Validation of VMC++ for photon beams in the energy range of 20-1000 keV

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Introduction

In teletherapy VMC++ is known to be a very accurate and efficient Monte Carlo (MC) code [1] which is also implemented as a dose calculation algorithm in the Swiss Monte Carlo Plan (SMCP) [2]. In principle, the MC method is also a powerful dose calculation tool in Brachytherapy or for orthovoltage radiotherapy. However, VMC++ is not validated for the low energy range of these applications. Thus, this work aims in the validation of the VMC++ MC code for photon beams in the low energy range, i.e. between 20 and 1000 keV.

Material and Methods

Dose calculations using VMC++ with kerma approximation were performed in a 40x40x40 cm^3 water phantom with two 4 cm thick slabs of bone and lung for mono-energetic (ranging from 20 - 1000 keV) 10x10 cm^2 sized parallel beams. Additionally, dose distributions of the parallel beam using the energy spectrum for Iridium-192 and Iodine-125 were calculated in the same phantom. The resulting dose distributions were compared with those calculated using EGSnrc [3], which is used as golden standard in this work. The statistical uncertainty of all calculated dose distributions was within 1% (1σ) for voxels with doses > 10% of D_{max}. A voxel size of 4x4x4 mm^3 was used for all dose calculations.

Results & Discussion

At energies between 50 and 400 keV, EGSnrc and VMC++ calculated dose distributions agree within statistical uncertainty. For 20 keV beams, local dose differences for doses > 10% of D_{max}, referred to as local DD, of up to 4% occur when VMC++ and EGSnrc are compared. Turning off Rayleigh scattering and binding effects for Compton scattering in EGSnrc (not implemented in VMC++) leads to an agreement between both MC codes within 2% (local DD). For energies around 400 keV, the kerma approximation leads to a local dose difference of about 4% close to the phantom surface. As expected, this error becomes larger for higher energies in the vicinity of the phantom inhomogeneities. VMC++ and EGSnrc calculated dose distributions using the Iridium-192 spectrum show an agreement within 2% (local DD), except at very shallow depths of the phantom where dose differences of about 4% occur. This is due to the kerma approximation used in VMC++. For Iodine-125, local DD of up to 10% occur when comparing EGSnrc with VMC++. These dose differences become insignificant when Rayleigh scattering and binding effects for Compton scattering are ignored in EGSnrc.

Conclusion

VMC++ has been validated for photon beams with energies ranging from 20 - 1000 keV. Generally, VMC++ agrees with EGSnrc (Rayleigh scattering and binding effects for Compton scattering turned off) within statistical uncertainty for the phantom considered and all energies studied including the energy spectrum for Iridium-192 and Iodine-125 except at very shallow depths of the phantom. Thus, further improvements could be achieved by implementing Rayleigh scattering and binding effects for Compton scattering into VMC++.

References

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