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# Assessment of the Dose Coverage at the PTV for EBRT for Cervical Cancer Treatment Plan Using AAA Varian Eclipse TPS at Ocean Road Cancer Institute, Tanzania

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**Abstract**

The implementation of the Eclipse treatment planning system software (Version 15.1) at Ocean Road Cancer Institute (ORCI), Tanzania has made the Anisotropic Analytical Algorithm (AAA) the necessary routine tool for dose calculations. However, the accuracy of the AAA algorithm in planning doses specifically for cervical cancer treatment is not well known. Therefore, this study investigated the accuracy of the AAA in dose calculation in terms of the dose coverage at the Plan Target Volume (PTV) for cervical cancer treatment at the ORCI. 50 treatment plans of adult patients with International Federation of Gynecology and Obstetrics (FIGO) stage IB-IIIB cervical cancer who underwent 3D-CRT were analyzed. The results show that most of the patients received at least 95% of the prescribed dose, averaging 48.3 Gy, which is about 96.6% of the prescription. The average maximum dose was about 53.7 Gy, equivalent to 107.4% of the prescribed dose. When compared to other studies, minor dosimetric differences, typically less than 2% for all the PTV dose parameters, were observed. In conclusion, the results affirm that the Eclipse AAA algorithm is sufficiently accurate for dose calculations for cervical cancer treatment planning at the ORCI.

**Keywords:** AAA; Cervical cancer; FIGO; PTV; TPS

## Introduction

Cervical cancer is one of the leading causes of death worldwide and its burden is more serious in low- and middle-income countries like Tanzania (Cao et al. 2021). In 2020, approximately 604000 cases of cervical cancer were reported, resulting in about 342000 deaths worldwide (Sung et al. 2021). On a global scale, cervical cancer stands as the fourth utmost cause of cancer-related death in women, preceded by breast cancer, colorectal cancer, and lung cancer (Hull et al. 2020, Sung et al. 2021). In Tanzania, cervical cancer is the leading and primary cause of the cancer-related deaths among women (Amour et al. 2019, Henke et al. 2021). Cervical cancer is, however, a highly curable type of cancer, especially when diagnosed and treated at the early stages of its development (Amour et al. 2019, Murat et al. 2019, Rooshenas et al. 2020). The curability nevertheless depends on the ability to accurately deliver the prescribed dose to the target volume (Padmanaban et al. 2014, Flejmer et al. 2015, Rooshenas et al. 2020).

Adequate coverage of the Planning Target Volume (PTV) is of paramount importance in attaining effective control of the local tumor for better treatment outcomes (Çakir and Akgün 2019). It is important to note that, a larger PTV offers a distinct advantage in terms of an increased probability of attaining

the necessary dose coverage for the tumor, which contributes to enhanced treatment efficacy (Tsang et al. 2017). Authorities like the International Commission on Radiation Units and Measurements (ICRU) advocate that dose delivery accuracy should fall within 95% to 107% of the prescribed doses for optimal coverage of a well-controlled PTV (ICRU 1976, Chiuyo et al. 2013, Mrozowska and Kukołowicz 2015, Amour et al. 2019). Dose delivery at this level of accuracy primarily depends on the dose calculation algorithm used (Rooshenas et al. 2020).

Several dose calculation algorithms are being used to calculate the radiation dose for patients each of which is based on various assumptions for radiation transport (Kim et al. 2020). Among them, the Anisotropic Analytical Algorithm (AAA) has appeared as the most prevalent within the Eclipse treatment planning system (TPS) especially when performing an external beam radiation therapy (EBRT). Several studies have been conducted to assess the accuracy of the AAA dose calculation algorithm in modeling the dose distribution around the PTV (Flejmer et al. 2015, Gete et al. 2012, Sterpin et al. 2007). However, most of these studies are mainly concentrated on assessment of the accuracy of AAA in dose calculations with accent on lungs (Ono et al. 2010, Gete et al. 2012, Kroon et al. 2013, Fogliata et al. 2016), nasopharynx (Kan et al. 2011), and cranial (Calvo-Ortega et al. 2014). To the best of our knowledge no other study conducted to assess the accuracy of AAA in dose calculation in cervical cancer. Therefore, this study investigates the accuracy of the AAA in dose estimation and dose coverage at the PTV for cervical cancer treatment at the Ocean Road Cancer Institute (ORCI).

## Materials and Methods

### Patients' Selection

This study involved a cohort of 50 treatment plans of adult patients who were previously diagnosed with International Federation of Gynecology and Obstetrics (FIGO) stage IB-IIIB Cervical Cancer who underwent 3D-CRT at the ORCI. In this study staging was the only criteria considered for patient selection.

### Computed Tomography Scanning

A Computed Tomography scan (CT) scan for each patient was done in a room equipped with a big bore 3D-CRT CT simulator (SIEMENS, Healthineer SOMATOME, USA). Before scanning began, each of the 50 patients was placed on the treatment couch in a supine position with arms placed on the chest. The treatment isocenter on a patient was defined using the low-energy lasers with markers reference points placed to match with the gantry axis of rotation during treatment. Finally, a CT scan was performed to acquire the anatomy to be involved in the treatment. The CT scan was used to identify the lesion(s) and surrounding normal critical organs that are needed for developing a treatment plan that guided the treatment machine to target the lesion(s) accurately and spare critical organs as much as possible. After the simulation had been completed, the CT images obtained were sent to a Varian Eclipse treatment planning system (Varian, Alto, CA, USA) software version 15.1 to perform dose planning for the respective patient.

### Treatment Planning

For irradiation of the exact targeted location of the cancer tumor, treatment planning for the dose to be delivered is an important factor in radiation therapy. The treatment plan includes the location of the tumor with suitable margins, PTV, and volumes of the organs at risks (OARs). In this study, treatment planning was performed with the Varian Eclipse treatment planning system (Varian, Palo Alto, CA, USA) software version 15.1. The planning technique involved a four-field box method with parallel opposed anterior-posterior (AP) and posterior-anterior (PA) and two lateral opposite fields. All the fields were equally spaced around the PTV to avoid the overlaps at the entrance and exit through the patient's body. The beam angles involved the counterclockwise from 0° to 90°, 90° to 180°, 180° to 270°, and 270° to 360° with the collimator and couch angles both set to 0°.

### Coverage of the Plan Target Volume

Coverage of the PTV was assessed based on the dose prescription parameters generated by the dose volume histogram (DVH) using the Eclipse Treatment Planning System. The parameters include the Conformity Index (*CI*), Minimum Dose ($D_{min}$), Mean Dose ($D_{mean}$), $D_{95\%}$ and the Maximum Dose ($D_{max}$). According to the ICRU report No.50, the maximum dose in the PTV should not exceed 107% of the prescribed dose and the minimum dose should not be smaller than 95% of the dose at the ICRU dose ($D_{ICRU}$) reference point (ICRU 1976). The conformity index used to evaluate the treatment plans was calculated using equation 1 (Israngkul-Na-Ayuthaya et al. 2021)

$$CI = \frac{PTV}{TV} \tag{1}$$

where, PTV is the volume of the target receiving the prescription dose while TV denotes the overall target volume. In this context, the CI serves as a quantitative parameter for evaluating the quality of radiotherapy treatment plans.

**Data Analysis**

A quantitative analysis of the results was undertaken using Origin 9.0 software (OriginLab, Northampton, MA, USA) and the percentage deviation was evaluated using equation 2.

$$\%Deviation = \left( \frac{D_{AAA} - D_{ICRU}}{D_{ICRU}} \right) \times 100\% \tag{2}$$

where $D_{AAA}$ is the amount of maximum dose received by a patient as calculated by AAA and $D_{ICRU}$ radiation dose constrains set by the ICRU.

**Results and Discussions**

**At least 95% of the prescribed dose within the PTV**

The dosimetric results of the PTV region receiving at least 95% of the dose for 50 patients are presented in Figures 1(a) and (b). The results in Figures 1(a) and (b) show that about 90% corresponding to the majority 45 number patients of received a radiation dose that covered at least 95% of what was prescribed for the PTV. This indicates that the treatment was highly successful in delivering the intended radiation dose to the targeted tumor. The average radiation dose received was about 96.6%, the value approximately 3.4% less than the total prescribed dose across the entire PTV. Quantitatively, this translates to an average dose of 48.3 Gy, with a standard deviation of ±1.12 Gy. In comparison with the originally prescribed dose, this value suggests that, on average, the patients received approximately 1.7 Gy less, the results that agrees well with radiation therapy protocol.

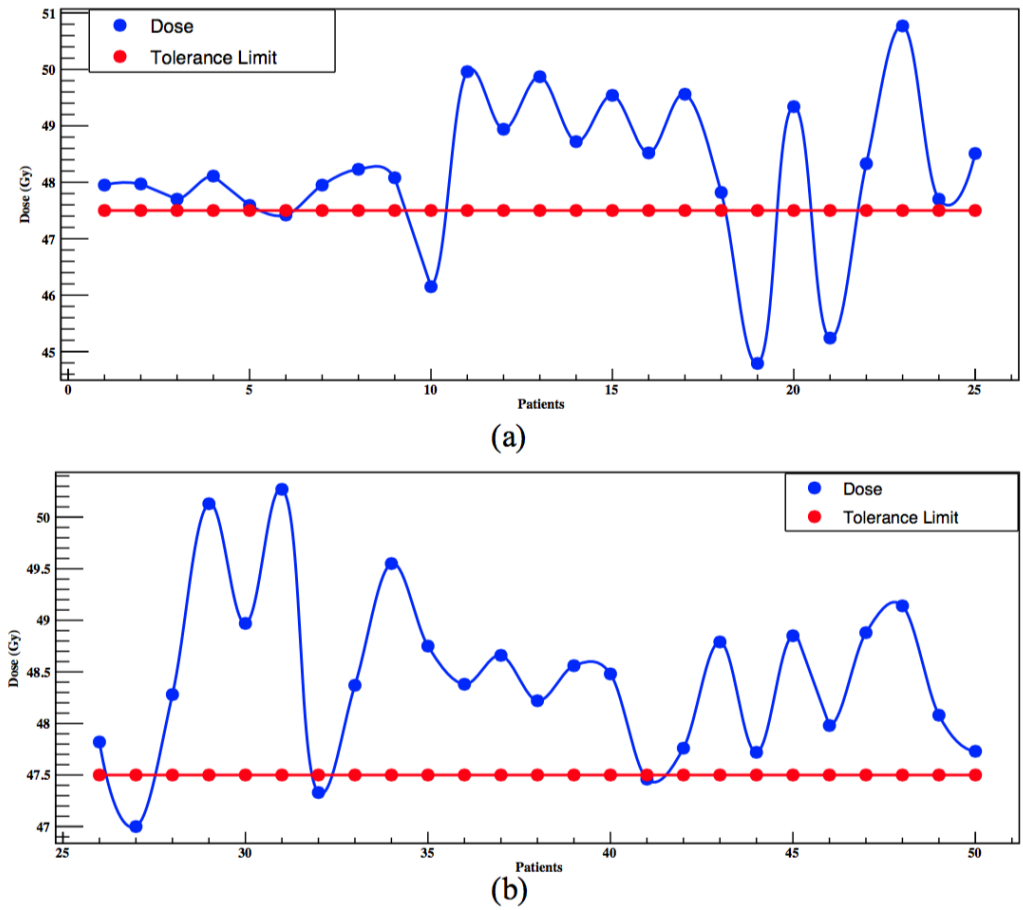


**Figure 1:** A plot of 95% of the dose delivered to the PTV against patients at the tolerance limit of 47.5 Gy (a) 1-25 and (b) 26-50 patients.

Similar trends were reported by Gete et al. in 2012, who compared the AAA for lung treatments against Monte Carlo calculation methods and the pencil beam dose calculation. The results are also in good agreement with the earlier work by Liu et al. 2017, which focused on dosimetric comparisons involving AAA and Monte Carlo methods for 3D-CRT with a female pelvic phantom. The dosimetric differences in dose values between the current work and that of Gete et al. 2012 and Liu et al. 2017 (Table 1) were less than 2.5%.

**Table 1**: Comparison between the AAA dose results.

| Studies | 95% of Prescribed Dose | % Deviation from ICRU | P-value |
|---|---|---|---|
| This Study | 96.6 | 1.6 | <0.001 |
| Gete et al. 2012 | 96.5 | 1.5 | <0.001 |
| Liu et al. 2017 | 99 | 4 | <0.001 |

In view of these results, a good agreement between the AAA algorithm and the ICRU dose constraints, specifically, $V_{95\%}$ exist. For almost all cases, AAA radiation dose calculations for cervical cancer patients fell within the ICRU recommended range, (-5% to +7%). It is recommended that the delivered dose should not deviate from the prescribed

dose by more than ±5% for better tumor control (ICRU 1976 and Chiuyo et al. 2013). In the present study, the AAA dose calculation algorithm was successfully used to estimate the dose to cover at least 95% of the target volume for 90% of the patients, which equivalent to 45 patients out of the 50 that were involved in the investigation.

It is important to note that, the AAA estimations of the radiation dose needed to cover at least 95% of the prescribed amount were not the same for all the patients. Particularly, Figure 1 (a) and (b) show the patients with serial numbers 23, 29, and 31 who had the most significant differences, with their doses deviating significantly as much as +7% from the lowest recorded dose value. These variations in dose estimation between patients can be attributed to a variety of factors. These factors may include differences in the patients' body sizes, the size of the treatment zone also called PTV, the specific location of the tumor within the body, and the total amount of time that each patient was exposed to radiation (Yang 2020). These factors are explored in depth in a study conducted by Brosch-Lenz et al. (2023), where more insights are provided into how they influence dose differences among various patients (Brosch-Lenz et al. 2023).

However, for patients with serial numbers 10, 19, 21, 27, and 32 dose results calculated using the AAA algorithm show slight underestimate of the radiation doses delivered (up to about 10% less than the prescribed dose) within the PTV. This suggests that some patients received PTV doses that were marginally lower than the dose limits established by the ICRU. These standard dose limits define the minimum dose required for effective tumor eradication. For interpretation, Table 2 presents an overview of the patients who received PTV doses less than $D_{95\%}$, along with the corresponding percentage deviation from both the prescribed doses and the ICRU dose constraints.

**Table 1:** Illustration of the number of patients that received the PTV dose less than $D_{95\%}$.

| Patients | Patients doses as calculated by AAA (Gy) | % Deviation from $D_{95\%}$ (%) | % Deviation from the prescribed dose (%) |
|---|---|---|---|
| Patient 10 | 46.15 | - 2.84 | - 7.84 |
| Patient 19 | 44.79 | - 5.70 | - 10.42 |
| Patient 21 | 45.24 | - 4.76 | - 9.52 |
| Patient 27 | 47.00 | - 1.05 | -6.00 |
| Patient 32 | 47.33 | - 0.36 | - 5.34 |

The results (Table 2) show that there may be a relatively lower level of tumor control for certain patients following the prescribed protocol. Therefore, before interpreting the dose deviation in a clinical context, it is important to understand the possible causes of the deviation. The results from this study may contain statistical uncertainties, which can arise from the calculations performed with commercial algorithms can have influence on the observed dose deviations. One significant factor in these dose variations is the precision of algorithms in calculating lateral electronic disequilibrium. It occurs when the radiation field is too small or the material density fail to supply enough electrons to the dose area therefore resulting to underestimation of the radiation dose (Yang 2020).

Another potential cause of the deviations in radiation doses could be due to the inability of the AAA to precisely estimate doses in materials with high atomic numbers, such as bones and muscles (Liu et al. 2020). The cervical region primarily consists of tissues and muscles with high density, that can create

a diverse environment for radiation treatment. Under this condition, the AAA's dose calculations may not be able to capture the density variations within the tissues, therefore resulting to either overestimation or underestimation of the radiation dose.

**Maximum Dose to the PTV**

The dosimetric results for the patients' PTV region receiving the maximum prescribed dose ($D_{max}$) are depicted in Figures 2 (a) and (b), with a particular emphasis on a singular dosimetric parameter. The results from Figures 2 (a) and (b) show that more than 60% of patients consistently received the maximum PTV prescribed dose which remained below the maximum ICRU dose limit (107%). The results reveals further that the average maximum PTV dose administered to the patients was around 53.7 Gy, with a slight deviation of 1.12 Gy, reflecting typical clinical variations. Significantly, this calculated average corresponds to 107.4% of the total prescribed dose, marginally exceeding the ICRU's maximum dose limit by only 0.4%. Conversely, the results revealed that the AAA estimated doses for some of the patients were significantly higher than the prescribed dose by about 15%. This 15% deviation essential surpasses the practical allowance set by the ICRU, which typically permits a maximum of up to 7% over the prescribed dose.

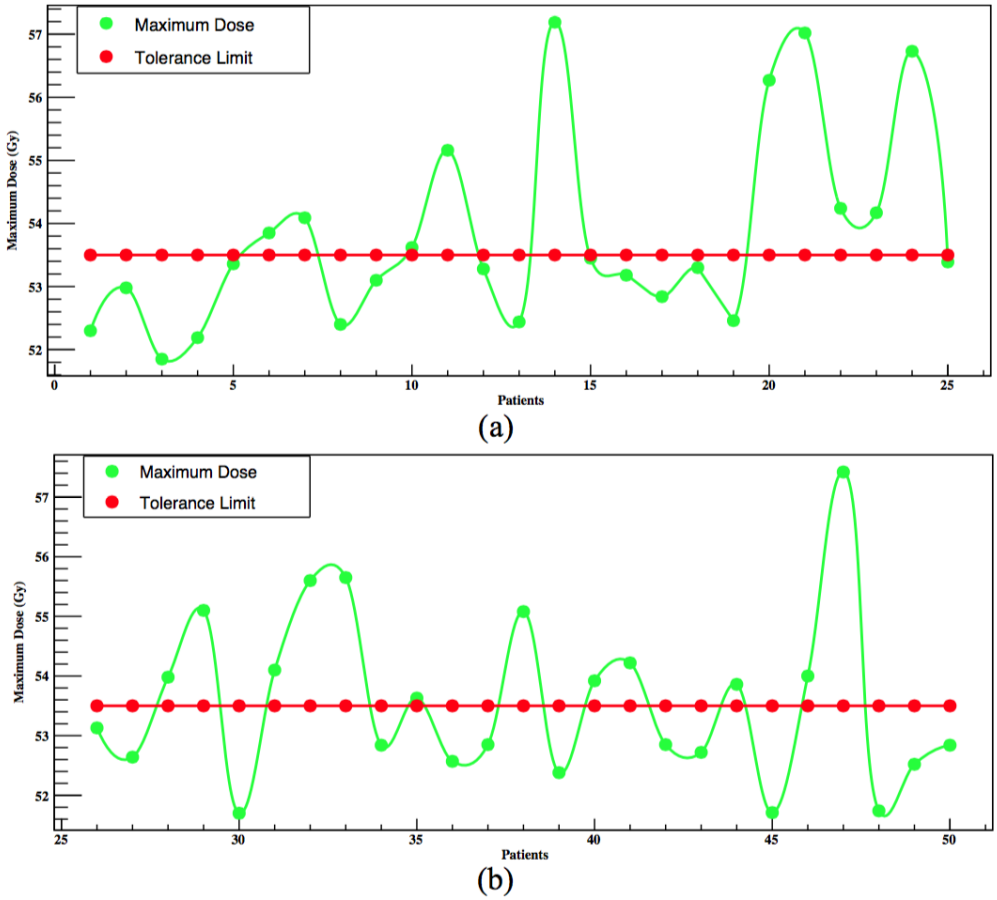


**Figure 2:** A plot of the maximum dose delivered to the PTV against patients at the tolerance limit of 53.5 Gy (a) 1-25 and (b) 26-50 patients.

A 15% deviation from the intended dose, could be indicative of success in ensuring that the radiation dose was accurate to the tumor, thus leading to the successful elimination of

the tumor. However, delivering a radiation dose higher than initially planned comes with detrimental effects. There is a chance that such an elevated dose could unintentionally harm the healthy tissues and OARs in the proximity of the tumor site.

## Conclusions

The accuracy of the AAA in dose calculations for cervical cancer treatment using the Varian Eclipse Treatment Planning System was assessed for the first time at the ORCI. This assessment adhered to the recommendations of the ICRU reports No. 50 and 62, and to the earlier studies reported on the dose calculation. 50 adult patients with FIGO stage IB-IIIB cervical cancer who underwent 3D-CRT were selected and their treatment plans were analyzed. The results show that, for the PTV, most patients received about 95% of the prescribed radiation dose with average of around 48.3 Gy equivalent to about 96.6% of the prescribed dose value. The highest dose given was approximately 53.7 Gy, or equivalent at 107.4% that is slightly higher than the prescription value. Therefore, the results from the present study suggest that the Eclipse AAA dose calculation algorithm is appropriate with proper accuracy for cervical cancer treatment planning. However, further studies are recommended that will consider patient-specific factors that can refine the observed dose variations in a way enhancing the accuracy of planning algorithm and optimizing the radiation treatment at the ORCI.

## Declaration of Competing Interest

The authors declare that there is no any conflict of interest regarding this work.

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