# In Vivo Dosimetry in Radiotherapy: Techniques, Applications, and Future Directions

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In vivo dosimetry (IVD) is a vital component of modern radiotherapy, ensuring accurate and safe delivery of radiation doses to patients by measuring dose parameters during treatment. This paper provides a comprehensive overview of IVD, covering its fundamental principles, historical development, and the technologies used in clinical practice. Key techniques, including thermoluminescent dosimeters (TLDs), optically stimulated luminescent dosimeters (OSLDs), diodes, metal-oxide-semiconductor field-effect transistors (MOSFETs), and electronic portal imaging devices (EPIDs), are discussed, highlighting their clinical applications, advantages, and limitations. The role of IVD in external beam radiotherapy, brachytherapy, and pediatric treatments is emphasized, particularly its contributions to quality assurance, treatment validation, and error mitigation. Challenges such as measurement uncertainties, technical constraints, and integration into clinical workflows are explored, along with potential solutions and emerging innovations. The paper also addresses future perspectives, including advancements in artificial intelligence, adaptive radiotherapy, and personalized dosimetry systems. This entry underscores the critical role of IVD in enhancing the precision and reliability of radiotherapy, advocating for ongoing research and technological development.

In vivo dosimetry | patient safety | radiotherapy | thermoluminescent dosimeters | optically stimulated luminescent dosimeters | diodes | MOSFETs | electronic portal imaging devices | Monte Carlo simulation | nanotechnology

## Introduction

In vivo dosimetry (IVD) refers to the measurement of the radiation dose delivered directly to the patient during radiotherapy treatments. Unlike pre-treatment dose calculations or phantom-based measurements, IVD provides real-time or near-real-time data on the actual dose received by the patient, ensuring that it aligns with the planned dose distribution [1]. By directly monitoring the radiation delivery process, IVD plays a significant role in maintaining the accuracy and reliability of radiotherapy treatments [2][3].

The primary purpose of IVD is threefold: to ensure precise dose delivery to the target area, to enhance patient safety by identifying and mitigating potential deviations from the treatment plan, and to validate treatment plans by providing feedback for quality assurance (QA) protocols [4]. Through these functions, IVD acts as a safeguard against errors arising from equipment malfunctions [5], patient positioning inaccuracies [6], or anatomical changes during treatment [7].

In radiotherapy, where techniques like total body irradiation (TBI) [8], intensity-modulated radiotherapy (IMRT) [9], volumetric modulated arc therapy (VMAT) [10], and stereotactic body radiotherapy (SBRT) [11] demand high levels of precision, the role of IVD has become more significant. Its integration into clinical workflows aligns with international QA standards and guidelines, such as those established by the International Atomic Energy Agency (IAEA) [12] and the American Association of Physicists in Medicine (AAPM) [13]. By ensuring the consistent and accurate delivery of prescribed radiation doses, IVD contributes to improving treatment outcomes and patient safety, making it an essential component of contemporary radiotherapy practice.

In addition to providing a comprehensive overview of IVD techniques and applications, this entry paper also addresses recent advancements and future directions in the field, building upon the foundational work of previous reviews. Notable among these are the studies by Olaciregui-Ruiz et al., which outline the requirements and future directions for IVD in external beam photon radiotherapy [14]; those by Esposito et al., which review in vivo measurement methods for dose delivery accuracy in stereotactic body radiation therapy [15]; and those by Houlihan et al., which discuss IVD in pelvic brachytherapy [16]. By integrating these perspectives, in this paper, we aim to provide a more holistic understanding of the current state and future potential of IVD in radiotherapy.

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