JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

Dosimetric Assessment of Absorbed Radiation Energy and Distribution of Various Types of Radiation in the Human Body

Bekmirzayev Eshquvvat Ro'ziboyevich
eshquvvatbekmirzaev@gmail.com
Ro'ziyev Qo'shoq Fayzimamatovich
qoshoqroziyev@gmail.com
Raxmatullayev Farxod Muxtorali o'g'li
farxodraxmatullayev51@gmail.com
Xudoyberdiyeva Adiba Raxmatillo qizi
xudoyberdiyevaadiba56@gmail.com

Abstract

Radiation dosimetry is a fundamental discipline in radiation medicine, radiological protection, nuclear medicine, and radiation oncology. It provides quantitative information regarding the amount of energy deposited by ionizing radiation in biological tissues and organs. Accurate dosimetric assessment is essential for ensuring the effectiveness of radiation therapy while minimizing harmful effects on normal tissues. The distribution of radiation energy within the human body is influenced by multiple factors, including radiation type, energy, tissue composition, anatomical characteristics, and exposure geometry. Different forms of ionizing radiation, such as photons, electrons, protons, heavy ions, alpha particles, and beta particles, exhibit distinct physical and biological properties that determine their penetration depth, energy deposition patterns, and biological effectiveness. Modern dosimetry combines advanced detector technologies, computational modeling, treatment planning systems, and quality assurance protocols to achieve precise dose estimation and optimization. Furthermore, understanding the distribution of various radiation types within the human body is crucial for clinical applications ranging from diagnostic imaging to cancer treatment and radiation protection. This review examines the principles of dosimetric assessment of absorbed radiation energy and analyzes the distribution characteristics of different radiation types in the human body. Emphasis is placed on fundamental dosimetric concepts, radiation interactions with tissues, methods of dose measurement, and the clinical significance of dose distribution in modern medical practice.

Keywords: Radiation dosimetry, absorbed dose, equivalent dose, effective dose, photon radiation, proton therapy, radiation distribution, radiation protection, medical physics, ionizing radiation.

Introduction

Ionizing radiation has become an indispensable component of modern medicine. It is widely utilized in diagnostic radiology, interventional procedures, nuclear medicine, and radiation therapy. Alongside its considerable clinical benefits, radiation exposure carries potential biological risks that must be carefully managed through accurate measurement and assessment. Radiation dosimetry, the science of measuring and calculating radiation dose, plays a central role in ensuring the safe and effective application of ionizing radiation in healthcare.

JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

The concept of radiation dose refers to the amount of energy transferred from radiation to matter. In biological systems, this energy deposition can induce molecular and cellular changes that may result in either therapeutic benefits or adverse health effects. Consequently, understanding how radiation energy is absorbed and distributed within the human body is essential for optimizing treatment outcomes and minimizing toxicity.

The development of radiation dosimetry has evolved significantly over the past century. Early radiation applications relied on limited knowledge of dose-response relationships and often resulted in excessive exposure. Advances in radiation physics, radiobiology, computer technology, and detector systems have transformed dosimetry into a highly sophisticated scientific discipline. Modern dosimetric methods enable accurate estimation of absorbed dose at the organ, tissue, and cellular levels.

The human body consists of tissues with varying densities, elemental compositions, and physiological characteristics. As a result, different radiation types interact with tissues in distinct ways. Photons may penetrate deeply into the body, while electrons are primarily absorbed in superficial tissues. Protons and heavy ions demonstrate highly localized energy deposition patterns, making them attractive options for precision radiation therapy. Internal radionuclides distribute according to physiological and biochemical mechanisms, producing organ-specific dose distributions.

An accurate understanding of these distribution patterns is critical for treatment planning in radiation oncology, risk assessment in radiation protection, and dose optimization in diagnostic imaging. The growing adoption of advanced treatment modalities such as intensity-modulated radiation therapy (IMRT), image-guided radiation therapy (IGRT), stereotactic radiotherapy, and proton therapy has further increased the importance of precise dosimetric calculations.

This review aims to summarize the fundamental principles of dosimetric assessment and to analyze the distribution of various types of ionizing radiation within the human body. The discussion focuses on the physical basis of radiation interactions, methods of dose measurement, and the clinical implications of radiation distribution.

Materials and Methods

This review was conducted through a comprehensive analysis of scientific literature published between 2005 and 2026. Relevant publications were identified using electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, and the International Atomic Energy Agency (IAEA) database.

Search terms included:

Radiation dosimetry, Absorbed radiation dose, Equivalent dose, Effective dose, Radiation distribution, Photon therapy,Electron beam therapy, Proton therapy, Monte Carlo simulation, Radiation treatment planning.

Peer-reviewed original research articles, systematic reviews, meta-analyses, international guidelines, and authoritative textbooks were included. Publications not directly related to human radiation dosimetry or lacking scientific rigor were excluded.

Data extraction focused on:

Fundamental dosimetric quantities, Radiation interaction mechanisms, Methods of radiation dose measurement, Distribution characteristics of different radiation types, Clinical applications of dosimetry, Technological advances in dose calculation.

The collected information was synthesized qualitatively to provide an integrated overview of current knowledge regarding absorbed radiation energy and dose distribution in the human body.

Results

Fundamental Principles of Radiation Dosimetry

Radiation dosimetry is concerned with the measurement and calculation of energy deposited by ionizing radiation in matter. It forms the scientific basis for radiation protection, radiation therapy, and diagnostic imaging optimization.

The primary objectives of dosimetry include:

Quantifying absorbed energy in tissues, Evaluating biological risk, Optimizing therapeutic radiation delivery, Ensuring patient and occupational safety, Verifying treatment accuracy.

The biological effects of radiation depend largely on the amount and distribution of absorbed energy. Therefore, accurate dose assessment is essential for both clinical and research applications.

Absorbed Dose

Absorbed dose is the most fundamental quantity in radiation dosimetry. It represents the energy deposited by ionizing radiation per unit mass of irradiated material.

Mathematically:

$$\mathbf{D = dE/dm}$$

where:

D = absorbed dose;

dE = deposited energy;

dm = mass of tissue.

The SI unit of absorbed dose is the Gray (Gy).

JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

1 Gy = 1 joule per kilogram (J/kg).

Absorbed dose provides a physical description of energy deposition but does not account for differences in biological effectiveness among radiation types.

Equivalent Dose

Equivalent dose incorporates the biological effectiveness of radiation by applying radiation weighting factors.

It is calculated as:

$$H = D \times w_R$$

where:

H = equivalent dose;

D = absorbed dose;

w_R = radiation weighting factor.

The unit of equivalent dose is the Sievert (Sv).

Equivalent dose allows comparison of biological risks associated with different radiation qualities.

Effective Dose

Effective dose further refines risk estimation by considering the radiosensitivity of individual tissues and organs.

It is expressed as:

$$E = \Sigma w_T \times H_T$$

where:

E = effective dose; w_T = tissue weighting factor; H_T = equivalent dose to tissue.

Effective dose is widely used in radiation protection and epidemiological studies because it estimates overall health risk resulting from radiation exposure.

Methods of Dosimetric Assessment: Accurate dose determination requires reliable dosimetric instruments and methodologies.

Ionization Chambers

Ionization chambers are considered the gold standard for radiation dosimetry.

JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

Advantages include: High precision, Excellent stability, Standardized calibration procedures.

Applications include beam calibration and quality assurance in radiation therapy.

Thermoluminescent Dosimeters (TLDs)

TLDs measure radiation exposure through the release of stored energy in crystalline materials when heated.

Advantages: Small size, Reusability, Tissue-equivalent response.

They are commonly used for personnel monitoring and in vivo dose measurements.

Semiconductor Detectors: Semiconductor detectors generate electrical signals proportional to absorbed radiation energy.

Their advantages include:

High sensitivity, Real-time measurements, Compact design.

These devices are increasingly employed in modern treatment verification systems.

Radiochromic Films

Radiochromic films change color following irradiation and provide detailed spatial information regarding dose distribution.

They are particularly useful for: Two-dimensional dose mapping, Verification of complex treatment plans, Quality assurance procedures.

Distribution of Photon Radiation in the Human Body

Photons, including X-rays and gamma rays, are the most frequently used forms of ionizing radiation in medicine.

Because photons have no mass and no electrical charge, they can penetrate deeply into tissues.

Major photon interactions include: Photoelectric effect, Compton scattering, Pair production.

The intensity of photon radiation decreases exponentially as it passes through tissue. Consequently, photon beams deliver dose both to the target and to tissues beyond the target volume.

Clinical advantages include:

Deep penetration, Broad applicability, Efficient treatment of internal tumors.

However, the presence of an exit dose may increase exposure to surrounding healthy structures.

JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

Distribution of Electron Radiation in the Human Body

Electron beams consist of charged particles with limited penetration capabilities.

Their dose distribution is characterized by: High surface dose, Relatively uniform dose within shallow tissues, Rapid dose fall-off beyond a specific depth.

The penetration depth depends directly on electron energy.

These properties make electron therapy suitable for:

Skin cancers, Superficial tumors, Chest wall irradiation, Scar boost treatments.

Because electron beams deliver minimal dose beyond the target, they reduce unnecessary irradiation of deeper organs.

Distribution of Proton Radiation in the Human Body

Protons possess unique physical characteristics that distinguish them from photons and electrons.

As protons travel through tissue, they gradually lose energy. Near the end of their range, they deposit a large amount of energy within a narrow region known as the **Bragg Peak**: Advantages of proton dose distribution include: Reduced entrance dose, Minimal exit dose, Precise dose localization, Improved normal tissue sparing.

These characteristics are particularly beneficial in pediatric oncology and tumors located near critical organs.

Distribution of Heavy-Ion Radiation

Heavy ions, particularly carbon ions, combine favorable physical and biological properties.

Their dose distribution resembles that of protons, including a pronounced Bragg Peak. However, heavy ions possess higher linear energy transfer (LET) and greater relative biological effectiveness (RBE).

Potential clinical benefits include:

Enhanced tumor cell destruction, Greater effectiveness against radioresistant tumors, Superior dose conformity.

The use of heavy-ion therapy remains limited because of the high cost and technical complexity of treatment facilities.

Table 1. Characteristics and Distribution Patterns of Various Types of Radiation in the Human Body

Radiation Type	Penetration Depth	Dose Distribution Pattern	Biological Effectiveness	Main Clinical Applications
Photons	Deep	Exponential attenuation	Moderate	External beam radiotherapy, imaging
Electrons	Superficial	Rapid dose fall-off	Moderate	Skin tumors, chest wall irradiation
Protons	Adjustable depth	Bragg Peak	Moderate to high	Pediatric and CNS tumors
Carbon ions	Deep	Bragg Peak with high LET	High	Radioresistant cancers
Alpha particles	Very short	Highly localized	Very high	Targeted radionuclide therapy
Beta particles	Moderate	Intermediate penetration	Moderate	Nuclear medicine
Neutrons	Deep	Variable distribution	High	Specialized radiotherapy

Results (Continued)

Internal Distribution of Radionuclides in the Human Body

Internal exposure occurs when radioactive substances enter the human body through inhalation, ingestion, injection, or absorption through damaged skin. Unlike external radiation sources, internally deposited radionuclides irradiate tissues continuously until they are eliminated from the body or undergo radioactive decay. Therefore, understanding their biodistribution is essential for internal dosimetry, nuclear medicine, and radiation protection.

The distribution of radionuclides depends on their chemical properties and physiological behavior. Certain radionuclides demonstrate affinity for specific organs because they participate in normal metabolic pathways.

Radioiodine

Radioactive iodine isotopes, particularly iodine-131, are selectively concentrated within thyroid tissue through the sodium-iodide symporter.

Clinical applications include: Treatment of hyperthyroidism, Ablation following thyroidectomy, Management of differentiated thyroid carcinoma.

Because of its selective uptake, radioiodine delivers high radiation doses to thyroid tissue while limiting exposure to other organs.

Strontium

Strontium isotopes resemble calcium and therefore accumulate predominantly within bones.

Clinical significance includes: Palliation of pain from skeletal metastases, Potential irradiation of bone marrow during accidental exposure.

Radium: Radium also exhibits affinity for osseous tissue.

Modern radionuclide therapy utilizes radium-223 for the treatment of metastatic prostate cancer involving bone.

Cesium

Cesium distributes relatively uniformly throughout soft tissues due to its biochemical similarity to potassium.

Internal contamination with cesium may lead to whole-body irradiation and requires careful dosimetric assessment.

The evaluation of internal dose distribution relies on biokinetic models that estimate radionuclide uptake, retention, and elimination from specific organs. These models provide the basis for individualized internal dosimetry and risk estimation.

Clinical Significance of Dose Distribution

Dose distribution is one of the most important determinants of both treatment success and radiation-induced toxicity. The spatial arrangement of deposited energy influences tumor control probability as well as the likelihood of normal tissue complications.

In radiation oncology, the primary objective is to deliver an adequate dose to eradicate malignant cells while preserving the function of surrounding organs. Achieving this balance requires precise understanding of tissue-specific dose distributions.

Several factors influence clinical outcomes: Total radiation dose, Fractionation schedule, Dose rate, Irradiated tissue volume, Radiation quality, Anatomical location of the target.

Non-uniform dose distributions may increase the risk of complications, including fibrosis, necrosis, organ dysfunction, and secondary malignancies. Conversely, insufficient target coverage may result in local recurrence and treatment failure.

The introduction of advanced treatment techniques has significantly improved dose conformity and reduced toxicity. Modern planning strategies enable clinicians to shape dose distributions according to patient-specific anatomical characteristics.

Modern Computational Approaches in Dosimetry

The increasing complexity of radiation delivery has necessitated the development of sophisticated computational methods capable of accurately predicting dose distributions within heterogeneous tissues.

ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

Contemporary dose calculation methods include: Pencil beam algorithms, Convolution-superposition methods,Grid-based Boltzmann solvers, Monte Carlo simulations.

These computational approaches account for tissue heterogeneity, scatter effects, and beam characteristics, thereby improving the reliability of dose estimations.

Advanced software systems now permit three-dimensional visualization of radiation dose distributions and facilitate optimization of treatment plans before therapy begins.

Monte Carlo Simulation

Monte Carlo simulation is considered the most accurate method for radiation transport calculations.

This technique employs statistical sampling methods to simulate millions of individual particle interactions occurring within biological tissues. The trajectories of photons, electrons, protons, and other particles are tracked as they undergo absorption, scattering, and energy deposition.

Advantages of Monte Carlo simulations include: Superior calculation accuracy, Detailed modeling of tissue heterogeneity, Applicability to all radiation modalities, Improved prediction of complex dose distributions.

Clinical applications include: Verification of treatment plans, Proton therapy dose calculations, Brachytherapy dosimetry, Internal radionuclide dosimetry, Research involving novel radiation techniques.

Although historically limited by computational demands, improvements in computer processing power have facilitated the integration of Monte Carlo methods into routine clinical practice.

Treatment Planning Systems

Treatment Planning Systems (TPS) are computerized platforms designed to calculate and optimize radiation dose delivery.

The planning process generally includes several stages.

Patient Simulation

Simulation establishes the geometric framework for treatment planning.

This phase involves: Patient positioning, Immobilization procedures, Acquisition of planning images.

Computed tomography (CT) remains the standard imaging modality because it provides both anatomical detail and electron density information required for dose calculations.

Additional imaging modalities include:

Magnetic resonance imaging (MRI);

JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

Positron emission tomography (PET);

PET/CT fusion studies.

Target Delineation

Accurate contouring is essential for successful treatment.

Target volumes include:

Gross Tumor Volume (GTV):
The visible extent of malignant disease.

Clinical Target Volume (CTV):
The GTV plus regions potentially containing microscopic disease.

Planning Target Volume (PTV):
The CTV with additional margins to account for uncertainties related to patient positioning and organ motion.

Organ-at-Risk Delineation

Critical structures adjacent to the target must be identified and protected.

Examples include: Brainstem, Spinal cord, Kidneys, Heart, Lungs, Optic apparatus.

Plan Optimization

Optimization algorithms determine beam arrangements capable of maximizing target coverage while minimizing normal tissue exposure.

Treatment plans are subsequently evaluated using dose-volume histograms and conformity indices.

Quality Assurance in Radiation Dosimetry

Quality assurance (QA) encompasses all activities intended to guarantee accurate and safe radiation delivery.

Rigorous QA procedures are particularly important because small dosimetric deviations may significantly influence treatment outcomes.

Quality assurance programs generally include:

Equipment Quality Control

Routine machine evaluations assess: Output constancy, Mechanical accuracy, Beam symmetry, Imaging performance.

JOURNAL OF APPLIED MEDICAL SCIENCES
ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

These assessments are performed daily, monthly, and annually according to established protocols.

Patient-Specific Verification

Advanced treatment techniques require individualized verification procedures, including:

IMRT quality assurance, VMAT verification, Independent dose calculations, End-to-end testing.

Dosimeter Calibration

Dosimetric instruments require periodic calibration against internationally recognized standards to ensure measurement accuracy.

Organizations involved in standardization include:

International Atomic Energy Agency (IAEA);

International Commission on Radiation Units and Measurements (ICRU);

American Association of Physicists in Medicine (AAPM).

Safety Culture

A strong safety culture contributes significantly to error prevention.

Important components include: Staff training, Standard operating procedures, Incident reporting systems, Continuous quality improvement initiatives.

Discussion

Dosimetric assessment of absorbed radiation energy constitutes a cornerstone of modern radiation medicine. Accurate determination of dose distribution enables healthcare professionals to optimize clinical outcomes while minimizing adverse effects associated with radiation exposure.

This review demonstrates that different radiation types possess distinct physical and biological characteristics that influence their interactions with human tissues. Photon beams remain the most widely used modality because of their versatility and ability to treat deeply located tumors. However, their unavoidable exit dose contributes to irradiation of healthy tissues.

Electron beams offer advantages in the management of superficial lesions due to their limited penetration and rapid dose fall-off. Proton therapy has emerged as a major advancement in radiation oncology because the Bragg Peak phenomenon permits highly conformal treatment with reduced exposure beyond the target volume. Carbon-ion therapy further enhances biological effectiveness and may improve outcomes in radioresistant malignancies.

Internal radionuclide dosimetry represents another critical area of radiation science. Organ-specific radionuclide accumulation patterns require individualized assessment to maximize therapeutic benefit while minimizing toxicity.

Technological innovations have transformed dosimetric practice. Advanced treatment planning systems, sophisticated detector technologies, and Monte Carlo simulations have substantially improved the precision of dose calculations. These developments have contributed to enhanced treatment effectiveness and greater patient safety.

Nevertheless, several challenges remain. Inter-patient anatomical variability, respiratory motion, uncertainties in biological modeling, and disparities in access to advanced technologies continue to affect treatment quality. Future progress in dosimetry is expected to involve adaptive radiotherapy, artificial intelligence-assisted planning, biologically guided treatment approaches, and real-time dose monitoring.

Conclusion

Dosimetric assessment of absorbed radiation energy is essential for the safe and effective application of ionizing radiation in medicine. The amount and distribution of deposited energy determine both therapeutic efficacy and the risk of radiation-induced complications.

Different radiation types exhibit unique distribution characteristics within the human body. Photons provide deep penetration, electrons are suitable for superficial lesions, and protons and heavy ions offer highly conformal dose distributions through the Bragg Peak phenomenon. Internal radionuclides demonstrate organ-specific biodistribution patterns that necessitate individualized dosimetric evaluation.

Modern dosimetry integrates advanced computational techniques, treatment planning systems, and comprehensive quality assurance programs to improve the accuracy of dose estimation and radiation delivery. Continued scientific and technological advancements will further optimize patient outcomes, strengthen radiation protection practices, and support the development of personalized approaches in radiation medicine.

References (Vancouver Style)

1. Khan FM, Gibbons JP. *Khan's The Physics of Radiation Therapy*. 6th ed. Philadelphia: Wolters Kluwer; 2024.
2. Hall EJ, Giaccia AJ. *Radiobiology for the Radiologist*. 9th ed. Philadelphia: Lippincott Williams & Wilkins; 2023.
3. Podgorsak EB. *Radiation Oncology Physics: A Handbook for Teachers and Students*. Vienna: IAEA; 2005.
4. ICRP. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann ICRP. 2007;37(2–4):1–332.
5. Paganetti H. *Proton Therapy Physics*. 2nd ed. Boca Raton: CRC Press; 2018.
6. Baskar R, Lee KA, Yeo R, Yeoh KW. Cancer and radiation therapy: current advances and future directions. Int J Med Sci. 2012;9(3):193–199.
7. Bentzen SM, Constine LS, Deasy JO, et al. Quantitative analyses of normal tissue effects in the clinic (QUANTEC). Int J Radiat Oncol Biol Phys. 2010;76(3 Suppl):S1–S160.
8. Verhaegen F, Seuntjens J. Monte Carlo modelling of external radiotherapy photon beams. Phys Med Biol. 2003;48:R107–R164.

ISSN(Online): 2984-6730
Volume-9, Issue-04, Published |12-06-2026|

9. Rogers DWO. Fifty years of Monte Carlo simulations for medical physics. Phys Med Biol. 2006;51:R287–R301.
10. Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. Med Phys. 2008;35(1):310–317.
11. Bortfeld T. IMRT: A review and preview. Phys Med Biol. 2006;51:R363–R379.
12. Durante M, Loeffler JS. Charged particles in radiation oncology. Nat Rev Clin Oncol. 2010;7(1):37–43.
13. Bolch WE, Eckerman KF, Sgouros G, Thomas SR. MIRD Pamphlet No. 21: A generalized schema for radiopharmaceutical dosimetry. J Nucl Med. 2009;50(3):477–484.
14. International Atomic Energy Agency. *Accuracy Requirements and Uncertainties in Radiotherapy*. Vienna: IAEA; 2016.
15. International Atomic Energy Agency. *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*. Vienna: IAEA; 2014.