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Abstract

Robotic radiosurgery Monte Carlo commissioning using commercial 3D-array with Multiplug inserts

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Objectives: Stereotactic system commissioning is a challenging procedure especially when the system is used in presence of large inhomogeneity (e.g. lung). Our aim was to validate the Ray-Tracing (RT) based model and commission the measurement-driven Monte Carlo (MC) algorithm of the Cyberknife (Accuray), furthermore to evaluate the added value of the high variability of the ArcCheck (AC) Multiplug insert for commissioning within this specific domain.

Methods: During the preparation phase, the MC model was created using Multiplan 5.1 according to the manufacturer specifications, and the AC was calibrated for detector response (Elekta Synergy linear accelerator) and for absolute dose (Cyberknife).Taking advantage of the cylindrical shape of the AC, various experimental setups were used. For all twelve fixed Cyberknife collimators, baseline measurements were performed under reference conditions (reference = central insert of the AC).Inhomogeneity conditions were introduced by maximizing lung inserts along the beam path. Three different scenarios were constructed replacing the water with lung inserts: vertical line along the beam's central axis, horizontal line perpendicular to the beam's central axis and a combination of the two previous one. Differences between MC and RT were compared using gamma criteria of 3%/1mm.As a last step, nine lung stereotactic patient plans were tested in reference point with and without lung inserts surrounding it. Insert holes were used to place in-air fiducials for positioning purposes. Gamma criteria of 2%/2mm were chosen to evaluate calculation algorithm differences.Differences between the RT and the MC models were compared with paired t-test with a significance level at p-value<0.05.

Results: Given the existing tools of Multiplan, reasonably good agreement (+/- 1% difference on 95% of given points) on profiles and tissue phantom ratios (TPRs) were achieved for the MC model.The ArcCheck calibration was straightforward and within expected tolerances.The mean of the gamma differences between MC and RT was 3.3% for baseline measurements for all twelve collimators. For inhomogeneous situations, 3.2%, 3.6% and 0% mean gamma differences between MC and RT were obtained for three lung insert configurations. Single beam tests showed no statistical differences between calculation algorithms.Resulting from successful tracking of the AC without inhomogeneity material, mean gamma-index of 89% (range [74.1-96.4]) and 82.5% ([66.8- 94.8]) were obtained for MC and RT. Introducing lung inserts, mean

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gamma-index of 94.1% (range [90.7-98.4]) and 86.2% ([68.7- 95.4]) were observed for MC and RT. For patient specific QA, differences between MC and RT are presented on the figure and were statistically significant for both water and lung inserts (p=0.02 and p=0.03).

Conclusions: The AC device allowed for easy validation of our RT model. Using several lung Multiplug configurations and patient specific QA, commissioning of our MC model was achieved. Using the AC for patient specific QA with Cyberknife plans was feasible, hence closing the bridge of Cyberknife specific and classical QA tools. The limitation of our current results is that only entrance and exit dose measurements were performed, thus the next step is the assessment of MC model inside AC inserts (films and/or ionization chambers) with lung and air inserts.