Dependence of Tissue Inhomogeneity Correction Factors on Photon Beam Energy

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I. INTRODUCTION

When using megavoltage photon beams in the radiotherapy treatment of cancer, commissioning of the treatment planning system includes the accuracy of dose calculation in inhomogeneous media. Several results for measurement of inhomogeneity correction factors (ICFs) have already been published. However, a dependence of ICFs on beam energy may preclude such results from being applied to the general user's beam. The purpose of the study was to assess the dependence of ICFs on the tissue phantom ratio ($TPR_{20,10}$), the so-called photon beam quality index (QI).

II. METARIALS & METHODS

The range of $TPR_{20,10}$ was found to be 4.2% and 2.2% for photon beams with nominal energies of 6 MV and 15 MV, respectively. This range of QI was obtained based on data collected for the 42 accelerators installed in Poland (as part of the database of the local Secondary Standards Dosimetry Laboratory). Therefore, the QI range was considered as $TPR_{10}^{20} = 0.67 \pm k * 0.01$ and $TPR_{10}^{20} = 0.76 \pm k * 0.01$ for 6 and 15 MV respectively, where k = -3, -2, -1, 0, 1, 2, 3.

A preliminary study on the dependence of ICFs on energy was performed with the Batho correction method for several geometries comprising lung 0.25g/cm^3. Three different thicknesses of lung (3, 5 and 8 cm), introduced as broad slabs, oriented normal to the beam axis, within an otherwise homogenous water-equivalent phantom, and with a front surface at a depth of 3 cm. The front surface of the water phantom was at a source-to-surface (SSD) distance of 100 cm. The calculations were performed at four different field sizes of 5x5, 10x10, 15x15 and 20x20 cm^2 defined at the surface. The calculations were undertaken using an in-house developed Microsoft Visual Basic programme.

Water phantoms containing regions of lung (0.26g/cm^3), adipose tissue (0.92g/cm^3) and bone (1.85g/cm^3) were constructed in the Eclipse treatment planning system. Dose calculations were performed with the Anisotropic Analytical Algorithm (AAA) method for several beam sizes and for points lying at several depths inside of and below different thicknesses and densities of the inhomogeneities.

ICFs were also measured in a CIRS (Norfolk, VA) Tissue Simulation Phantom (thorax with lungs) for 10x10 cm^2 field size, for the 6 MV and 6 MV FFF generated in a TrueBeam accelerator. A PTW (Freiburg, Germany) Farmer type ionization chamber and Unidos (PTW, Freiburg, Germany) electrometer were used for measurements.

III. RESULTS

In calculations employing the Batho power law method, a linear dependency of ICF on beam QI was obtained. A maximum variation in ICFs of 3.7% (6 MV) and 4.1% (15 MV) was observed across the considered range of beam QI, when calculated at 5 cm depth below a 5 cm slab of lung.

Calculations with AAA predicted that 6% variations in QI lead to changes of ICFs of 10.0% (6 MV) and 13.8% (15 MV) for points 1 cm below the water-lung interface for a 5x5 cm^2 field size.

For the slab of adipose, less than 1% range in ICF was found across the considered range of QI for both energies. 2% (6 MV) and 2.4% (15 MV) differences were found for points lying 1 cm below the bone slab. These differences of ICFs decreased when calculated inside of inhomogeneities.

ICFs also decreased with increasing field size. Measurements with the CIRS phantom also demonstrated differences of ICFs consistently up to 6% between the 6 MV and 6 MV FFF beams.

IV. CONCLUSIONS

For a range of QIs representative of the range of beam qualities encountered in practice, small changes in correction factors were found in inhomogeneous phantoms in the regions where charged particle equilibrium (CPE) exists.

For regions, where there is no charged particle equilibrium, the dependence of the ICFs on the beam quality is more complicated. In addition, the field size significantly affects the results, especially if there is a lack of lateral CPE.

Results of measurements carried out with the CIRS phantom were consistent with calculations. The dependence of ICFs on beam quality was close to the linear.

Therefore, it is concluded that the ICFs measured for one accelerator beam can be used with some caution on another with the same nominal energy.

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