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Validation and clinical implementation of commercial secondary check software with heterogeneity corrections

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ABSTRACT

Aim: To validate and implement PTW diamond secondary check software (SCS) in a routine clinical use.
Background: The secondary independent monitor unit or dose calculation verifications have led to a significant increase in the workflow associated with QA treatments. Modelling, validation and commissioning are necessary steps thereby making it a useful tool for QA.
Materials and methods: PTW Diamond SCS is capable of calculating VMAT fields, based on modified Clarkson integration, accounting for multi-leaf collimators (MLC) transmission and measured collimator scatter factors. Validation for heterogeneity corrections is made using circular phantom with inserts of various density materials. 150 VMAT plans were compared using (i) plans calculated in homogeneous cylindrical phantom and (ii) VMAT plans calculated with heterogeneity corrections using electron density values for each organ.
Results: Diamond SCS calculated dose for homogeneous cylindrical phantom resulted in average deviation of ($0.1 \pm 2.14\%$) with Eclipse TPS calculated dose and ($-2.0 \pm 1.66\%$) with absolute measured dose. PTW's OCTAVIUS-4D phantom with 729 ion chamber detector array measurements agreed well with Eclipse TPS calculated dose showing an average deviation of ($-1.69 \pm 1.56\%$). Diamond SCS dose calculations were performed with heterogeneity corrections for 124 VMAT plans with isocentre at a region above -350 HU. The overall MU variations between Diamond SCS and TPS Acuros-XB algorithms were within $\pm 5\%$.
Conclusion: Hence, the Diamond SCS can be used as an additional tool along with phantom measurements for patient specific quality assurance of VMAT plans with heterogeneity corrections having isocentre at a region above -350 HU.
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1. Background

The main goal of a secondary MU (monitor unit) calculation is to prevent serious errors during the MU calculation by Treatment Planning System (TPS). In radiotherapy, a significant proportion of errors are related to TPS.[1] Potential errors affect not only conventional 3D treatments, but also all other treatments, even though the ultimate source of error remains the same (errors on data input for modelling, on the geometric parameters of the unit, wedge factors, tray, multi-leaf collimator (MLC) transmission, etc.). An alternative calculation method is therefore recommended in order to verify the accuracy of the TPS, regardless of a treatment technique used. In the case of complex 3D (3-dimensional) conformal or intensity modulated radiation therapy (IMRT) or volumetric modulated arc therapy (VMAT) treatments, the manual method of MU calculation is too complicated and time consuming. Therefore, subsequent quality control (QC) requires the use of tools that minimize the time necessary for MU calculations.[2–4] Algorithms used for such independent monitor unit calculations are simpler and make it possible for most calculations of conventional 3D fields to be manually performed using dosimetric data from radiation units.[5] In contrast, independent monitor unit verification calculation (MUVC) for complex MLC shaped 3D fields,[6] sliding windows, step and shoot IMRT[7–10] and tomotherapy[11–13] must be performed with the aid of software applications, commercial or in-house developed. Some publications describe the modelling based on measured geometric and dosimetric data before the implementation of MUVC in clinical use. Validation of independent dose calculation software with dose differences should fall in the range ±3%. Similar research describing point dose calculation methods for validating independent dose calculation software for both conventional and VMAT fields are published.[14,15] In our work, validation of independent secondary dose calculation (Diamond, Secondary check software, version-6, PTW, Germany) was used to calculate MU for clinically approved VMAT plans. PTW's diamond secondary check software (SCS) uses modified Clarkson's integration technique[16] to calculate MUs for irregular MLC field segments. Percentage depth dose (PDD), total scatter factor ($S_{c,p}$), collimator scatter factor (S_c), phantom scatter factor (S_p), off axis factor (OAF) were measured and modelled in Diamond SCS.

2. Aim

The aim of the present work is also to perform patient specific QA using independent dose calculation software with and without heterogeneity corrections for VMAT plans.

3. Material and methods

VMAT plans were generated in a treatment planning system (TPS) Eclipse version-11, for TrueBeam linear accelerator supplied by VARIAN. The dose calculation algorithms used were AAA (analytical anisotropic algorithm) and Acuros-XB. Secondary, independent dose calculations were performed using Diamond SCS version-6 provided by PTW. Acuros-XB algorithm calculates dose by implementing linear Boltzmann transport equations. Dose distributions calculated by Acuros-XB have been reported to be accurate and to be in good agreement with BEAMnrc/DOSXYZnrc Monte Carlo dose calculations.[17] In the literature, comparisons between AXB and AAA algorithms have been reported by Bush et al.[17] and Kroon et al.[18] Prakash et al. developed an in-house excel spread sheet based MUVC program for volumetric modulated arc therapy (VMAT) using Clarkson's integration technique[19] with water equivalent depth (WED), calculated using the isocentre CT image section and an in-house developed MATLAB program was used for each segment.

3.1. *Diamond SCS – modified Clarkson's integration calculation algorithm*

Diamond SCS provides two algorithms as a function of complexity of the field. In conventional photon fields, a simple algorithm is used, based on equivalent squares and TPR/TMR tables obtained from PDD and S_c/S_p data. For IMRT/VMAT field calculations, integration was performed using the Clarkson method.[16] A 'point-eye-view' algorithm was used to integrate scattering from the linear accelerating head to the calculation point. This algorithm includes the source and flattening filter position, and the aperture modified by the MLC, using S_c measurements.[20] Points-eye-view refers to the calculation method of S_c by projecting back into the collimation elements the view of the source, primary collimators, flattening filter and ion chamber as seen by the point taking into account the upper and lower collimators and the shaping effect of the MLC. This method is described in the literature as detectors-eye-view (DEV).[21] Diamond SCS integrates the head scatter through an algorithm that takes into account the unique scatter from the collimator jaws and the MLC by the use of measured scatter values. For collimator (or) jaw configuration in Diamond SCS, the Cunningham and Johns (C and J) penumbra model[22] is used. The coefficients for jaws are a1, a2 and source diameter are used to describe the penumbra with an analytical curve. The source size for the linear accelerator is the size of the beam at the flattening filter. Coefficient a1 described the slope inside the field and a2, under the collimator or block. When the MLC is used, the collimator and jaw calculation under the MLC is replaced by the MLC leaf transmission. The AcuTrack algorithm is a unique MLC profile model that allows precise tracking of the measured MLC profile (MLC shape), which is particularly important for small field segments. In Diamond SCS, MLC Leaf parameters were modelled using the jaw profile and MLC profile measured in True Beam linear accelerator which are particularly important for small field segments. The values input into the software for both jaws and MLCs are adjusted to exactly align the measured profile. In Eclipse TPS, the 'isocentre' or a 'reference point' is the point of calculation for monitor units. This ensures that the correct point coordinates are contained in the exported DICOM file. The RT plan is exported using the DICOM export functionality within Eclipse, which contains all necessary plan information for Diamond SCS calculations.

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