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Medical Physics Contribution:

AAA and AXB algorithms for the treatment of nasopharyngeal carcinoma using IMRT and RapidArc techniques

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ABSTRACT

The aim of this study is to evaluate the impact of anisotropic analytical algorithm (AAA) and 2 reporting systems (AXB-D_m and AXB-D_w) of Acuros XB algorithm (AXB) on clinical plans of nasopharyngeal patients using intensity-modulated radiotherapy (IMRT) and RapidArc (RA) techniques. Six plans of different algorithm-technique combinations are performed for 10 patients to calculate dose-volume histogram (DVH) physical parameters for planning target volumes (PTVs) and organs at risk (OARs). The number of monitor units (MUs) and calculation time are also determined. Good coverage is reported for all algorithm-technique combination plans without exceeding the tolerance for OARs. Regardless of the algorithm, RA plans persistently reported higher $D_{2\%}$ values for PTV-70. All IMRT plans reported higher number of MUs (especially with AXB) than did RA plans. AAA-IMRT produced the minimum calculation time of all plans. Major differences between the investigated algorithm-technique combinations are reported only for the number of MUs and calculation time parameters. In terms of these 2 parameters, it is recommended to employ AXB in calculating RA plans and AAA in calculating IMRT plans to achieve minimum calculation times at reduced number of MUs.

Introduction

Radiotherapy is a very important option in cancer treatment. In nasopharyngeal carcinoma, it is used as a single radical treatment. In the last decade, radiotherapy techniques developed rapidly, providing more benefits such as reduced side effects and reduced treatment time on the machine. Besides intensity-modulated radiotherapy (IMRT) technique, which is based on dose painting idea to deliver appropriate dose-to-target and reduce dose-to-adjacent critical structures,[1-3] volumetric-modulated arc therapy technique represents an emerging competitor because of its ability to deliver accurate dose with small number of monitor units (MUs) in short delivery time.[4-7] Moreover, volumetric-modulated arc therapy provides not only the ability to control multileaf collimator motion (as in IMRT), but also the ability to change important treatment variables such as dose rate and gantry speed.[4,8-10]

There are wide varieties of dose calculation algorithms commercially available for clinical radiation treatment planning such as anisotropic analytical algorithm (AAA) and Acuros XB algorithm (AXB). AAA is implemented on Eclipse treatment planning system (TPS). It is based on

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convolution-superposition algorithm, which consists of 2 components: the configuration algorithm (determines the physical parameters of the fluence and energy spectra of photons and electrons of the beam and their scattering properties in water-equivalent medium) and the dose calculation algorithm (determines the heterogeneity of the medium to provide a reliable estimation of dose distribution in the plans).[11]

Recently, a new commercially available Acuros XB advanced dose calculation algorithm (AXB) is implemented on the Eclipse TPS to produce more accurate dose distribution in IMRT and RapidArc (RA) techniques. It is based on the same machine source model of AAA. AXB algorithm calculates the dose in the medium based on energy deposition in a way similar to Monte Carlo besides being less sensitive to the number of fields.[12,13]

This study focuses on performing a comparison between AAA and AXB algorithms in the calculation of the dose distribution in patients with nasopharyngeal carcinoma in conjunction with different combinations of each of IMRT and RA techniques. Extensive analysis of dose-volume histogram (DVH) and plan parameters are performed for the purpose of defining the best combination that provides the most reliable treatment parameters.

Despite previous work that reports possible differences between AAA and AXB algorithms, there is no sufficiently comprehensive study that compares all different possible algorithm-technique combinations on Eclipse TPS. Moreover, there is a need to provide the radiotherapist with, possibly, the best treatment combination when many options are available. This necessitated the initiation of the present study that evaluated such treatment choices and suggested the best for nasopharyngeal carcinoma cases.

Methods and Materials

In this study, 10 patients with nasopharyngeal carcinoma with bilateral lymph nodes were selected. On Eclipse TPS (Varian Medical Systems Inc., version 11.0, UK) supporting AAA and AXB algorithms and using grid size of 2.5 mm, 6 plans were done for each patient. The plans were as follows: AAA-IMRT, AAA-RA, AXB-D_m-IMRT, AXB-D_m-RA, AXB-D_W-IMRT, and AXB-D_W-RA, where D_w and D_m denote dose to water in medium and dose to medium in medium, respectively.

Three planning target volumes (PTVs) were treated, PTV70, PTV60, and PTV54, with prescribed doses of 70 Gy, 60 Gy, and 54 Gy, respectively, in 35 daily fractions.

For IMRT planning, 9 equi-spaced coplanar fields with angles starting from 0° around the patient were used at 300cGy/min dose rate. Optimization was done using dose-volume optimizer. For RA planning, 2 full arcs were used with 30° collimator and dose rate of 600cGy/min. Optimization was done using progressive resolution optimizer.

The plans were delivered using UNIQUE (Varian Medical System Inc., UK), employing millennium multileaf collimator-120 that offered 0.5 cm leaf resolution at isocenter for the central 20 cm of the 40×40 cm^2 field. It produced a photon energy of 6 MV and a dose rate up to 600 MU/min.

Risk structures including eyes, optic nerves, chiasma, brain stem, parotids, cochlea, mucosa, and spinal cords were delineated and prescribed according to tolerance of normal tissue to therapeutic radiation.[14,15] DVH data were then collected and compared for all patients' plans. MUs, number of segments, and calculation times were compared.

Plan evaluation was based on DVH in which D_2% and D_{98}% represented the maximum and minimum doses of the PTV, respectively. Conformity index and homogeneity index (HI) were calculated[16] (Equations (1) and (2))

$$CI = \frac{TV_{98\%}}{PTV_{98\%}} \tag{1}$$

and

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \tag{2}$$

where $TV_{98\%}$ is the treated volume receiving 98% of the prescribed dose.

Duncan multiple variant statistical test built in SPSS Statistics version 21 (SPSS Inc., Chicago, IL) is used to compare each DVH parameter value for all 6 algorithm-technique combinations.

Results

Figure 1 shows the difference in dose distribution between IMRT and RA plans calculated using AAA, AXB-D_m, and AXB-D_w algorithms, respectively. All plans show good coverage.

The DVH parameters of the 10 patients with nasopharyngeal carcinoma are summarized in Tables 1 and 2. Table 1 shows the average ± standard deviation of $D_{98\%}$, $D_{95\%}$, $D_{2\%}$, conformity index, and HI of PTV70, PTV60, and PTV54. The average mean or maximum doses of the eyes, optic nerves, brain stem, chiasm, parotids, mucosa, and cochlea extracted from AAA-IMRT, AAA-RA, AXB-D_m-IMRT, AXB-D_m-RA, AXB-D_W-IMRT, and AXB-D_W-RA are presented in Table 2.

In Tables 1 and 2, for a certain DVH parameter, values having different symbols are significantly different at p-value < 0.05, whereas values having the same symbol are insignificantly different. A value with an "ab" symbol is insignificantly different from values having an "a" symbol or a "b" symbol.

In Table 1, no significant difference is reported for PTV60 and PTV54 between any of the investigated algorithm-