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Effect of detector choice for commissioning measurements propagated trough beam modelling to final dose calculation

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Introduction of the study

Different small field detectors are available for commissioning measurements. For each task, i.e. depth dose curves, profiles and output factor measurements, the detector response depends on properties such as the active volume size, material composition and density relative to water. In the absence of an ideal detector, measurements are typically a compromise between detectors available and the need to address different measurement tasks correctly.

In the treatment planning system, a beam model is fitted to match the measured data. Beam characteristics, such as the photon energy spectrum, the focal spot size and electron contamination, are tuned to reproduce dose distributions that follow the measured data. The goal of this work was to investigate how changes in the measured data affect the final dose computation.

Methodology

The clinical beam model of a 6 MV Elekta Versa HD accelerator was copied in the Philips Pinnacle treatment planning system and eight alternative models were created, each differing from the initial reference model in one aspect. One model parameter was altered, such that the newly modelled curve deviated by an amount typical for choosing a non-ideal but reasonable detector, for example small ionization chambers of different sizes for profiles or different diodes for output factor measurements and depth dose curves. Detector response differences were taken from measurements and from literature data.

Three clinical VMAT plans per category head and neck, prostate, vertebrae, three breast step-and-shoot IMRT, three 3D-conformal breast tangent plans and three cranial stereotactic treatments were recalculated using the alternative models. Representative dose parameters for target volumes or organs at risk (OAR) were evaluated.

Additionally, all plans were measured using the Sun Nuclear ArcCHECK cylinder phantom including a central dose measurement using a 0.125 ccm ionization chamber. Measurements were compared with the calculated dose distributions of the original and alternative models using gamma analysis.

Results

Many of the implemented changes only led to minute changes in the dose calculation for DVH parameters representing the target volume prescriptions (often < 0.3 %). The magnitude of the observed deviations depended on the body region and technique. Modifications of the depth dose distribution became apparent for targets at large depths (prostate plans) and with vertebrae plans due to dense bone material (changes approximately 1-2 %). Changes in the build-up region were generally not observable, even with surface-near target volumes (breast, head and neck). Changes in output factor tables influenced small stereotactic fields (up to around 6% change) and to a much smaller degree some of the VMATs (approximately 0.5% change). Modified penumbra did not affect the 3D-conformal breast plans, but introduced dose changes in most other plans, exceeding 1% in four of the VMAT plans. Especially dose to spared OAR, adjacent to the target volume, differed for this modification. Stereotactic treatments changed the most (3%-6% prescription dose changes).

Results of the gamma analysis on the phantom differing from the body geometry did not always coincide with the changes in DVH. Modifications of the depth dose curve led to dose changes most apparent in prostate plans, but notably reduced gamma passing rates only for the 3D-conformal breast and the stereotactic plans. Changes of the electron contamination in the surface-near region are not accessible for the detector array measuring at approximately 3 cm depth. Substantial reductions of the gamma passing rate for most treatment techniques were only observed for the modified penumbra, with the largest changes for the stereotactic treatment and hardly any changes for the prostate and head and neck plans.

The predicted central dose obtained with the ionization chamber changed by 1-2% for all plans for the depth dose modification and approximately 10% for the penumbra cases when the position of the ionization chamber corresponds to an organ at risk adjacent to the target volume.

Conclusions

In practice, choosing a non-optimal detector and consequently creating small errors of the beam model affects only dose calculations under certain conditions. However lacking correlation between dose calculation errors

and quality assurance metrics, poor modelling may go unnoticed. Critical modelling parameters for most plans are the penumbra, the depth dose curve for deep targets and output factors especially for small targets. It seems necessary to validate a new beam model not only in one phantom geometry and not only with typical clinical plans (head and neck, prostate), but with dedicated or challenging plans to encompass typical errors (complex VMAT, 3D-conformal, small fields) independent of the treatment scope of the linac.

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