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Influence of Planning Target Volume (PTV) on Gamma Pass Rate for 6 MV and Flattening Filter Free (FFF) Beams in Volumetric Modulated ARC Therapy (VMAT)

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Abstract:

Background: *Many patient-specific quality assurance studies have not considered the influence of planning target volume (PTV) on the gamma passing rate.PTV volume geometries may become more complex with an increase in PTV volumes. There is therefore the need to determine how increasing volumes of planning target volumes influences the gamma pass rates in 6 MV and flattening filter free plans to determine which is ideal for the treatment of cervical cancer with pelvic lymph node metastasis.*

Methods: *The study involved the use of VMAT plans for fifteen cervical cancer patients with pelvic lymph node metastases. VMAT plans for both 6 MV and flattening filter free beams were created for each patient using the RayStation treatment planning system (RaySearch Laboratories AB Sweden) giving a total of thirty plans. Two treatment arcs were used to create each plan. Radiation dose constraints for the primary tumour and lymph node volumes were met for all treatment plans.*

Results: *The mean gamma pass rate for the 6 MV plans was 99.97% while that of the flattening filter free plans (FFF) was 98.45%. There was a higher significant difference ($p < 0.05$) in pass rate for the 6 MV and flattening filter free plans. Most individual 6 MV plans had a 100% gamma pass rate as the planning target volume increased. There was a constant gamma pass rate for the 6 MV plans whereas increasing PTV volume decreased the gamma pass rate for the FFF plans.*

Conclusion: *For larger planning target volumes in cervical cancer patients with pelvic lymph node metastasis, it is advisable to use conventional 6 MV beams with flattening filter since it offers a better dose distribution.*

Keywords: *gamma pass rate, flattening filter free, multileaf collimator, planning target volume*

1.0 Introduction

Modern volumetric modulated arc therapy (VMAT) techniques involve the use of either conventional flattened beams or flattening filter free beams (FFF). In treatment planning, a margin is typically added to the clinical target volume (CTV) to create the planning target volume (PTV), which helps to ensure optimal dose coverage to the CTV(1). It is necessary to have sufficient PTV margins to avoid geographic misses. Many patient-specific quality assurance studies have not considered the influence of planning target volume (PTV) on the gamma passing rate especially in pelvic cancer cases where there is usually larger PTVs. PTV volume geometries may become more complex with an increase in PTV volumes and this could affect treatment dose distribution(2).

The study aimed to analyse the influence of the planning target volume (PTV) on the gamma pass rates for conventional 6 MV beams and flattening filter free (FFF) beams in a volumetric modulated arc therapy (VMAT) of cervical cancer patients with pelvic lymph node metastasis.

2.0 Materials and Method

An Elekta Versa HD linear accelerator (manufactured and installed in 2017) which produces photon and electron beams of various energies and have the ability to perform VMAT treatment was used. The linac has 160 multileaf collimator. The photon beam energies used for this study were conventional 6 MV and 6 MV flattening filter free (FFF).

A 2014 Delta4 phantom from ScandiDos (Sweden) was also used.Delta4 has a resolution of 50 nGy and it measures the dose with high density in the high gradient zone.

The study involved the use of VMAT plans for fifteen cervical cancer patients with pelvic lymph node metastases. VMAT plans for both 6 MV and flattening filter free beams were created for each patient using the RayStation treatment planning system (RaySearch Laboratories AB Sweden) giving a total of thirty plans for the fifteen patients. Two treatment arcs were used to create each plan. Radiation dose constraints for the primary tumour and lymph node volumes were met for all treatment plans.

The Delta4 phantom was positioned on the treatment couch and the treatment setup lasers were well aligned at its isocenter. The VMAT plans were then delivered on the phantom and dose differences between the measured and calculated plans were recorded at each measured site on the phantom. The gamma pass rates were calculated by the Delta4 software.

The clinical criteria for the pass rate was a gamma pass rate of at least 90% with a dose deviation of less than 3% and 3mm. This is based on protocol used in the department. Gamma pass rates of 90% or more were considered successful. Gamma pass rates below 90% were deemed to have failed. If the 3 % / 3mm requirement is met for each measured point, the local gamma index (GI) is lower or equal to unity.

3.0 Results and Discussion

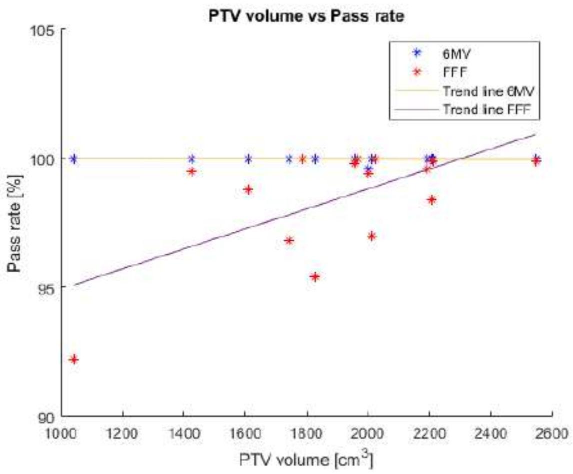

Figure 1: Scatter plot of PTV vs the gamma pass rate for 6 MV and FFF plans. Trendlines are included for both 6 MV and FFF plans.

The maximum PTV was 2546.02 cm^3 whereas the lowest PTV was 1040.70 cm^3.It can be observed in **Figure 1**that as the volume of the PTV increased, there was a constant gamma pass rate for the 6MV plans. Most individual 6MV plans had a 100% gamma rate as the planning target volume increased. This could be due to the fact that conventional beams with flattening filter are homogeneous and hence there is easy modulation of the multileaf collimators (MLCs) even as the planning target volume increased(3).

Although all flattening filter free (FFF) plans passed the gamma pass rate criteria of 90%, the 6 MV plans had a higher gamma pass rate than the corresponding flattening filter free plans. It was also observed by Kumar (4) that increasing PTV volume seems to decrease the total gamma pass rate for FFF plans.

The inhomogeneous nature of FFF beams generate inferior dose distribution and hence this could affect the pass rate for the FFF plans(5). The gamma pass rate for the FFF plans is scattered from **Figure 1.** For volumes between 1400 cm^3 and 2000 cm^3, it is observed that with increasing planning target volume, the pass rate increases to about 98% and then drops to 95%. Increasing the PTV volume decreased the individual pass rate for the FFF plans and this could be due to the fact that an increase in planning target volume makes the geometry of the PTV more complex and hence the modulation of the multileaf collimators in flattening filter free beams become more complex.

4.0 Conclusion

This study suggests that for larger volumes of PTV in cervical cancer patients with pelvic lymph node metastasis, it is advisable to use conventional 6 MV beams with flattening filter.

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