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Original Article

The effect of version update in radiotherapy treatment planning system on early-stage glottic laryngeal cancer plans

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ABSTRACT

Objectives: The study focus on to compare different versions of eclipse anisotropic analytical algorithm (AAA), AAA 10.0.28 and AAA 13.7.20, on the treatment plans designed with intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) techniques for early-stage glottic laryngeal cancer patients through the dose-volume histograms (DVHs).

Patients and methods: Computerized tomography (CT) images of 10 cases' were taken and transferred to the Eclipse treatment planning system (TPS). Double VMAT and 7-field IMRT plans were designed and calculated with two versions of Eclipse AAA, 4 calculated plans for each patient. Values obtained from DVH, for the planning target volume (PTV) homogeneity index (HI) and conformity index (CI), the dose received by 2% of the volume (D2%), D95%, and D98% values; for carotid artery right and carotid artery left the mean dose (Dmean), the volume receiving a 35Gy dose (V35Gy) and V50Gy, and for the spinal cord the maximum dose (Dmax) were recorded. Statistical analysis was performed with the non-parametric Wilcoxon sample test in the SPSS 17.0 program, and the significance was determined as $p<0.05$.

Results: For PTV, HI and CI values, the difference between the versions for VMAT and IMRT plans was not significant. While D2%, made a significant difference between the versions but only for the VMAT plans. Moreover, a significant difference was found between the versions of the IMRT plans in D95% and D98%. In the analysis of the right carotid artery, there was a significant difference between the versions of the IMRT plans for Dmean and the VMAT plans for V35Gy. In the left carotid artery analysis, there was a significant difference between the versions for Dmean and V35Gy for the IMRT plans. For Dmax values of the spinal cord, a significant difference was observed between versions for only IMRT treatment plans.

Conclusion: This study has proven that the use of the most up-to-date version of technology provides a more realistic dose distribution, especially in head and neck cancer patients in terms of high precision calculation of dose transition between tissues of different densities and maximum doses. As well as considerable to determining the patient's normal tissues and target volume very clearly and designing an accurate plan for radiotherapy.

Keywords: Anisotropic analytical algorithm, head and neck cancer, treatment planning algorithm, version update.

Radiation therapy (RT) plays a key role in curative-intent treatments for head and neck cancer (HNC). Its use is indicated as a sole therapy in early-stage tumors or in combination with surgery or concurrent chemotherapy in advanced stages.[1]

Treatment of HNC using intensity modulated radiation therapy (IMRT) or volumetric modulated arc therapy (VMAT) is a promising technique due to its ability to conform the high dose to irregularly shaped volumes and to minimize doses away from multiple critical normal organs.[2]

One of the most vital choices during radiotherapy treatment planning is the determination of the appropriate technique for the treatment area and then the calculation algorithm suitable for both the treatment technique and treatment area.

In external radiotherapy, computerized treatment planning systems (TPS) are used to generate beam shapes and dose distributions in order to provide maximum tumor control while minimizing critical organ doses.[3]

In TPS, calculation algorithms are integrated to simulate conditions of tissue-beam interactions to demonstrate the dose distribution after treatment is delivered to the patient, under

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defined conditions and terms of the patient plan.

The algorithm established in the TPS should calculate the dose distribution fast enough to facilitate clinical application while taking photon-matter interactions and tissue inhomogeneities into account in the most realistic way.

The quality of a patient's treatment plan not only depends on the skill level of a medical physicist but also on the inherent accuracy of the dose calculation algorithm installed in the TPS. The accuracy of a dose calculation algorithm is a function of many variables: *(i)* quality of input data used in the commissioning of the system, *(ii)* implementation and related assumptions of physical processes of the underlying algorithm, *(iii)* interpretation of patient image data, and *(iv)* heterogeneity of the anatomic site treated.[4]

The dose calculation algorithm in TPS can be broadly categorized by methods based on the correction-based, model-based, and solving of the Linear Boltzmann Transport Equation.[5,6]

Model-Based Algorithms are more complex than Correction-Based Algorithms and must be performed by high-performance computers. The problems in the traditional dose calculations, like correction-based, occurred from tissue inhomogeneities, and absorbed-dose differences due to varying field shape geometries were overcome by model-based algorithms. These algorithms were based on convolution or superposition methods.[3]

Anisotropic analytical algorithm (AAA) known as an advanced ('type b') dose calculation algorithm, now routinely available in commercial TPS shows improved accuracy compared to the previous pencil beam (PB) ('type a') algorithms.

The convolution-superposition algorithm, the AAA, and the collapsed cone convolution algorithm (type-b algorithms) were proved to significantly overestimate the doses near air/tissue interfaces.[2,7-10]

In our clinic, the AAA algorithm has been installed in the Eclipse radiotherapy TPS, and the version has been upgraded from Eclipse AAA 10.0.28 to Eclipse AAA 13.7.20. With the version update for the AAA algorithm, it has been aimed to make more realistic calculations between the versions of the same algorithm.

In this study following such a version update, the treatment plans of 10 patients diagnosed with early-stage glottic laryngeal cancer were redesigned using VMAT and IMRT techniques, and these plans were calculated with two different algorithm versions.

Dose-volume histograms obtained from TPS calculations of the designed plans were compared in terms of target volume and doses received by normal tissues after the TPS algorithm update.

PATIENTS AND METHODS

This retrospective study was conducted at Kartal Dr. Lutfi Kirdar City Hospital Radiation Oncology Department between January 2016 and December 2018. A total of 10 patients (8 males, 2 females; mean age: 58.2±3.2 years; range, 45 to 68 years) diagnosed with early-stage glottic laryngeal cancer were included in the study.

Treatment planning

Computed tomography (CT) images of 10 cases and were screened from the TPS archive of the clinic in order to redesign treatment plans with the new version of the AAA algorithm. Patients' CT images had been taken by General Electric BrightSpeed CT with a 2.5 mm slice thickness to be used in TPS. Planning CT images taken for each patient were transferred to the Eclipse (Varian Medical Systems, Palo Alto, CA, USA) TPS, and target volumes and critical organs were determined for each patient by the same radiation oncologists.

Two planning techniques have been determined to design for each patient. In the double ARC VMAT design, the target is defined as the planning target volume (PTV) and the double arc rotated the whole 360 degrees from clockwise 181 to 179 and counterclockwise 179 to 181, with 30 degrees collimation on each field.

The IMRT technique is set to design 7 fields; the PTV is defined as the target and 7 fields are set to PTV with 51-degree intervals at whole 360 degrees with 5 degrees collimation on each field. Double ARC VMAT and 7 fields IMRT plans were designed with a treatment dose of 69.96 Gy/2.12 Gy days on the TPS.

Treatment plans were calculated with two different versions, representing Eclipse AAA 10.0.28 before the upgrade and Eclipse AAA 13.7.20 after the upgrade of the TPS algorithm for both double ARC VMAT and 7 fields IMRT. The difference between the versions is compared within themselves for VMAT and IMRT planning techniques. Dose distributions of the four plans were evaluated for each of the 10 patients, as shown in Figure 1.

The dose was normalized to PTV in all patient plans. For each plan, the normalization value was chosen in the range (98±1%). For PTV, homogeneity index (HI), and conformity index (CI), dose received by 2% of the volume (D2%), D95%, and D98% values obtained from dose-volume histograms (DVH) were recorded as the evaluated data.

The carotid artery and spinal cord were selected for evaluation of normal healthy tissue. Even if they have different dose criteria on plan evaluation, both could be dose-limiting for treatment planning.

For the carotid artery right and left the mean dose (Dmean), the volume receiving a 35Gy dose (V35Gy), and V50Gy are determined to assess and analyzed statistically.

The maximum dose of the spinal cord was evaluated (Dmax). It is very important to know max dose delivered to the spinal cord instead of dose to volume due to its properties of structure and cell type of composition.

Statistical analysis

Statistical analysis was performed with the non-parametric Wilcoxon sample test in the PASW version 17.0 software (SPSS Inc., Chicago, IL, USA) program, and the significance was determined as $p<0.05$.

Plan 1: AAA 10.0.28 VMAT	Plan 3: AAA 10.0.28 IMRT
Plan 2: AAA 13.7.20 VMAT	Plan 4: AAA 13.7.20 IMRT

Figure 1. Four plan chart to be calculated for each patient.
AAA: Anisotropic analytical algorithm; VMAT: Volumetric modulated arc therapy; IMRT: Intensity modulated radiation therapy.

RESULTS

For the planned curative treatment dose the target volume is 69.96 Gy/2.12 Gy daily. For each patient, we generated four treatment plans and plans analyzed through the DVH's in terms of determined limitations in this study for the target volume and healthy tissues, as shown in Table 1.

Planing target volume

The effect of versions Eclipse 10.0.28 and 13.7.20 of the AAA algorithm on two different planning techniques for PTV was evaluated via HI, CI, D2%, D95% and D98%. Statistical analysis was carried out, for VMAT by comparison between Eclipse AAA 10.0.28 and AAA 13.7.20 versions, and for IMRT by comparison between Eclipse AAA 10.0.28 and AAA 13.7.20.

In Table 1, comparison results of HI, CI, D2%, D95% and D98% demonstrated for PTV. Results of the statistical analysis revealed that for PTV HI and CI values, there is no significant difference between the versions both for VMAT and IMRT techniques. The dose received by 2% of the volume D2%, represents the max dose, here the difference between the versions is statistically significant for the VMAT technique 13.7.20 version ($p=0.005$). On the other hand, both PTV D95% and D98% values were statistically significant in the comparison between versions only for the IMRT technique 13.7.20 version (respectively $p=0.011$, $p=0.012$).

Carotid arteries

To validate the impact of different versions of the AAA algorithm at two different planning techniques for Carotid Arteries Left and Right were evaluated Dmean and the percentage of V35 and V50 for each. Statistical analysis was carried out, for VMAT by comparison between Eclipse AAA 10.0.28 and AAA 13.7.20 versions, and for IMRT by comparison between Eclipse AAA 10.0.28 and AAA 13.7.20.

Left carotid artery

As a result of the left carotid artery Dmean values, there is no statistical significance for the VMAT technique between versions, but there is a statistical significance ($p=0.007$) for the IMRT 13.7.20 version. A similar result was obtained for the V35 and there is no

Table 1. Statistical evaluation of plans calculated with Eclipse AAA 10.0.28 and AAA 13.7.20 versions for VMAT and IMRT techniques in terms of the target volume and determined normal tissues

	AAA 10.0.28 *vs.* AAA 13.7.20 for VMAT	AAA 10.0.28 *vs.* AAA 13.7.20 for IMRT
PTV		
HI	NS	NS
CI	NS	NS
D2%	p=0.005	NS
D95%	NS	0.011
D98%	NS	0.012
Right carotid arteries		
Dmean	NS	0.006
V35	0.009	NS
V50	NS	NS
Left carotid arteries		
Dmean	NS	0.007
V35	NS	0.027
V50	0.035	NS
Spinal cord		
Dmax	NS	0.05

AAA: Anisotropic analytical algorithm; VMAT: Volumetric modulated arc therapy; IMRT: Intensity modulated radiation therapy; PTV: Planning target volume; HI: Homogeneity index; CI: Conformity index; V35: Volume receiving 35; V50: Volume receiving 50; Dmax: Maximum dose; NS: Not significant.

significant difference between VMAT versions while there is a significance (p=0.027) for the IMRT 13.7.20 version. The opposite was observed for V50 values of left carotid artery, the only significant difference between versions was for the VMAT technique 13.7.20 version (p=0.035).

Right carotid artery

In terms of Dmean values, there is no statistical significance for the VMAT technique between versions, but there is a statistical significance (p=0.006) for the IMRT 13.7.20 version.

Results for the right carotid artery were different than the left carotid artery. For the V35 values, there was a statistically significant difference between versions for the VMAT technique 13.7.20 version (p=0.009), while no significance for the V50 values was observed in either VMAT or IMRT techniques.

Spinal cord

To validate the impact of different versions of the AAA algorithm at two different planning techniques for the spinal cord we evaluated the Dmax. Statistical analysis was carried out, for VMAT by comparison between Eclipse AAA 10.0.28 and AAA 13.7.20 versions, and for IMRT by comparison between Eclipse AAA 10.0.28 and AAA 13.7.20.

As a result of the spinal cord Dmax values, there is no statistical significance for the VMAT technique between versions, but there is a statistical significance (p=0.05) for the IMRT technique 13.7.20 version.

DISCUSSION

Intensity modulated radiation therapy or VMAT techniques used in the treatment of HNC are beneficial techniques that adapt high doses to irregularly shaped volumes in target volumes and can provide desired low dose distributions in multiple critical organs.[1]

The computational accuracy of these complex planning systems is possible with the selection of reliable computational algorithms. The choice of calculation algorithm in treating HNC is critical because of the significant amount of bone structure and air spaces surrounding and forming this region. The limitations of the chosen algorithm may affect the precision of the dose distribution. Using an accurate algorithm in the TPS to calculate dose distribution has a crucial role to deliver the prescribed dose to the target tissue and minimize the extra dose to the organ at risk.[5,11,12]

In many studies in the literature that it has been mentioned the effect of media/tissue differences through the beam path is an important problem in the design of computational algorithms, dose calculations in water and heterogeneous media are different from each other.[5,13,14]

Many different algorithms have been used for calculations until today, and it has been emphasized in the literature that these algorithms have some limitations.

One of the algorithms used in TPS is pencil beam convolution (PBC). The PBC algorithm, a correction-based algorithm, and its equivalent path length corrections are used to determine inconsistencies. Changes in the transmission of electrons and photons are not modeled.[5,15]

The development of a superposition-convolution method known as AAA has been shown to be more accurate than PBC in photon dose calculations. By considering lateral scattering, the AAA algorithm provides better calculations of photon beam interactions in regions with complex tissue heterogeneities.[16]

One of the other algorithms is the Acuros XB (AXB) algorithm, which considers the behavior of beam particles (neutrons, photons, electrons, etc.) by moving and communicating with matter.[5,6,17]

In a study where a similar version update was evaluated over the AXB algorithm, it was found that AXB11's significant improvement over AXB10 was the accuracy of dose calculation in the air gaps.[18]

As demonstrated in the study by Ojala et al.,[18] the most important goal of version updates is to improve dose calculation accuracy. Similarly, we observed significant differences between the upgraded Eclipse AAA 13.7.20 and the old version Eclipse AAA 10.0.28 in our study with early-stage laryngeal cancers. These significant differences were observed especially for determined hot spots and PTV volumes definitions. Air gaps calculation accuracy and the sharpness of the maximum dose gain more importance and precision with the updated version.

There is no other study in the literature showing the version update difference via the AAA algorithm and a specific treatment area/patient group like our study.

In the literature, only one study has been identified that investigated the effects of the AAA algorithm version update. In this study by Krishna et al.[19] it is seen that the treatment areas include anatomically different structures such as the lung, head and neck, cervix, stomach, and breast. Due to the tissue heterogeneity between the areas included in the study, the calculation algorithm is considered to be more difficult to distinguish between version update differences. With this diversity, it may not be possible to show an upgrade difference in the study of Krishna et al.[19]

The distinction of our study is that it only included cases with early-stage laryngeal cancer planned with a similar treatment area.

The difference between the updated versions in our study is the patient group with the same characteristics and the unity in our study the prescribed dose for the treatment, the treatment area, similar tissue inhomogeneities in this area (air-bone transitions), and selected treatment techniques. In our study, which includes treatment plans with similar treatment areas and tissue characteristics, it is predicted that the version update differences can be more accurate and the statistical significance determined for the version upgrade reflects the reality.

In the Krishna et al.[19] study with the version update, it was found that the treatment quality of the new version is the same as the old version but provides faster dose calculation data. In our study, dose calculation rate differences between versions were not evaluated.

The limitation of this study is that it included 10 patients. Increasing the number of patients will strengthen our study.

In conclusion, this study has proven that the use of the latest version of technology provides a more realistic dose distribution, particularly in HNC patients. These updates allow to calculate the dose transition between tissues of different densities and to display the maximum doses with high precision.

Ethics Committee Approval: The study protocol was approved by the Kartal Dr. Lütfi Kırdar City Hospital Clinical Research Ethics Committee (date: 25.01.2023, no: 2022/514/242/3). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Since the study was designed retrospectively, no written informed consent form was obtained from patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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