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ORIGINAL ARTICLE

Radiology

Utilizing the VMAT Technique for Treating Head and Neck Cancer with Fixed Collimator Jaws

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Abstract

Radiotherapy is the preferred option for early-stage head and neck cancer (HNC), especially in cases where surgery is not feasible or for patients with other co-morbidities. Head and neck radiation therapy is still improving for better management and control of the cancer. The volumetric modulated arc therapy (VMAT) technique ensures precise and accurate treatment delivery. This study presents a clinical comparison between plans with fixed collimator jaws and free collimator jaws generated head-and-neck VMAT plans made for clinical use. The study involved 10 patients with HNC, each receiving a dose prescription of 54.00 Gy and 63.00 Gy, administered in 30 fractions with daily doses of 1.8 Gy delivered to planning target volume (PTV) and 2.1 Gy delivered to boost target volume (BTV), respectively. All patients underwent treatment using the Electa Infinity linear accelerator, with the treatment plan generated using the Monaco treatment planning system. In our study, all cases were treated using two complete arcs, with one arc following a Gantry heading CW-180.1°-180° and the opposite arc following a Gantry heading CCW-180°-180.1°. Our findings indicate that employing the VMAT technique with one side of the collimator jaws fixed and the other side free, and in the opposite order, leads to a reduction of approximately 8-10 Gy in the maximum dose to the spine for all patients, compared to the collimator method, where both collimator jaws are free.(**International Journal of Biomedicine. 2024;14(3):474-477.**)

Keywords: head and neck cancer • radiotherapy • collimator • spinal cord

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Abbreviations

BTV, boost target volume; **CW**, clockwise; **CCW**, counterclockwise; **HNC**, head and neck cancer; **MU**, monitor units; **MLC**, multileaf collimator; **PTV**, planning target volume; **VMAT**, volumetric modulated arc therapy.

Introduction

The treatment modality for head and neck cancer (HNC) depends on several factors, including the type of tumor, size, stage, location, and the feasibility of performing surgery.[1-5] Radiotherapy emerges as the optimal choice for early-stage HNC, particularly in cases where surgery is not a viable option due to tumor location or the presence of other co-morbidities. For advanced-stage tumors, a comprehensive treatment approach involving surgery, radiotherapy, and chemotherapy is recommended.[6] In the context of radiation therapy, planning for the head and neck region poses considerable challenges due to the potential dose exposure of critical organs, namely the spinal cord and parotid glands.[7]

The volumetric modulated arc therapy (VMAT) technique ensures accurate treatment, even when the prescription dose is 72 Gy.[8] With the VMAT technique, the maximum dose received by the spinal cord does not surpass predefined constraints; typically, the accepted maximum dose is up to 42 Gy on average.[8] However, can we further protect the spinal cord with even lower doses? Our research demonstrates that, even with high-dose prescriptions, the dose to the spinal cord can be limited to, or less than, 30 Gy.[9]

This treatment technique offers the possibility that if, in future years, the patient requires irradiation in regions close to the spinal cord, the dose in the spine does not exceed the allowed limit of 42-45 Gy.[10,11] In situations where the contour of the planning target volume (PTV) is extensive, the opening and closing of the multileaf collimator (MLC) cannot be executed as swiftly in the collimator in relation to the dose emanating from the gamma-ray radiation source.

Typically, VMAT treatments are conducted with one or two complete rotations (with two full arcs), starting from the gantry position of 180.1°-180°in the clockwise (CW) direction or in the opposite direction of 180°-180.1° as counterclockwise (CCW).[12]

If the isocenter of the fields falls within the mandibular bone, marking the transition from the head to the neck, the MLC issue becomes apparent in the directions 0° leaves X1 and X2. This is due to the considerable distance from the beginning of the PTV on the left side up to the end on the right side.[13, 14]

In this study, we employed the VMAT technique [15] with two full arcs in both CW and CCW directions. Specifically, during the CW direction, we maintained the collimator jaw X1 fixed at approximately 1-2 cm from the center and subsequently turned the fixed collimator jaw X2 by a similar distance. This method is illustrated in Figures 1 and 2.

For the Monaco treatment planning system, we estimate X1 as Length 1 and X2 as Length 2. Consequently, X1 + X2 equals XOR Length 1 + Length 2 equals Length in both the CW and CCW directions.

With both techniques, treatment plans were made for 10 patients, so there are 10 treatment plans with the fixed collimator technique, and the same were compared with the free collimator technique.

The results are given in Table 1. In all 10 patients, the treatment plans consistently demonstrate that the maximum dose to the spine is 8-10 Gy lower compared to cases where jaw X1 is fixed in one Arc from 180.1°-180°, extending no further than 1cm from the center. Similarly, in counter rotation, jaw X2 is kept fixed, no further than 1cm from the center.

While employing this method results in an increased number of monitor units (MU) for the defined dose, the associated decrease in dose to organs at risk is deemed acceptable, aligning with the primary objective of our study – dose reduction. [16-18]

Table 1.

The values of Jaws X1 and X2 opened automatically from the isocenter, and the values of X1 and X2 were fixed. The corresponding doses to the spinal cord and MU for each case are shown.

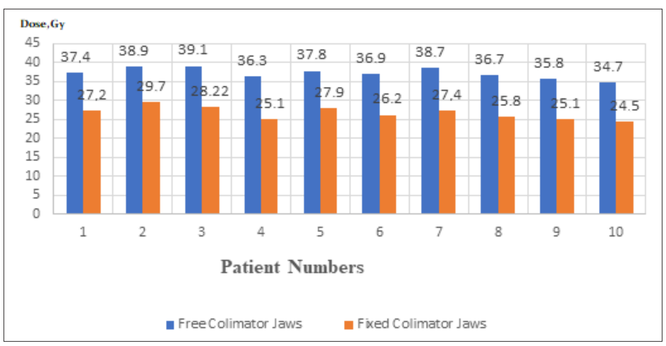
	Jasw X1 and X2 are free, approximately equidistant from the isocenter						Jaws X1 and X2 are fixed near isocenter					
	Total Dose 30 Fx*1.8Gy/2.1 Gy = 54/63 Gy											
Nr. of patient	Gentry	X cm	X1 cm	X2 cm	MU	Dmax Gy/S. Cord	Gentry	X cm	X1 cm	X2 cm	MU	Dmax Gy/S. Cord
1	CW	20.4	10.5	9.9	242	37.4	CW	12.5	10.5	2,0	362	27.2
	CCW		9.9	10.5	235		CCW		2.5	10.5	349	
2	CW	18.2	9	9.2	159	38.9	CW	10.3	9	1,3	329	29.7
	CCW		9.2	9	161		CCW		1.3	9	332	
3	CW	21.8	11	10.8	214	39.1	CW	12.3	11	1.3	382	28.22
	CCW		10.8	11	226		CCW		1.3	11	367	
4	CW	20	10	10	253	36.3	CW	11	10	1	335	25.1
	CCW		10	10	251		CCW		1	10	335	
5	CW	22	11	11	284	37.8	CW	12.8	11	1.8	398	27.9
	CCW		11	11	293		CCW		1.8	11	403	
6	CW	21.4	10.4	11	301	36.9	CW	11.9	10.4	1.5	403	26.2
	CCW		11	10.4	304		CCW		1.5	10.4	408	
7	CW	23.3	12	11.3	287	38.7	CW	13	12	1	377	27.4
	CCW		11.3	12	293		CCW		1	11	375	
8	CW	21.6	10.9	10.7	218	36.7	CW	12.9	10.9	2	244	25.8
	CCW		10.7	10.9	224		CCW		2	10.9	234	
9	CW	23.9	11.9	12	234	35.8	CW	12.9	11.9	1	298	25.1
	CCW		12	11.9	225		CCW		1	11.9	309	
10	CW	22.5	11	11.5	254	34.7	CW	12	11.5	0.5	303	24.5
	CCW		11.5	11	250		CCW		0.5	11.5	305	

Materials and Methods

The study involved 10 patients with HNC, each receiving a dose prescription of 54.00 Gy and 63.00 Gy, administered in 30 fractions with daily doses of 1.8 Gy delivered to planning target volume (PTV) and 2.1 Gy delivered to boost target volume (BTV), respectively. An important criterion for case selection was the matching of the PTV and the boost volume, with efforts made to ensure nearly identical volumes in each clinical case. All patients underwent treatment using the Electa Infinity linear accelerator, employing the Monaco treatment planning system. Before treatment, all cases underwent verification by EPIbeam and IBA Matrix Resolution and successfully passed the quality assessment control.

Results

The treatment was administered up to a total dose of 54Gy-63Gy. The values of MU for the two cases are presented in Table 1, along with the dimensions of jaws (X1, X2, and their sum, X1+X2). Of utmost significance is the total dose to the spine. In Graph 1, we present a comparison between the maximum dose scenarios: the first, where one of the collimator jaws is fixed and the other is free and the second, where both collimator jaws on both sides are free. The Graph 1 illustrates that the lowest dose is observed when one of the collimator jaw is fixed while the other is free.



Graph 1. *Comparison of the spine dose for the free collimator jaws and fixed collimator jaws method.*

In scenarios where the jaws are automatically opened, the multileaf collimator experiences a longer path for both opening and closing over the PTV segment. Conversely, the opposite holds true when the jaws are fixed. Referring to Table 1, it is evident that in no instance, for the total dose in Gy, the dose in the spinal cord cannot remain below 34.7 Gy when the collimator jaws are automatically fully opened over the PTV. In cases with fixed collimator jaws, the dose to the spine consistently remains below or at a maximum of 30 Gy, with no instances exceeding this threshold.

Figure 1a illustrates the gantry rotation in the CW direction, spanning from 180.1° to 180°. In this configuration, Jaw Length 1 (X1) remains fixed, positioned 1 cm away from the isocenter, while Jaw Length 2 (X2) exceeds the dimension of the PTV on that side. In Figure 1b, the reverse is applied. During the CCW rotation or 180°-180.1°, Jaw Length 2 (X2) is fixed at 1 cm from the center, with the value of X1 larger than the PTV.

Figure 2 shows isodoses from the Monaco treatment planning system. Figure 2 a depicts a scenario where the values of X1 and X2 are not fixed jaws, i.e., they exceed the PTV dimension in both CW and CCW rotations. In Figure 2a, with free collimator jaws, the spine is surrounded by all isodoses. Therefore, the Dmax in the spinal cord of this method is approximately 10 Gy more than plans made with a fixed collimator. In Figure 2 b, i.e., with fixed collimator jaws, all the isodoses appear very dense and much further from the spine, i.e., very close to the PTV.

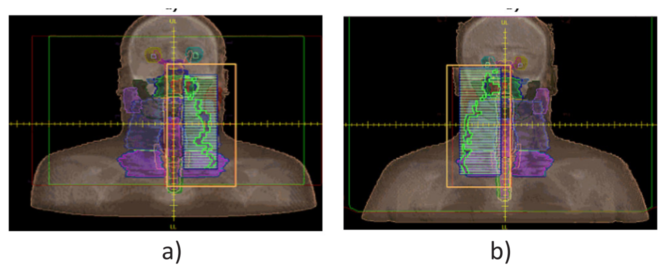


Figure 1. *Treatment with fixed jaws. a) Length 1 = 1cm and b) Length 2 = 1 cm*

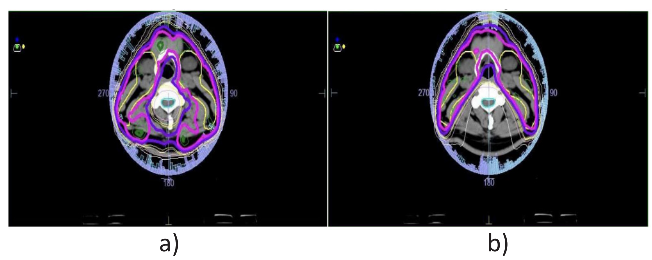


Figure 2. *Difference of the isodose lines: a) plan with free collimator jaws and b) plan with fixed collimator jaws*

Conclusion

The results unequivocally indicate that the most effective approach to safeguard the spine, ensuring it does not surpass the maximum dose of 30 Gy in tumors of the head and neck region, involves keeping jaw X1 smaller than jaw X2 during the gantry's rotation in the CW direction (X1 ≤ 2 cm). Conversely, in the CCW direction, fixing jaw X2 from the isocenter (X2 ≤ 2 cm) achieves optimal protection. Implementing the fixed jaw method yields a much improved and denser isodose gradient ranging from 60-95%, enhancing the PTV coverage. It is worth noting that the treatment time will slightly increase for each gantry rotation in both CW and CCW directions. This is attributed to the greater number of MU, which directly influences the gantry rotation time. We suggest or prefer that the fixed collimator technique be used in cases where BTV is close to the spine or in cases where the patient needs to be irradiated one more time after a few months or a year of disease recurrence.

Competing Interests

The authors declare that they have no competing interests.

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