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Stereotactic, single-dose irradiation of lung tumors : a comparison of absolute dose and dose distribution between Pencil Beam- and Monte Carlo-algorithms based on actual patient CT scans based on a new method for Monte-Carlo dose calculation commissioning

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Stereotactic body radiotherapy (SBRT) is an effective local therapy in patients with early lung cancer that are medically inoperable. Due to dose calculation based on pencil beam (PB) algorithms has its shortcomings predicting dose in tissue heterogeneities. The aim of this study was to compare dose distributions of clinically applied non-IMRT 15MV-plans for SBRT between fast Voxel Monte Carlo calculation (XVMC) and PB calculation for lung lesions. XVMC for dose calculation in radiotherapy have only been implemented and commissioned for clinical linear accelerators successfully in a few locations worldwide. Therefore, the first part of the work (Part A), one virtual energy fluence head model (VEF) was created for commissioning a 6MV Elekta Synergy linac head by series measurements, its verification and additional adjustment to ensure utmost dose calculation accuracy. Part B of the study was the adaptation of an existing head model for another 15MV Elekta Sli Precise linac of the same type. To validate adapted VEF model and XVMC calculation , one treatment plan was verified in an inhomogeneous thorax phantom with EDR2 films. Both measured and calculated (PB and XVMC) dose distributions were compared regarding profiles and isodoses. Then, in Part C, 35 lung plans originally created for clinical treatment by PB calculation with the Eclipse planning system were recalculated by XVMC with VEF head model which established in Part A. Clinically relevant dose-volume parameters for target and lung tissue were compared and analyzed statistically. The results shows the differences between XVMC simulations and measurements in water from 2x2 cm^2 to 30x30 cm^2 were within 2%/2mm after optimizing the primary photon source diameter (σ_0) for a 6MV linac, especially for small fields. The XVMC calculation agreed well with film measurements (< 1% difference in lateral profile) while the deviation between PB calculation and film measurements was up to +15%. On analysis of 35 clinical cases, $D_{mean,}$ D_{100} and D_{95} of GTV were 1.14±1.72Gy, 1.68±1.47Gy, and 1.24±1.04Gy lower by XVMC compared to PB respectively (prescription dose 30Gy). The V_{9Gy} of lung was 2.73±3.12% higher when calculated by XVMC compared to PB. The largest differences were observed for small lesions circumferentially encompassed by lung tissue. PB dose calculation overestimates dose to the tumor and underestimates lung volumes exposed to a given dose consistently for 15MV photons. The degree of difference between XVMC and PB is tumor-size and -location dependent. XVMC calculation is therefore helpful to further optimize treatment planning. In addtion, it takes about 20min for a typical non-IMRT lung plan by XVMC calculation, the excecute time of XVMC is clinical acceptable. A new method of adapting existing head model to another linac of the same type is also demonstrated as a feasible and effective way for Monte Carlo dose calculation commissioning.