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IMPLEMENTATION OF ABSORBED DOSE STANDARDIZATION AT THERAPY-LEVEL IN BRAZIL

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ABSTRACT

At the present moment, IAEA presented the final document of the new International Code of Practice based on standards of absorbed dose to water, which will be implemented in Brazil gradually, making the transition from the existing Code of Practice[4] in the country. At Nuclear and Energy Research Institute (IPEN/CNEN/SP) and at National Laboratory for Metrology of Ionizing Radiation (IRD/CNEN/RJ), where the possibility of having an accelerator is remote, the approach used is to provide users with a calibration factor in terms of absorbed dose to water for the ionization chamber at the reference quality ^{60}Co and theoretically derived quality correction factors for that chamber type which must be applied for other beam qualities.

Keywords: absorbed dose standards, dosimetry protocols, secondary standardization.

I. INTRODUCTION

The goal of modern radiation therapy is to deliver a curative dose distribution to the target tissues in order to eradicate all its clonogenic tumour cells while keeping the acute and late reactions in healthy normal tissues to a minimum. This is a difficult task since it is impossible to deliver dose solely to the target volume without affecting healthy tissues, especially when deep tumours are treated with external beams. The primary purpose of radiation therapy is therefore to deliver sufficiently high dose to the tumour cells, maintaining at the same time the dose to surrounding normal tissues as low as possible.

With the increased availability of high quality electron and photon beams from advanced therapy accelerators, and with the widespread use of accurate diagnostic techniques like computed tomography as well as the improvement of dose planning systems (3D conformal radiotherapy, 3D commercial treatment planning programs), increased the demand for accurate dosimetry[6].

The Report “Determination of Absorbed Dose in a Patient Irradiated by Beams of X or Gamma Rays in Radiotherapy Procedures”[7] has concluded that there is evidence, for certain types of tumors, that the accuracy in the determination of absorbed dose to the target volume should be within ±5% or even lower if an eradication in the tumor is sought. The requirement of such accuracy can be considered as a tolerance for the deviation between the prescribed dose and the dose delivered to the target. Consequently, there is a great need for improving the dosimetry.

The estimation of given uncertainties in recent protocols showed that the largest contribution to the uncertainty during beam calibration originates from the different physical quantities involved and the large number of steps involved, resulting in uncertainties of up to 3 or 4%. These figures do not comply with the requirement for a low uncertainty to minimize the final uncertainty in patient dose delivery. This task will be accomplished only by the adoption of a new formalism based on absorbed dose standards which will simplify the determination of absorbed dose to water and, by consequence, reduce the uncertainties in all dosimetric chain[6].

II. PROTOCOLS BASED ON STANDARDS OF ABSORBED DOSE TO WATER

Absorbed dose to water is the quantity of main interest in radiation therapy, since this quantity relates closely to the biological effects of radiation. The main advantage of having such quantity as basic standard is that the same quantity will be employed within the calibration chain from primary standards to field instruments. Furthermore, the quantity absorbed dose to water, in terms of which primary standards deliver their readings will be close to the physical effect on which the standard is based, which will minimize the application of several correction factors as well as the uncertainties involved in this procedure. It should be pointed out that this concept of calibration in terms of absorbed dose to water is applicable to all types of radiation and to all energies.

Following this concept several standards laboratories (BIPM, NPL, NRC and PTB) have developed calorimeter as primary standard for absorbed dose to water in ^{60}Co and in accelerator beams. The first step is to provide the calibration factor in terms of absorbed dose to water to users in the reference quality, usually ^{60}Co γ rays. The second step consists of the determination of the chamber dependent quality factor at several energies.

The determination of absorbed dose to water is simply given by the product of the reading of the ionization dosimeter, by the calibration factor in terms of absorbed dose to water and by the product of the correction factors. These correction factors take into account all effects due to influence quantities deviating from the reference value. They can be experimentally obtained by comparing the ionization chamber with the primary standard under relevant conditions.

Influence quantities are those quantities which are not object of the measurement but influence the measured value, such as temperature, humidity, air pressure, polarizing voltage, dose rate and radiation quality. Radiation quality, in the DIN 6800 document[2], is now considered like the other quantities. The ^{60}Co gamma radiation is taken as the reference quality and measurements at other radiation qualities require a correction factor. This formal treatment results in only one calibration factor for an ionization chamber, and correction factors are related only to one influence quantity.

As it can be seen, this procedure eliminates uncertainties associated with the conversion of a calibration factor in terms of air kerma into a calibration factor in terms of absorbed dose to water, since it makes use of only one fundamental relation, reducing consequently the probability of errors by the user at the hospital.

Since the publication of DIN 6800[2], some Primary Laboratories started to adopt this formalism with the aim to determine the absorbed dose to water. Furthermore, several annual intercomparisons have been performed with the purpose of the practical application of this new formalism as well to establish the long-term stability of their absorbed dose standards.

By making a parallelism with the formalism based on absorbed dose to water calibration factor and the formalism based on absorbed dose to air, Andreo[1] demonstrated a direct connection between them. The ratio of the calibration factor in terms of absorbed dose to water to the calibration factor in terms of air kerma is numerically equal to the quality correction factor (the radiation quality in DIN 6800 nomenclature). In this paper, the author calculated beam quality factors normalized to ^{60}Co γ-rays which have been calculated from such comparison between the two formalisms, and provides sets of tables produced for the different ionization chambers listed in the IAEA Code of Practice[4] as a function of the quality of photon beams. The calculated set of data is compared with existing experimental determinations at Primary Standards Dosimetry Laboratories.

The photon beam quality factor values thus obtained do not vary more then 4-5% for the most commonly used range of photon beam qualities; furthermore, for a given quality, the quality factor values for different ionization chambers does not change by more than about ±1%, which validates the previous determinations given by Hohlfeld[3]. The comparison of the calculated values of beam quality factors with existing experimental data determined at Standards Dosimetry Laboratories gives the reliability of this approach. It was observed that differences between the results of Andreo[1] and the National Physical laboratory (NPL) data are smaller than 0,5% for most beam qualities, whereas discrepancies within about 1% exist with the data from Physikalisch-Technische Bundesanstalt (PTB).

Due to the fact that the photon beam quality factors have been obtained using the parallelism between the formalisms based on air kerma and absorbed dose to water, they are consistent with determinations according to existing dosimetry protocols and are not subject to the reported discrepancies existing at Standards Dosimetry Laboratories for experimentally determined calibration factor at higher energies. Moreover, the normalization at ^{60}Co gamma radiation is of special interest due to the good agreement among different PSDLs at this energy for standards of absorbed dose to water.

III. NEW IAEA CODE OF PRACTICE

The development of primary standards of absorbed dose to water for high-energy photon and electron beams, and improvements in radiation therapy concepts, offer the possibility of reducing the uncertainty in the dosimetry of radiotherapy beams. Thus a coherent dosimetry system based on standards of absorbed dose to water is possible for practically all radiotherapy beams. The Code of Practice[6] is addressed to users provided with calibrations in terms of absorbed dose to water traceable to a PSDL. Users who are not yet provided with calibrations in terms of absorbed dose to water, may still refer to the current air-kerma based Codes of Practice, such as TRS-277[4] and TRS-381[5], or adopt the present document using a calibration factor in terms of absorbed dose to water derived from an air kerma calibration as described in this dosimetry protocol.

Procedures to determine absorbed dose to water using methods to measure appropriate base or derived quantities have considerably improved at PSDLs in the last decade. The well-established procedures are the ionization method, chemical dosimetry, and water and graphite calorimeter. Although only the water calorimeter allows the direct determination of the absorbed dose to water in a water phantom, the required conversion and perturbation factors for the other procedures are now well known at many laboratories. These developments gave support to a change in the quantity used at present to calibrate ionization chambers and provide calibration factors in terms of absorbed dose to water for use in radiotherapy beams. Many PSDLs already provide this calibration at ^{60}Co gamma-ray beams and some laboratories have extended these

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calibration procedures to high-energy photon and electron beams; other are developing the necessary techniques for such modalities.

At Secondary Dosimetry Laboratories (SSDLs) calibration factors from a PSDL or from the *Bureau International des Poids et Mesures* (BIPM) are transferred to hospital users. For ^{60}Co gamma-ray beams most SSDLs can provide users with a calibration factor in terms of absorbed dose to water without much experimental effort, as all SSDLs have such beams. However, it is not possible for them, in general, to supply experimentally determined calibration factors at high-energy photon and electron beams. Numerical calculations of a beam quality correction factor, related to ^{60}Co gamma-ray beams can, however, be performed which should be equivalent to those obtained experimentally but with a larger uncertainty.

The new IAEA dosimetry protocol[6] will be implemented in Brazil gradually, making the transition from the existing Code of Practice[4] in the country. At National Laboratory for Metrology of Ionizing Radiation (IRD/CNEN) and Laboratory of Calibration of Instruments (LCI/CNEN) in Brazil, where the possibility of having an accelerator is remote, the approach used is to provide users with a calibration factor in terms of absorbed dose to water for the ionization chamber at the reference quality ^{60}Co gamma radiation and theoretically derived quality correction factors for that chamber type which must be applied for other beam qualities.

The advantages of a Code of Practice based on standards of absorbed dose to water are the following: reduced uncertainty; a more robust system of primary standards; and use of a single formalism.

The basic point in adopting this new formalism is that, compared with previous Codes of practice or dosimetry protocols based on standards of air kerma[4,5], will introduce small differences in the value of the absorbed dose to water determined in clinical beams. Where differences arise, it is important to notice that the might be due to two contributions: inaccuracies in the numerical factors and expressions in the air kerma method, and to a lesser extent, in the present Code of Practice; and the primary standards to which the calibrations in terms of air kerma and absorbed dose to water are traceable. Even for ^{60}Co gamma radiation, which is generally better characterized than other qualities, beam calibrations based on the two different standards differ by typically 1%; the value derived using the present Code of Practice is considered the better estimate.

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