of practice. This manual should be regularly updated to help meet this obligation. 3.