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Introduction of the IAEA/WHO Electron Beam Dosimetry Audit Service

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Introduction

The International Atomic Energy Agency (IAEA) together with the World Health Organization (WHO) have been providing dosimetry audits for radiotherapy facilities primarily in low- and middle-income countries around the world for over 50 years. Until recently, the regular audit service was limited to checking of absorbed dose to water in high energy photon beams in reference conditions. The new electron beam audit service has been thoroughly tested prior to conducting a multi-centre pilot study and eventually launching as a routine service.

Methodology

The IAEA/WHO audit service employs radiophotoluminescent glass dosimeters (RPLDs) for determining absorbed dose to water. The RPL dosimeter consists of a 12 mm long and 1.5 mm diameter GD-302M glass rod encapsulated in a watertight capsule made of high-density polyethylene. Each dosimeter set consists of two RPLDs for irradiation in one beam and one RPLD used for background monitoring. During a photon beam audit, RPLDs are irradiated in the reference conditions according to TRS-398 using the standard IAEA holder (10 cm depth in water, 10×10 cm² field, SSD or SAD geometry). Upon return to the IAEA, the dose (***D***) to an RPLD is calculated using the following equation:

D = M·N·SCF·f_{energy}·f_{holder}·f_{non-linearity}·f_{fading}

Where ***M*** is the counts of photoluminescence corrected for readout magazine position, ***N*** is the calibration coefficient of the RPLD system, ***SCF*** is the sensitivity correction factor for the RPLD used and ***f*** are the associated correction factors for the stated subscripts.

The reference depth for electron beams depends on the beam energy (TRS-398), thus a special RPLD holder was developed to allow for a precise dosimeter positioning at any depth. The holder comprises of a 1 cm thick disk made of PMMA with a hollow channel in the mid-plane, which has a variable diameter, so the RPLD can be tightly positioned in the middle of the disk. The disk can be mounted either on top of a Roos or Markus chamber holder using two adapter rings of corresponding diameters in a water tank. The audit participants would be expected to perform a measurement with a calibrated chamber to determine the absorbed dose to water in the electron beam audited, replace the chamber with the RPLD holder, insert glass dosimeters and irradiate them one by one in the same conditions.

Commissioning tests for the audit methodology were conducted at the IAEA Dosimetry Laboratory using a Varian TrueBeam linac with seven electron beams with energies ranging from 6 MeV to 22 MeV. These tests were performed to evaluate the electron beam specific energy (*f_{energy}*) and holder correction factors (*f_{holder}*) for RPLDs. The energy correction factor was measured as the ratio of the RPLD responses in a ⁶⁰Co beam to each of the other seven electron beam energies. The holder correction factor was determined as the ratio of a detector's response in water without and with the holder in the same irradiation geometry. The measurements were done using an Exradin W1 plastic scintillation detector and an IBA Razor diode. The experimental setup was established in a PTW MP3 water tank with the detectors positioned at the reference depths for each electron energy using a 10 × 10 cm² applicator, 100 cm SSD. Reference depths were determined using a Roos chamber through PDD curve measurements.

Additional developments were performed on an organisational level to facilitate the execution of electron beam audits. These included the preparation of instructions, datasheets and database developments. Finally, several blind dose irradiations following the developed methodology were conducted to test it internally, in preparation for a multi-centre pilot study and international service roll out.

Results

The results of the holder and energy correction factor determination are shown in Figure 1. The holder correction factor values are based on the results of 10 measurement sessions per energy for each of the two detectors used and the type A relative standard uncertainty *u_r* (*f_{holder}*) of the factors measured is 0.1%. The energy correction factor values are based on the response of 20 RPLDs per beam energy and the associated type A *u_r*(*f_{energy}*) is 0.5%. For the electron beam energies used, the product of the two correction factors described ranges between 1.04 and 1.05, compared to photons where it ranges from 1.01 to 1.04 in the therapeutic energy range. While holder corrections are of comparable magnitude for both modalities, energy corrections are substantially larger for electron beams and do not exhibit a linear dependence like for photon beams.

Conclusion

A new RPLD holder was developed and the required correction factors specific for electron audits were measured. In combination with the administrative developments described, they will enable the new service for auditing electron beams to be available in 2021, following a multi-centre pilot audit.

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