RETROSPECTIVE STUDY OF SEGMENT COMPLEXIBILITY WITH PLAN QUALITY IN HEAD AND NECK IMRT PLANS

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Abstract— **The aim of this study was to evaluate the impact of segment number on plan quality and delivery efficiency in intensity-modulated radiotherapy (IMRT) for head-and-neck (H&N) cancer, and to identify an optimal range balancing conformity and efficiency. A retrospective analysis was performed on 30 H&N IMRT plans with segment counts of 40, 70, and 100. Dosimetric parameters included conformity index (CI), target coverage (V100, V95), spinal cord maximum dose, and mean parotid doses. Monitor units (MU) were used as a surrogate for delivery efficiency. Correlation analysis and intergroup comparisons were performed to assess relationships between segment number, plan quality, and efficiency. Increasing segments from 40 to 70 improved CI by an average of 1.8% (0.924 → 0.952) and enhanced coverage with minimal MU increase. However, increasing from 70 to 100 segments did not improve CI (slight decrease of 0.7%) and offered no consistent benefit in organ-at-risk sparing, while increasing MU and plan complexity. For most Head & Neck IMRT cases, 60–75 segments represent an optimal range that balances plan quality and delivery efficiency. Segment counts beyond 70 offer minimal quality improvement and may unnecessarily increase complexity. These findings support a targeted approach to segment selection to optimize both clinical outcomes and resource utilization.**

Keywords— **IMRT, Segments, Conformity Index**

I. INTRODUCTION

Intensity Modulated Radiation Therapy is considered as one of the novel techniques in Radiotherapy for conformal treatment. The purpose of this study was to evaluate the number of segments for intensity-modulated (IMRT) treatments and their effects on the plan quality. The study retrospectively analyzed IMRT plans for 30 patients with head and neck cancer. In the context of Intensity Modulated Radiation Therapy (IMRT), segments are distinct sub-fields or portions of a larger radiation beam that are delivered sequentially to create a modulated intensity pattern across the treatment area. These segments are the building blocks of an IMRT treatment, allowing for the precise sculpting of the radiation dose to the tumor while protecting healthy tissues and organs [1]. Head and neck tumors have potential advantages from IMRT because of the complexity and concavity of the target volume and the proximity of radiosensitive organs at risk [2]. The major challenge is to spare the spinal cord and preserve the function of the parotid glands without compromising the dose to the target.

Selection of segment settings can affect the optimization of the dose in Planned Target Volume PTV, intensity modulation, complexity and delivery of plan. Increasing the number of segments can lead to unnecessary complications in plan implementation and increase in treatment time. [3-8]

II. MATERIALS AND METHODS

Case Selection and Dose Prescription

About thirty patients who were treated between June 2024 to July 2025 in Eden Medical Center, Dimapur, Nagaland with Head and Neck cancer were retrospectively selected. The general prescription dose for these patients was 44Gy in 22 fractions, i.e. 2Gy per fraction. Oncentra (v 4.3) was used for planning these IMRT plans. These cases were selected keeping in mind the concavity and complexity of targets for IMRT planning.

Simulation

The CT images of the head and neck region was acquired using Somatom Emotion CT (Seimens AG Germany) with a slice thickness of 3 mm. Patients were immobilized in the course of CT scans acquisitions using a head support with a three clamps immobilizing mask (Posicast Precuts, Civco medical solutions) covering the head and the thorax secured to a carbon fiber plate. The CT datasets were then transferred to the Oncentra treatment planning system (v 4.3) for contouring.

Planning

All dynamic IMRT plans were designed and optimized using the Treatment planning Systems (TPS) Oncentra (v 4.3, Nucletron BV, Veenendal, the Netherlands). The Collapsed Cone algorithm was adapted to calculate the dose distribution, and the plan was delivered utilizing the Elekta Platform (Sweden) linear accelerator with 6 MV X-rays and an upper jaw replacement configuration type MLC with 40 leaf pairs of 1 cm resolution at isocenter. In each plan, seven evenly distributed coplanar radiation fields were used, and the angles were set to 0°, 51°, 102°, 153°, 204°, 253° and 304°. In this study, three representative segment numbers (40, 70, and 100) were selected to capture low, intermediate, and high modulation regimes. A segment number of 40 was chosen as a baseline corresponding to limited modulation, while 70 represents an intermediate level commonly used in clinical practice and close to the default optimization settings of the treatment planning system. A segment number of 100 was selected to represent highly modulated plans approaching the upper practical limit, where diminishing returns are expected.

Intermediate segment values (e.g., 50, 60, or 80) were not explicitly evaluated because the relationship between segment number and plan quality is known to be gradual and monotonic. The selected segment numbers therefore adequately characterize the effect of increasing segmentation while maintaining a manageable and clinically relevant comparison. The window of the segmentation settings is shown in Figure 1. Following physical optimization parameters: target margin, tight (0.5 cm); fluence matrix X resolution 0.6 cm and inhomogeneity correction was on. The dose calculation grid size was 3 mm.

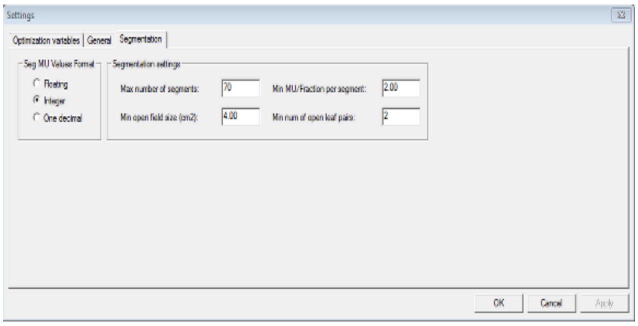

Figure 1: Window of the segmentation settings in the Oncentra TPS (v 4.3).

The segmentation algorithm tries to reproduce the ideal fluence distributions, beam by beam, as closely as possible by positioning the MLC leaves and optimizing the MU/segment. The software also aims to create efficient segments with the default value of 70 segments for 7 beams. To avoid issues with leaf movement and small MLCs, which can lead to issues like noise in the plan or increased treatment time, we set the minimum segment size to 4 cm^2 for all the plans shown in Figure 1. The intensity of each segment is defined by the MUs assigned to it. The minimum MUs assigned per segment was 2 MU.

The IMRT optimization was performed on the PTV with a goal dose of 44 Gy to at least 95% of the target volume. The minimum and maximum Dose Volume Objectives (DVO) for the PTV were set at 44 Gy to 100% of the target volume and 47Gy representing 107% of prescription dose to 0.0% of the target volume respectively. The doses delivered to the OARs were kept at tolerable levels according to RTOG protocol.

The weight for the DVO of the PTV, OARs and the external structure were primarily set to 1 (Figure 2). However, as optimization went on, the weights and number of segments were slightly adapted in some cases to produce a better result.

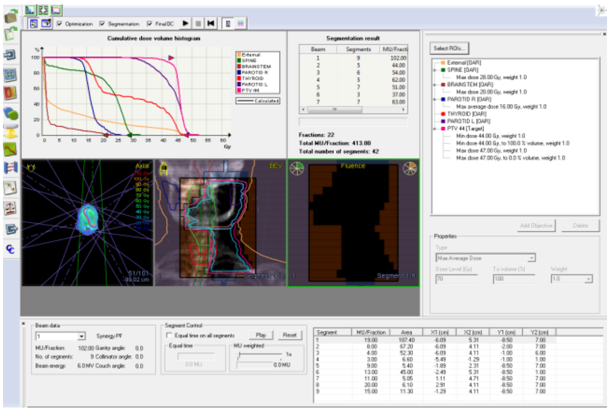

Figure 2: Window showing the objectives definition for PTV and the OARs along with DVH curves and the fluence.

Evaluation of plan quality

As a measure of how good the DVO was achieved, the conformity Index was used as a parameter to evaluate the plan. V_{RI} is the volume of the target area included in the prescription isodose, and TV is the target volume.

$$CI = V_{PI}/\, TV \qquad (1)$$

According to the RTOG guidelines, this ratio should be between 1 and 2, and if achieved, there will be no deviation from protocol. Less than 1, but greater than 0.9 can be called minor deviation while less than 0.9 is categorized as a major deviation. CI between 2 and 2.5 are classified as minor deviations, and greater than 2.5 is classified as a major acceptable deviation. An RTOG CI equal to 1 corresponds to perfect conformation. CI greater than 1 shows that the irradiated volume is greater than the Target volume and includes healthy tissues. If the CI is less than 1, the Target Volume is only partially irradiated [9].

In addition, the MUs and the number of segments were recorded to evaluate and compare the execution efficiency of each group of IMRT plans. For the OAR the average dose to the parotid glands and the maximum dose D_{max} to the spinal cord were recorded.

Data Analysis

The statistical test ANOVA (Analysis of Variance) was used to check if there is any overall statistically significant difference in CI across all the segment groups. When the overall ANOVA was significant, post-hoc pairwise comparisons were conducted using Turkey's Honestly Significant Difference (HSD) test.

Dosimetric validation of the plans was beyond the scope of this planning study and was therefore not included in the manuscript.

III. RESULTS

Monitor Units (MUs)

Average MUs increase with more segments. This is expected — more segments generally mean more modulation and slightly longer delivery.

OAR Dose

OAR Spinal cord dose was fairly stable across segments (~33 Gy mean), with SD of ~0.679 between number of segments. Left & Right parotid mean doses are similar across segment counts (~17–18 Gy) with SD of ~1.361 between no. of segments, showing no strong correlation with segment number (Figure 3)..

Table 1: Mean and standard deviations of all patients for different parameters.

	No. of Segments					
	70		100		40	
	Mean	SD	Mean	SD	Mean	SD
CI	0.952	0.012	0.9556	0.0158	0.9248	0.039
MU	572.9	99	592.06	104.89	521.6	85.15
SP	33.42	4.24	34.305	9.1762	32.928	5.388
PA L	18.03	8.78	17.33	8.2	17.43	8.250
PA R	20.02	10.56	16.72	7.85	17.25	7.82

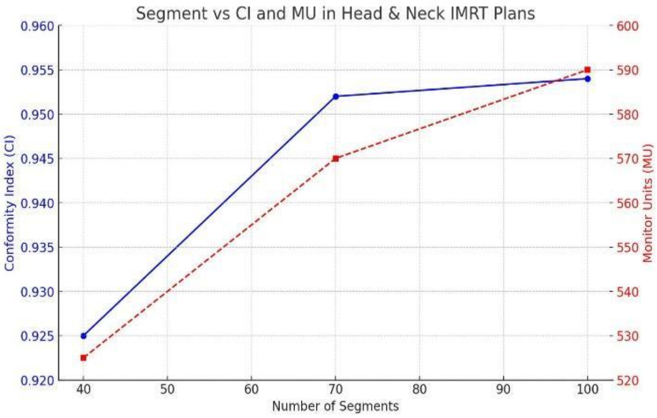

Figure 3: Variation of CI and MU with segment numbers

Conformity Index

The Best average CI was recorded to be at 70 segments (~0.952). There is a slight drop at 100 segments (~0.945) and a more noticeable drop at 40 segments (~0.934). Table 1 Indicates diminishing returns beyond 70 which gives us an impression that more segments do not necessarily improve conformity.

Table 2: Comparison of segments (40, 70, 100) using Bonferroni Test

Segment	Contrast	Std. Err.	Bonferrroni t	P>|t|	Bonferroni [95% conf. Interval]	
70 vs 40	.0181306	.0071369	2.54	0.039	.0007082	.0355529
100 vs 40	.0109396	.0071369	1.53	0.387	-0.0064827	.028362
100 vs 70	-.0071909	.0071369	-1.01	0.949	-0.246132	0.0102314

Analysis of variance indicated a statistically significant difference in conformity index (CI) across the segment groups ($p<0.05$). Post hoc pairwise testing demonstrated that only significant difference was observed between the segment 70 and segment 40 group($p<0.05$).

IV. DISCUSSION

In our findings, segment 70 and segment 40 differ significantly in CI suggesting that increasing the number of segments beyond 40 can meaningfully influence conformity. However, additional increment above 70 did not yield further improvements, indicating a potential plateau effect. This aligns with previous reports that conformity gains from increasing segments are most notable up to a certain threshold, after which treatment efficiency and monitor unit burden must also be considered. Thus, there is a trade-off between the number of segments, conformity and the total MUs to be considered while planning. More segments with smaller sizes allow for greater precision in shaping the dose and better conformity to the target. However, smaller segments and a larger number of them can increase the total number of monitor units and the overall treatment time. Thus, a minimum segment size is crucial for plan delivery. For the OARs, no significant differences could be observed with regard to changes in the number of segments.

In some patients, the parotids were completely inside the target volume and hence the standard variation is seen to be quite high since low weightage for volumetric constraint was given to avoid under coverage.

CONCLUSION

This work gave us an overall idea that giving 70 segments for 7 beams produced an optimum plan quality and the necessity of increasing or decreasing the segments is not required. Higher segments do not seem to improve conformity. Instead, it increases the risk of MLC movements. Although plan verification was not performed, the issue with the MLC is certain with the increase in the number of segments making the plan much more complicated. A simple yet efficient and precise plan is always opted for all the plans rather than a complex one.

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