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Original Paper

Comparison between In-house developed and Diamond commercial software for patient specific independent monitor unit calculation and verification with heterogeneity corrections

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ABSTRACT

The study was aimed to compare two different monitor unit (MU) or dose verification software in volumetric modulated arc therapy (VMAT) using modified Clarkson's integration technique for 6 MV photons beams. In-house Excel Spreadsheet based monitor unit verification calculation (MUVC) program and PTW's DIAMOND secondary check software (SCS), version-6 were used as a secondary check to verify the monitor unit (MU) or dose calculated by treatment planning system (TPS). In this study 180 patients were grouped into 61 head and neck, 39 thorax and 80 pelvic sites. Verification plans are created using PTW OCTAVIUS-4D phantom and also measured using 729 detector chamber and array with isocentre as the suitable point of measurement for each field. In the analysis of 154 clinically approved VMAT plans with isocentre at a region above −350 HU, using heterogeneity corrections, In-house Spreadsheet based MUVC program and Diamond SCS showed good agreement TPS. The overall percentage average deviations for all sites were (−0.93% + 1.59%) and (1.37% + 2.72%) for In-house Excel Spreadsheet based MUVC program and Diamond SCS respectively. For 26 clinically approved VMAT plans with isocentre at a region below −350 HU showed higher variations for both In-house Spreadsheet based MUVC program and Diamond SCS. It can be concluded that for patient specific quality assurance (QA), the In-house Excel Spreadsheet based MUVC program and Diamond SCS can be used as a simple and fast accompanying to measurement based verification for plans with isocentre at a region above −350 HU.

Introduction

Uncertainties in dose delivery can originate by means of errors in daily treatment, which includes human errors, or errors in the process of calculating monitor units (treatment planning). The former class of errors will probably affect only one treatment session, but the latter can affect the whole course of treatment and more than likely many patients [1]. A significant number of reported incidents could have been prevented by performing independent monitor unit verification prior to treatment [2–5], even more so, the International Commission on Radiological Protection (ICRP) [6] has indexed the task "monitor unit calculation" with a risk level of 3 being the maximum. Beam configuration and collimation properties of the treatment machines in treatment planning systems (TPS) ensure correctness of dose delivery planned by them [7]. Still there is a need to verify the complex treatment plans and check the number of MU delivered to the patient, which was carried out by in-house developed program or commercial software [8–10]. Descriptions of MUVC algorithms developed either in-house or commercially are reported in the literature for Conventional, IMRT and VMAT plans [11–18]. An in-house developed, Excel Spreadsheet based MUVC program using modified Clarkson's integration technique to calculate MUs for irregular MLC field segments was developed by Prakash et al. [18] for VMAT plans. In literature, using PTW's Diamond software, (version 5.3 or higher), there are two references, one proposing validation procedure and the other one analysing the results of 1 year of clinical experience for VMAT fields without heterogeneity corrections [19–21]. The aim of the present work is to compare two different methods of monitor unit verification calculations for VMAT plans with heterogeneity corrections. In our work, VMAT (Rapid Arc) plan monitor units are calculated and verified by two methods. One by in-house developed Excel Spreadsheet based MUVC program and second method by commercial available PTW's Diamond, secondary check software (SCS), version-6. Both the program uses modified

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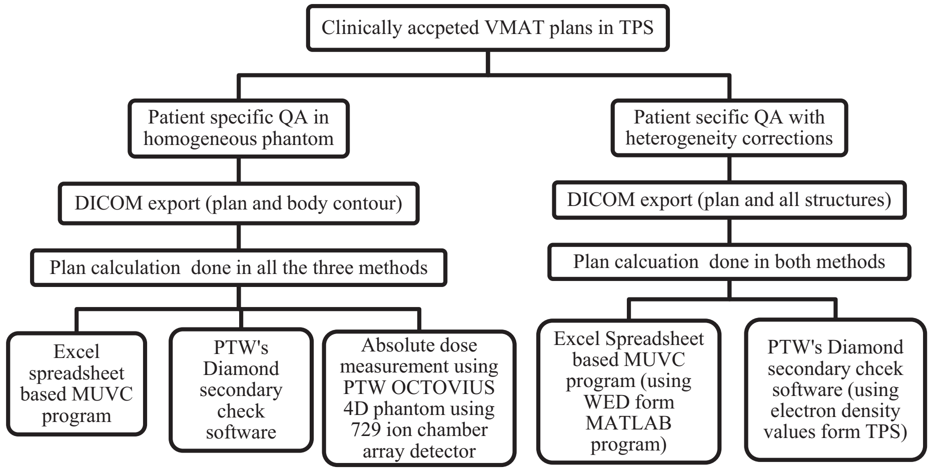

VMAT = Volumetric modulated arc therapy, QA = quality assurance, TPS = treatment planning system, DICOM = Digital Imaging and Communications in Medicine, MUVC = Monitor Unit Verification Calculation, RIDC = Redundant Independent Dose Calculation, WED = Water Equivalent Depth

Figure 1. A schematic summary of the methods for MU calculations in VMAT plans for patient specific QA.

Clarkson's integration technique [22] to calculate MUs or dose for irregular MLC field segments. The above mentioned procedure is schematized in Fig. 1.

Materials and methods

MU and dose verification was performed for 180 VMAT (Rapid Arc) plans. The plans were grouped into head and neck, thorax and pelvic plans consisting 61, 39 and 80 plans respectively. The plans were generated for True Beam and Varian Clinac-2100C/D linear accelerators with Millennium 120 leaves MLC. In the treatment planning system (TPS) Eclipse version-11, Dose calculation was performed using Acuros-XB (AXB) algorithm. Acuros-XB algorithm calculates dose by implementing solution to 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 [23]. Comparison between anisotropic analytical algorithm – version 11 (AAA) and Acuros-XB algorithms have been reported by Bush et al. [23] and Kroon et al. [24]. The same authors have also reported that, for plans with isocentre at a region below −350 HU, in low density regions Acuros-XB algorithm is more accurate and the doses calculated by AAA algorithm can be higher up to 30%.

In-house developed Excel Spreadsheet based MUVC algorithm

Independent MU check was carried out using In-house developed MUVC algorithm and all of them were point dose calculations. The In-house developed MUVC algorithm was programmed using Microsoft Excel 2010 (c) Microsoft Corporation. The program uses modified Clarkson's integration technique [22] to calculate MUs or dose for irregular MLC field segments. In TPS, VMAT plans is defined using control points where the leaf positions, gantry angle and cumulative MU weight are defined. The plans under consideration had either 177 or 178 control points for each arc. For each control point, the depth of isocentre varies depending on the patient's body contour. To account for the patient heterogeneity effect, water equivalent depth (WED) are used for each field segment path length. For VMAT plans the treatment report provides the data for the start gantry angle only. Alternatively, WED measurement tool in the TPS can be used along the direction of the sub-fields individually but the manual process is time consuming and tedious. Hence an algorithm was developed using MATLAB software to determine the WED for the sub-fields. Attenuation due to the accelerator couch is also accounted while determining the WED. The required WED for gantry angle of each segment are obtained by interpolation.

Spread sheet based algorithm has been developed by Prakash et al. [18] for MUVC for VMAT plans by incorporating MLC transmission, MLC round edge transmission, and tongue and groove effect. A MATLAB based algorithm has also been developed to measure WED for various gantry angles of the segments of VMAT arcs. All the treatment plans were exported from TPS to excel spread sheet program and the information of (i) isocentre dose, (ii) TPS calculated Monitor Units (iii) jaw positions (iv) MLC positions for each control point and (v) MU weight for each control point were obtained. Prior to its clinical use, validation procedure was performed for conventional fields and VMAT fields (A more detailed description can be found in reference [18]). In our work, using In-house developed Excel Spreadsheet based MUVC, dose calculations were performed for homogenous water equivalent cylindrical phantom (diameter = 30 cm and length = 40 cm) and also for VMAT plans with heterogeneity corrections.

PTW's Diamond secondary check software

Secondary check was also carried out using PTW's Diamond software, (version-6), the program uses modified Clarkson's integration technique [22] to calculate MUs or dose for irregular MLC field segments and all of them were point dose calculations. Diamond SCS includes two features related to algorithm, (i) body contour importation and (ii) heterogeneity corrections. The option to import the body contour for VMAT plans, makes it possible to assign a source to surface distance (SSD) and depth of calculation, to each control point (a VMAT field are composed of 177 or 178 control points), otherwise averaged values of SSD and depth must be assigned to all control points. In the previous studies [19–21] using PTW's Diamond software (version 5.01.02.131 or higher), the heterogeneity corrections are made by setting an effective depth different