



Dosimetry for FLASH Radiotherapy: A review of dosimetric systems

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1. Introduction

FLASH radiotherapy (FLASH-RT) is a method of treating cancer with high doses of radiation to the tumor region within fractions of seconds [1]. FLASH-RT has been reported since the 1960s, with full dose delivery occurring within just a single nanosecond pulse of X-rays, resulting in a marked increase in cell survival compared to conventional treatment [2]. The FLASH radiotherapy study has aroused the interest of researchers as it presents promising results in the treatment of cancer. One of the advantages of FLASH radiotherapy is the differential effect between the tumor and healthy tissues [3]. Preclinical studies on FLASH-RT showed that this treatment could control tumors while minimizing normal tissue toxicity when compared to conventional dose rate [1].

2. Methodology

The methodology of this work consists of reviewing updated scientific literature based on scientific data, to identify and collect academic articles, case studies and systematic reviews that address dosimetry in FLASH radiotherapy. The radiation detectors selected for this review were: ionization chamber, diamond detector, radiochromic films, EBT3 radiochromic films and thermoluminescent dosimeters. From this review, dosimetry parameters will be analyzed and the main dosimetry parameters used in FLASH radiotherapy treatments will be identified.

3. Results and Discussion

As a result of this survey, the systems commonly used in FLASH radiotherapy were identified, which will be listed below:

3.1 Ionization Chambers

Ionization chambers are radiation detectors widely used for reference dosimetry in clinical radiotherapy (RT) settings and are extremely valued for their ability to provide real-time dose measurements [4]. The calibrations of the ionization chambers are traceable to national standards or metrology laboratories, and, through the application of recognized dosimetric protocols, it becomes possible to perform precise dose measurements, taking into account several correction factors [5-7].

3.1.2 Diamond Detector

Diamond detectors come in two varieties, natural or synthetic, the latter being based on chemical vapor deposition (CVD) [8]. The most notable example of a single-crystal CVD-type detector is the microDiamond 60019 detector (PTW, Freiburg, Germany), which has a sensitive volume of only 0.004 mm^3 as defined by the depletion region extending through the intrinsic diamond layer. $1 \mu\text{m}$ thick [8].

3.1.3 Radiochromic Films

Radiochromic films are self-developed radiation dosimeters whose detection principle is based on radiation-induced polymerization of an active layer (diacetylene), resulting in coloration and measurable increase in optical density (OD) [9, 10]. The most common radiochromic films, radiochromic films, are inherently 2D and have been consistently demonstrated to have low dose rate and energy dependencies. These characteristics stand out as being desirable for application in ultra-high dose rate dosimetry to provide absolute dose, dose rate and dose distribution data in the highly variable and non-standardized beams used in the current FLASH-RT scenario [8].

3.1.4 EBT3 Radiochromic Films

The principle of detection of radiochromic films is based on the polymerization under irradiation of components of the active layer, resulting in coloration of the film. EBT3 type radiochromic films were released in 2011 as a replacement for EBT2. These third-generation films consist of a 28 μm active dosimetric layer sandwiched between two 100 μm polyester layers. Although the composition of the active layer remains the same, EBT3 films offer several improvements compared to EBT2 films, such as avoiding interference patterns and a symmetric structure [11].

3.1.5 Thermoluminescent Dosimeters

Thermoluminescent dosimeters (TLDs) are devices used to measure doses of ionizing radiation. They are made of solid materials that have the property of accumulating radiation energy during exposure. After exposure to radiation, these dosimeters are heated, and the accumulated energy is released in the form of light. The amount of light emitted is proportional to the dose of radiation absorbed by the dosimeter material [12]. Karsch [13] carried out the measurements at the ELBE (high-brightness, low-emittance electronic linac) superconducting linear accelerator at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR).

4. Conclusions

As a result, absolute dosimetry in FLASH beams is currently performed mainly with chemical and passive dosimeters, such as radiochromic films, alanine dosimeters or thermoluminescent dosimeters, whose responses are considered constant when passing from low to high dose beams per pulse [14]. The single-crystal synthetic diamond detector PTW microDiamond (60019) presents itself as an attractive option for the dosimetry application of FLASH-RT, both for X-rays and protons. Constituting a possible alternative to ionization chambers or silicon-based dosimeters, especially in applications that require real-time measurements. Its relatively constant dose rate and energy independence above 100 keV can mitigate the need to apply correction factors, simplifying and speeding up the routine dosimetry process in systems compatible with FLASH technology [8].

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