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Influence Of Monitor Units in the Intermediate-risk Group for Prostate Cancer Using Sliding Window and Step-and-Shoot Intensity Modulated Radiation Therapy Techniques

Karim A. El-Maraghy[1], Ehab M. Attalla[2], Wahib M. Attiah[3]
[1] *Radiation Physics Department, Oncology and Hematology Hospital, Maadi Armed Forces Medical Compound, Cairo, Egypt*
[2] *Radiotherapy & Nuclear Medicine Department, National Cancer Institute, Cairo University, Cairo, Egypt*
[3] *Physics Department, Faculty of Science, Suez Canal University, Ismailia, Egypt*
Corresponding Author: Karim A. El-Maraghy

Abstract: *This paper was carried out to studythe efficiency of Monitor Units (MUs) between Intensity Modulated Radiation Therapy (IMRT)Step-and-Shoot(SS) and Sliding Window(SW) modes.Fifty-onepatients with localized prostate carcinoma wereplannedby optimization process of treatment planning system. Patients had two planning target volumes (PTVs) for the primary and boost plans.*
Target coverage was evaluated with parameters of the mean target dose (D_{mean}), the maximum target dose (D_{max}), while its dose distribution and conformality was evaluated with several different indices such as Conformity Index (CI), the Homogeneity Index (HI), quality of coverage, Lesion Coverage Factor (LCF),Uniformity Index (UI), and Conformation Number (CN).Also, the treatment efficiency was assessed using mean values for monitor unit/ fraction (MU/fx), MU for lowest&highest number of segments,MU/segment,MU/cGy (modulation factor),andtreatment delivery time. The results were compared and tested by Statistical Package of Social Sciences (SPSS v25.0) with statistical significance level set at $p < 0.05$. In conclusion, SW mode showed a better plan quality & shorter treatment delivery time than SS mode despite of the higher values in its treatment efficiency.Whereas theSS mode showedbetter results for Organs at Risk (OARs).

Keywords: *Intensity Modulated Radiation Therapy, Monitor Units, Sliding Window, Step-and-Shoot,Prostate Cancer.*

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I. Introduction

Duringinvestigating complex intensity maps with a multileafcollimator (MLC), IMRT is able to deliver high conformal dose distributions tofit atumor well and spare critical organs and normal tissues[1]. IMRT treatments can be delivered with the MLC operating in one of two basic modes: Segmented MLC (SMLC) mode, often referred to as the Step-and-Shoot mode (SS), in which the beam holds while the leaves move;whereasDynamic MLC (DMLC) mode, also referred to as the sliding window mode (SW), in which the beam is continuously on while the leaves move[2,3].

For treatment of prostate cancer, IMRT has become an optimal technique, given a geometric relationship of the volumes for the target (increasing conformity) andnon-target (decreasing dosage) [4]. However, a negative aspectof IMRTis the number of MUs and treatment delivery time increases (double or more) for complicated plans in comparison to conventional techniques. This results in more radiation leakage and internal scatter which increases the integral dose to the patient's body. Subsequently a greater potential risk of secondary cancers (by a factor of 1.2 to 8.0)[5,6].

Increased treatment delivery time causes an increase in overalltreatment sessiontime. InSSmode, the treatment time is governed by thenumber of MLC segments. The proportionbetween minimizingirradiation time (number of MU) and the number ofMLC segments has been previouslydiscussed[7,8]. In this article, the influence of thenumber of MUs (which is proportional tothe irradiation time at constant dose rate (MU/min)[9]) will be studiedfor the plan quality, treatment efficiency and non-target tissue dosimetric.

II. Materials And Methods

2.1 Patient Selection, Target AndCritical Volumes Delineation

Fifty-one patients have been selected for prostate cancer treatments using the IMRT technique.All the patients were intermediate-risk group (Prostate-Specific Antigen (PSA)=10 - 20 ng/mL, Gleason score =7, and in stage T2b-T2c).For all patients, plans were run on CT scans acquired with 5 mm slice spacing in the entire treatment area set in supine position.The two Clinical Target Volumes (CTV_p and CTV_b) and OARwere delineated by radiation oncologist according to Radiation Therapy Oncology Group (RTOG) guidelines [10]. CTV_p included the prostate and seminal vesicles, while CTV_bincluded prostate only. The planning target volume PTV was generated by adding a 0.8 cm margin to the CTV in all directions, except for posteriorly,where a 0.5 cm margin was used and defined by PTV_p for primary plan and PTV_b for boost plan. The relevant OAR structures were the rectum, the bladder, the left femoral head, the right femoral head, and the penile bulb.

2.2 Dose Prescription, Planning AndTechniques

IMRT plans were generated following specific planning rules, using Eclipse® (version 11.0, Varian medical systems, Palo Alto, CA),Treatment Planning System (TPS) in a Varian machine, Clinac DMX® with On-Board Imager(OBI) option and 80-leaf millennium multileaf collimator (MLC). The Anisotropic Analytical Algorithm (AAA) dose calculation algorithm was usedwith a computation grid size of 2.5 mm. The inverse plan Dose Volume Optimizer (DVO version 11.0.31) was used to optimize IMRT plans. This optimization algorithm is used to determine the combination of field shapes and segmentweightswhich best approximate the desired dose distribution in the inverse planning problem. The total prescription dose was 81Gywith 1.8Gy/fractionduring 5 fractions/week. The mean dose delivery was planned for two phases using IMRT techniques; the primary plan was 50.4 Gy given to PTV_p in 28 fractions, while the boost plan was30.6Gygiven to PTV_b in 17 fractions. The IMRT planconsists of seven coplanar non-opposed fields arrangement of 0°, 51°, 103°, 154°, 206°, 257°, and 308° gantry angles with delivery type sliding window, or multiple static segment with intensity levels 10[11] for all fields in the Leaf Motion Calculator (LMC). Using 6 MV photon beams and a beam rate of 400 MU/min as the upper limit[12].

Normal tissue doses, in general, were limited using the Varian Eclipse Normal Tissue Objective option during optimization, which attempts to achieve a certain dose falloff around the PTV based on a user-set parameter. Normal tissue doses for all cases were set to fall from 105% to 60% of the prescription dose starting 3 mm from the PTV, with a fall-off rate of 1. This fall-off parameter is a unit less value that affects the character of an inverse exponential dose fall-off.It may be disputable whether to perform two optimization processes ‑one for SS and the other for SW. A separate calculation has been applied for each technique by keeping the machine and optimization parameters identicalduring the initiation[13].Plans aimed at achieving PTV coverage (95% of each PTV covered by at least 95% of the prescribed dose) without transgressing OAR sparing (rectum, bladder, femoral heads, penile bulb) and hotspots ≤+107% as recommended by ICRU [14,15].

2.3 Plan Comparative Evaluation

For comparisons between different IMRT techniques, plan sum was created for all phases. The mean and max. dose of structures in plans were compared using the Dose Volume Histogram (DVH) curve.

2.4 Plan Quality

To evaluate the compliance with the dosimetric basics and objectives assigned, all IMRT plans (SS and SW) were approach to keep the same mean dose to the PTV at the two phases. The plan quality evaluation with respect to the PTV coverage and OARs sparing are reported in Table 1. In the table, the Conformity Index (CI) was calculated as[16] the ratio between the volume receiving at least 95% of the prescribed dose and the volume of PTV ($CI_{95\%} = V_{95\%} / V_{PTV}$),and the Homogeneity Index (HI) was calculated as[17]the difference between the near-maximum and near-minimum dose normalized to the dose prescription ($HI = D_{5\%} - D_{95\%}/D_P$). The values of CI and HI ideally should be unity and zero, respectively. A greater CI and HI indicates lower conformity and higher heterogeneity (homogeneity decreases), respectively.

Conformity of high dose around the target has been evaluated by Conformation number (CN) as described by Van't Riet et al. (1997), because it took into account irradiation of the target volume and irradiation of healthy tissues [18]. This number was defined as follows:

$$\mathrm{CN} = \frac{\mathrm{TV}_{95} \times \mathrm{TV}_{95}}{\mathrm{V}_{95} \times \mathrm{TV}}$$

Where TV_{95} is the Target Volume (TV) covered by the 95% isodose volume (V_{95}).

Quality of coverage was defined as[19] the ratio between the minimum isodose surrounding the target and the reference isodose (Quality of coverage = I_{min}/RI), while Lesion Coverage Factor (LCF)was defined as[19] the ratio between the target volume covered by reference isodose and thetarget volume (LCF= TV_{RI} /

TV), and Uniformity Index was defined as the ratio between the minimum dose delivered to 5% volume of PTV and the minimum dose delivered to 95% volume of PTV ($UI = D_{5\%} / D_{95\%}$).

2.5 Treatment Efficiency

Monitor unit/ fraction (MU/fx), the number of segments(highest, lowest, and total) and its MUs, MU/segment, the number of MU/cGy (modulation factor), and treatment delivery time had been investigated and analyzed for both techniques.

Modulation factor is defined as the ratio of doses in the dynamic and corresponding open fields. This factor is estimated based on dose calculations made within our TPS[20].

The treatment delivery time is measured as the time taken fromthe first beam is turned on until the last beamis turned off. It is the beam-on time (from Clinac console software version 9.01)per field, plus the time that the gantry took to rotate between successive fields, plus a parameter "Delta time" which taken into account the time for mode up, data transfer of the MLC delivery files, error in the estimated rotation time, and operator reaction time for the console key switch & pressing motion enable of dedicated keyboard. The "Delta time" parameter was not added for the first beam because the data transfer and mode up happened before the first beam-on."Delta time" was determined (from 10prostate IMRT patients delivered at our center for each mode) as the difference between the actual delivery time as recorded by the system and the beam-on time from Clinac console software at 400 MU/min plus gantry rotation CW between successive fields from206° to 154°/min[21,22]. Note that for SS mode fields, there are two measuresbeam-on timefor theClinac console software;the firstincludesthe radiation beam-on timeonly (the time holds when the beam holds), while the second includesthe radiation beam-on time plus thebeam hold time.The latterwas performed fortreatment delivery time.

2.6 Organs AtRisk (OARs), Volume Receiving 2 GyAnd 5 Gy, And Integral Dose (ID)

The mean dose (D_{mean}),the max. dose (D_{max}) to nontarget tissues, and the percentage volumes of each patient receiving 2 Gy (V_{2Gy}) and 5 Gy (V_{5Gy}) were compared in this study as depicted inTable3.

The integral dose was defined as[23] the total amount of energy absorbed by a patient body or an organ during radiation exposure. The product of the mass tissue irradiated and the absorbed dose.ID= D. m = D.ρ.V (Gy.Kg), Where D, m, ρ, and V are average organ dose, organ mass,average organ density, and organ volume, respectively. For simplicity aconstant of average organ densityρ= 1 g/cm^3 was assumed for all pelvic structures.Therefore, the integral dose was calculated for the nontarget tissues as:

ID = D.V (Gy. cc).

2.7 Statistical Analyses

The data was compared by the SPSS v25.0 (SPSS Inc., Chicago, IL). By using a paired two-tailed Student's t-test to determine whether there is any statistically significant difference in any of the parameters examined with statistical significance p-values < 0.05.

III. Results

The size of PTV_p and PTV_b varied considerably among patients under this study. Also, bladder and rectumvolumes vary among patients depending on their filling i.e. patient's preparation. The amount of bladder and rectum receiving higher doses equal to PTV depends on their volumes. When bladder and rectum volumes are small, their distance from the PTV decreases. Therefore, their overlapped volumes increase resulting in a greater percentage in high dose areas and vice versa. The mean volumes and the volume ranges of PTV_p and PTV_b were 166.36±47.42 (range 90.1-362.5) cm^3 and 138.88±45.45 (range 71.7-322.6) cm^3, respectively. Whilst in OAR, the rectum, bladder, left femoral head, right femoral head, and penile bulb were 71.93±33.72 (range 29-197.8) cm^3, 166.09±137.04 (range 32.1-836.4) cm^3 ,169.8±20.29 (range 123.1-207.5) cm^3, 169.2±21.03 (range 125.3-214.7) cm^3 and 3.06±1.25 (range 1.0-5.5) cm^3, respectively.

Statistically significant difference was observed in all the plan quality and treatment efficiency variables between SS and SW techniques, depicted in tables1 and 2, except for quality of coverage and CN in the two phases; CI and D_{mean} to PTV_pin phase 1; D_{mean} to PTV_b for phase 2; and D_{mean} to PTVs in the sum plans.

Also the dosimetric results between SS and SW of IMRT techniques for the non-target tissues, as depicted in table 3, werestatistically significant in all the nontarget variables, except for right & left femoral heads, D_{mean} and ID of penile bulb in the phase1; rectum, D_{mean} and ID of bladder, and D_{max} of right & left femoral heads in phase 2; and D_{max} of left femoral head, D_{mean} and ID of penile bulb in the sum plans.

In the two modes of plans, the total MUs differed clearly, see MU/fxas depictedin table 2. The average total number of MU for SW is higher than SS, due to a continuous dose delivered through MLC movement,as shown in figure 1.

IMRT treatment plan contains seven fields(beam orientations)which are delivered as SS or SW. Each SS field contains 18–52 segments (total 148-240 segments) and SW field contains76-166 control points (total 662-996 control points) were obtained after automatic optimization process with no plan normalization mode. The fraction delivery time of SStooklonger than SW (less than a minute)as shown in figure 1,this is due to thetime taken for the beam hold when theMLC formalizesa new shape (beam hold time was on average 6.6 ± 0.68 per field as a result from Clinac console software). As a result, the totaltreatment delivery time for IMRT SS plans was on average5.07 minin comparison to 4.56 min for SW.The time that the gantry took to rotate between two successive fields ≤ 11.8 s.

The average "Delta time" value per IMRT field was determined to be 10.5 ± 0.4, and 9.92 ± 0.3 seconds per field based on 10 prostate IMRT patients for primary and boost (SW) IMRT plans, while it was 10.8 ± 0.4, and 10.7 ± 0.5 seconds per beam based on 10 prostate IMRT patients for primary and boost (SS) IMRT plans, respectively.

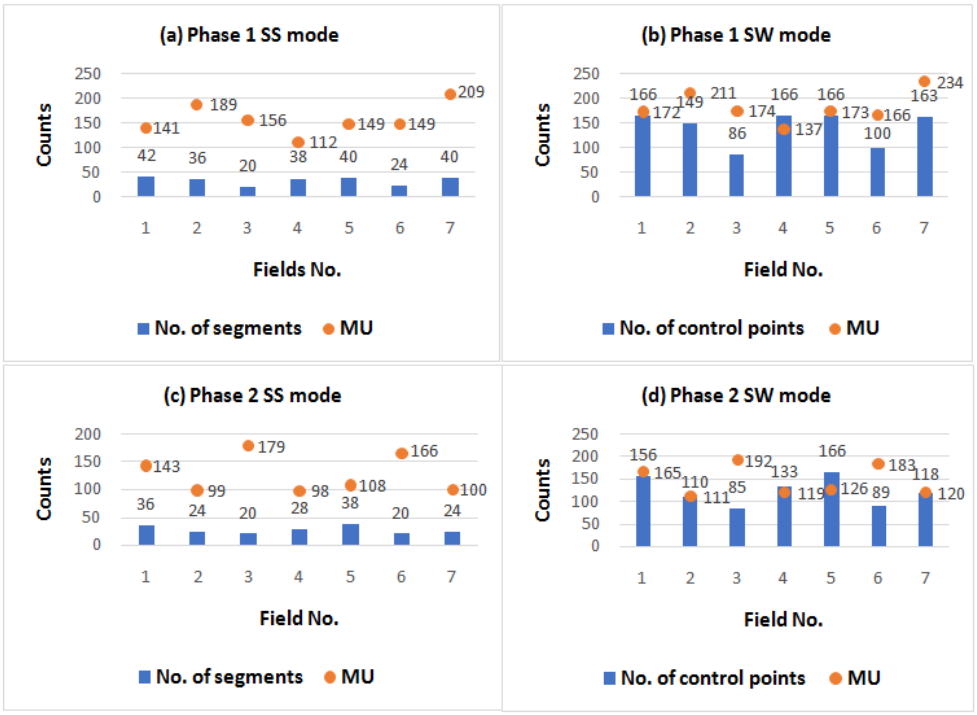


Figure 1: The MUs and number of segments (or control points) of each field (from field 1 at zero gantry angleascending to field 7 at 308° gantry angle) for one patient as an example of IMRT dose delivery in(a) phase 1 SS mode, (b) phase 1 SW mode, (c) phase 2 SS mode, and (d) phase 2 SW mode. The treatment delivery time for that patient was (a)361 s, (b) 318 s, (c) 318 s, and (d) 279 s.

The average value of MU/cGy, which represents the degree of modulation, is shown in table 2.The difference in MU/cGy between SS and SW showed the difference in the modulation degree because the technique is the same [24], as shown in figure 2. MU/segment isthe number of MUs contributedper segment towards the target's region of interest (target voxel) i.e. the delivered dose to the target voxels by each segment may also be quite different[25].In other words, the dose per segment varies inversely to the number of total segments. This is represented by MU for the lowest and highestnumber ofsegmentsas shown in table 2 and figure 3.

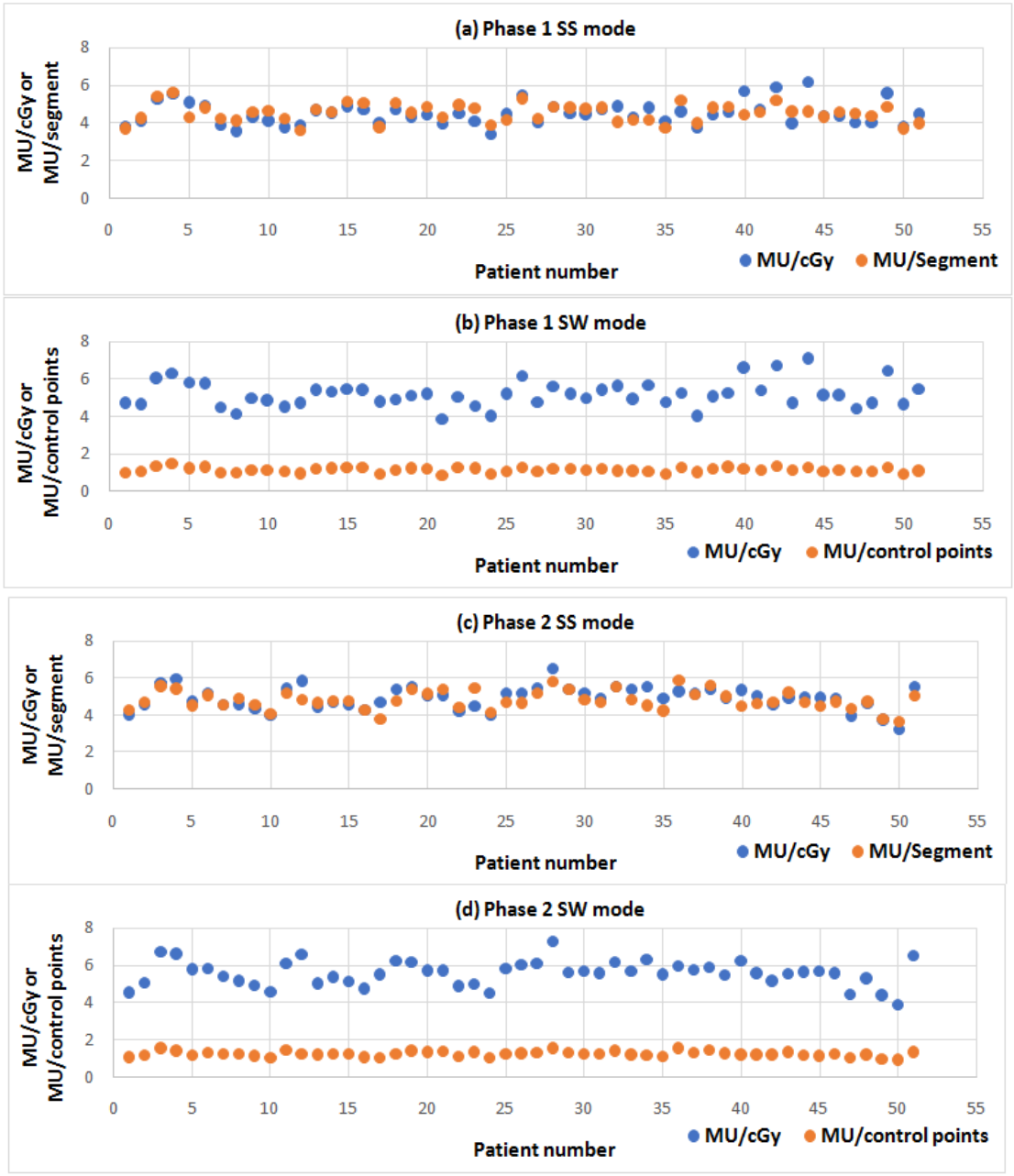
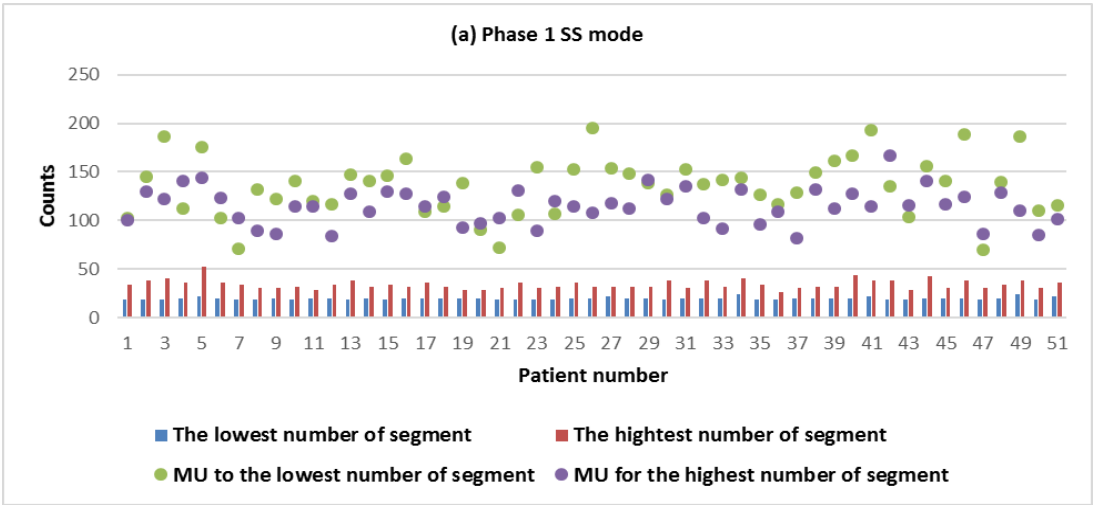
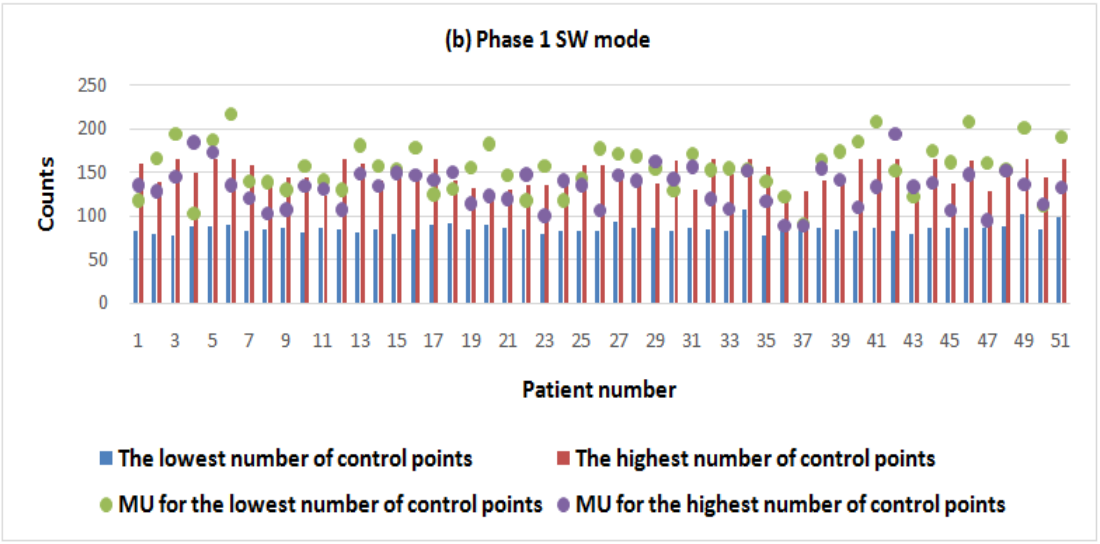
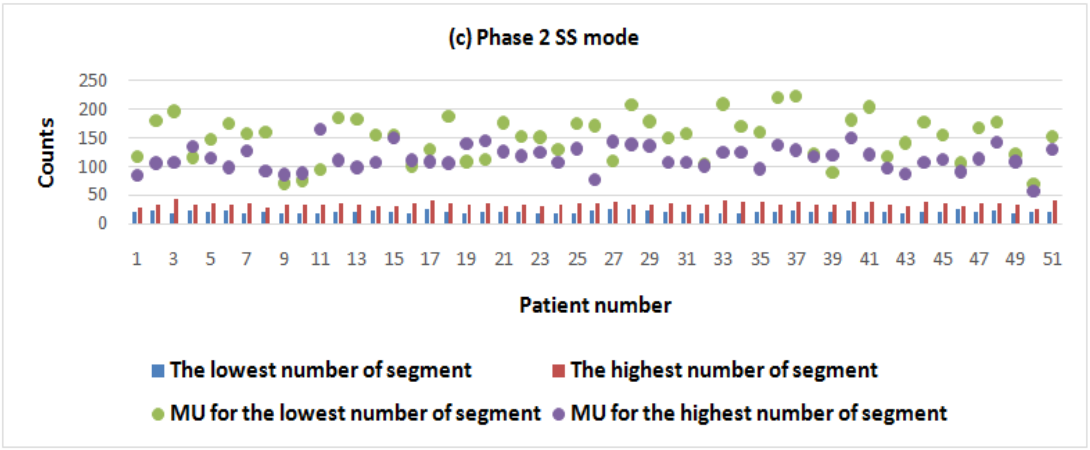


Figure 2: The number of MU/cGy as a modulation factor and MU/segment (or MU/control points) of IMRT dose delivery for each patient in (a) phase 1 SS mode, (b) phase 1 SW mode, (c) phase 2 SS mode, and (d) phase 2 SW mode.


(a) Phase 1 SS mode
Counts
Patient number
The lowest number of segment
The hightest number of segment
MU to the lowest number of segment
MU for the highest number of segment


(b) Phase 1 SW mode
Counts
Patient number
The lowest number of control points
The highest number of control points
MU for the lowest number of control points
MU for the highest number of control points


(c) Phase 2 SS mode
Counts
Patient number
The lowest number of segment
The highest number of segment
MU for the lowest number of segment
MU for the highest number of segment

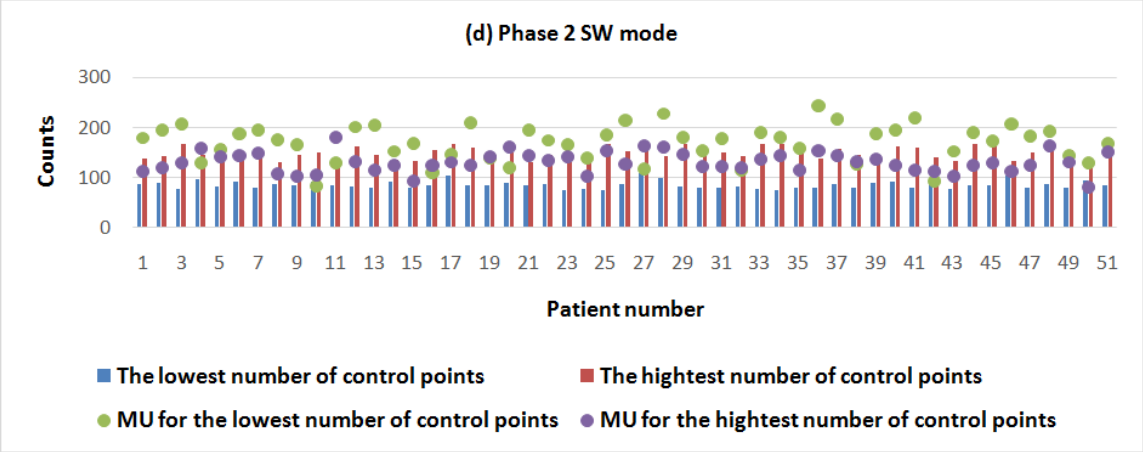


Figure 3: The relation between the MUs of the lowest and highest number ofsegments (or control points)of IMRT dose delivery in (a) phase 1 SS mode, (b) phase 1 SW mode, (c) phase 2 SS mode, and (d) phase 2 SW mode. Note that mostMUofsegments (or control points) varies inversely with the total number of segments (or control points).

Table 1. Shows the comparison of plan quality between two IMRT techniques in the primary, boost, and sum plans.

Variable	IMRT		P-value
	SS	SW	
Primary plan (mean ± standard deviation)			
CI	1.195±0.05	1.202±0.067	0.336
HI	0.059±0.008	0.05±0.008	<0.001[b)]
Quality of coverage	0.889±0.07	0.891±0.726	0.649
LCF	0.985±0.013	0.989±0.011	0.001[b)]
UI	1.061±0.009	1.051±0.009	<0.001[b)]
CN	0.813±0.028	0.816±0.049	0.653
D_{mean} to PTV_p (Gy)	50.577±0.268	50.603±0.251	0.232
D_{max} to PTV_p (Gy)	53.472±0.268	52.903±0.378	<0.001[b)]
Boost plan (mean ± standard deviation)			
CI	1.065±0.028	1.076±0.038	0.003[a)]
HI	0.066±0.014	0.059±0.016	<0.001[b)]
Quality of coverage	0.872±0.062	0.873±0.065	0.729
LCF	0.966±0.022	0.97±0.025	0.001[b)]
UI	1.069±0.017	1.062±0.019	<0.001[b)]
CN	0.877±0.031	0.875±0.037	0.49
D_{mean} to PTV_b (Gy)	30.379±0.136	30.384±0.138	0.638
D_{max} to PTV_b (Gy)	32.364±0.223	32.044±0.277	<0.001[b)]
Sum plans (mean ± standard deviation)			
D_{mean} to PTV_p (Gy)	78.366±1.997	78.387±1.992	0.352
D_{mean} to PTV_b (Gy)	80.841±0.358	80.844±0.331	0.904

A P-value < 0.05 is considered significant. The paired t-test was used to determine whether there was a statistically significant difference.

IMRT, intensity-modulated radiotherapy; SS, Step-and-Shoot; SW, Sliding Window; CI, conformity index; HI, homogeneity index; LCF, Lesion Coverage Factor;UI, Uniformity Index;CN, Conformation Number; PTV_p, primary planning target volume; PTV_b, boost planning target volume; D_{mean}, mean dose; D_{max}, maximum dose received.

[a)](SS) IMRT significantly better than the other technique[b)](SW) IMRT significantly better than the other technique.

Table 2. Shows the treatment efficiency between two IMRT techniques in the primary and boost plans.

Variable	IMRT		P-value
	SS	SW	
Primary plan (mean ± standard deviation)			
MU/fx	809.41±107.86	930.43±125.61	<0.001[a)]
Total number of segments or control points	179.68±19.31	807.94±75.15	<0.001[a)]
The lowestnumber of segmentsor control points	19.56±1.51	85.78±5.52	<0.001[a)]

MU for the lowest number ofsegments or control points	135.29±30.01	154.529±28.39	<0.001[a)]
The highestnumber of segments or control points	34±4.71	148.66±14.42	<0.001[a)]
MU for the highestnumber of segments or control points	114.56±18.51	132.45±22.45	<0.001[a)]
MU/(segment or control point)	4.51±0.46	1.15±0.13	<0.001[b)]
Modulation factor (MU/cGy)	4.49±0.59	5.17±0.69	<0.001[a)]
Treatment delivery time (S)	307.8±31.42	275.6±25.28	<0.001[b)]
Boost plan (mean ± standard deviation)			
MU/fx	884.17±109.53	1000.96±120.51	<0.001[a)]
Total number of segments or control points	184.86±15.97	808.82±64.30	<0.001[a)]
The lowestnumber of segments or control points	20.07±1.78	85.53±7.21	<0.001[a)]
MU for the lowestnumber of segments or control points	150.64±38.77	170.13±36.06	<0.001[a)]
The highestnumber of segments or control points	34.31±3.54	150.07±11.88	<0.001[a)]
MU for the highestnumber of segments or control points	114.92±20.79	131.25±20.24	<0.001[a)]
MU/(segment or control points)	4.78±0.50	1.24±0.14	<0.001[b)]
Modulation factor (MU/cGy)	4.91±0.60	5.56±0.67	<0.001[a)]
Treatment delivery time (S)	304.4±22.77	273.8±22.44	<0.001[b)]

A P-value < 0.05 is considered significant. The paired t-test was used to determine whether there was a statistically significant difference.

IMRT, intensity-modulated radiotherapy; SS, Step-and-Shoot; SW, Sliding Window; MU, Monitor Unit; fx, fraction; cGy, centi-gray; S, Seconds.

[a)] (SS) IMRT significantly better than the other technique,[b)] (SW) IMRT significantly better than the other technique.

Table 3. Shows the dosimetric comparison between two IMRT techniques of non-target tissues in the primary, boost, and sum plans.

Nontarget tissues	Variable	IMRT		P-value
		SS	SW	
Primary plan (mean ± standard deviation)				
Body	V_{2Gy} (%)	16.14±4.36	16.19±4.38	<0.001[a)]
	V_{5Gy} (%)	10.52±3.14	10.58±3.17	<0.001[a)]
Rectum	D_{mean} (Gy)	26.70±3.26	26.76±3.26	<0.001[a)]
	D_{max} (Gy)	52.35±0.50	52.07±0.48	<0.001[b)]
	ID ($Gy\times cm^3\times 10^3$)	1.90±0.88	1.91±0.88	<0.001[a)]
Bladder	D_{mean} (Gy)	25.09±5.34	25.25±5.36	<0.001[a)]
	D_{max} (Gy)	52.74±0.44	52.39±0.40	<0.001[b)]
	ID ($Gy\times cm^3\times 10^3$)	3.79±2.48	3.82±2.5	<0.001[a)]
Left femoral head	D_{mean} (Gy)	15.53±2.60	16.04±4.59	0.239
	D_{max} (Gy)	33.06±5.80	32.67±5.84	0.361
	ID ($Gy\times cm^3\times 10^3$)	2.64±0.56	2.73±0.88	0.239
Right femoral head	D_{mean} (Gy)	14.69±2.68	14.8±2.52	0.42
	D_{max} (Gy)	32.54±6.46	32.9±6.15	0.334
	ID ($Gy\times cm^3\times 10^3$)	2.48±0.53	2.50±0.52	0.348
Health tissues	D_{mean} (Gy)	2.07±0.61	2.09±0.63	0.005 [a)]
	D_{max} (Gy)	52.93±0.43	52.70±0.45	<0.001[b)]
	ID ($Gy\times cm^3\times 10^3$)	100.04±18.11	101.04±18.13	0.001 [a)]
Penile bulb	D_{mean} (Gy)	22.44±7.13	22.45±7.12	0.42
	D_{max} (Gy)	44.50±9.01	44.23±8.91	<0.001[b)]
	ID ($Gy\times cm^3\times 10^3$)	0.06±0.03	0.06±0.03	0.436
Boost plan (mean ± standard deviation)				
Body	V_{2Gy} (%)	10.65±3.05	10.70±3.06	<0.001[a)]
	V_{5Gy} (%)	6.21±1.96	6.24±1.97	<0.001[a)]
Rectum	D_{mean} (Gy)	10.25±2.01	10.29±2.04	0.164
	D_{max} (Gy)	31.48±0.48	31.42±0.46	0.108
	ID ($Gy\times cm^3\times 10^3$)	0.72±0.32	0.72±0.32	0.253
Bladder	D_{mean} (Gy)	11.99±3.95	12.03±3.95	0.06
	D_{max} (Gy)	31.98±0.40	31.74±0.35	<0.001[b)]
	ID ($Gy\times cm^3\times 10^3$)	1.73±0.99	1.73±1.00	0.146
Left femoral head	D_{mean} (Gy)	8.37±1.32	8.44±1.32	<0.001[a)]
	D_{max} (Gy)	20.12±2.83	20.16±2.91	0.555
	ID ($Gy\times cm^3\times 10^3$)	1.42±0.27	1.43±0.28	<0.001[a)]

Right femoral head	D_{mean} (Gy)	7.97±1.34	8.01±1.32	0.034[a)]
	D_{max} (Gy)	19.31±3.12	19.37±3.18	0.424
	ID (Gy×cm^3×10^3)	1.34±0.25	1.35±0.25	0.038[a)]
Health tissues	D_{mean} (Gy)	0.99±0.288	0.99±0.29	<0.001[a)]
	D_{max} (Gy)	31.92±0.41	31.8±0.46	0.003[b)]
	ID (Gy×cm^3×10^3)	48.06±10.28	48.33±10.34	<0.001[a)]
Penile bulb	D_{mean} (Gy)	13.23±4.13	13.25±4.15	0.028[a)]
	D_{max} (Gy)	26.87±5.38	26.77±5.34	0.002[b)]
	ID (Gy×cm^3×10^3)	0.04±0.02	0.04±0.02	0.015[a)]
Sum plans (mean ± standard deviation)				
Body	V_{2Gy} (%)	18.53±4.87	18.60±4.88	<0.001[a)]
	V_{5Gy} (%)	12.93±3.59	12.99±3.61	<0.001[a)]
Rectum	D_{mean} (Gy)	36.96±4.90	37.06±4.92	0.001[a)]
	D_{max} (Gy)	83.14±0.75	82.95±0.66	0.003[b)]
	ID (Gy×cm^3×10^3)	2.63±1.19	2.64±1.19	0.002[b)]
Bladder	D_{mean} (Gy)	37.09±9.06	37.26±9.07	<0.001[a)]
	D_{max} (Gy)	84.01±0.71	83.49±0.68	<0.001[b)]
	ID (Gy×cm^3×10^3)	5.53±3.44	5.55±3.47	<0.001[a)]
Left femoral head	D_{mean} (Gy)	23.90±3.79	24.05±3.79	<0.001[b)]
	D_{max} (Gy)	51.38±7.90	51.47±7.90	0.37
	ID (Gy×cm^3×10^3)	4.06±0.82	4.09±0.82	<0.001[a)]
Right femoral head	D_{mean} (Gy)	22.78±3.72	22.89±3.70	<0.001[a)]
	D_{max} (Gy)	50.25±8.83	50.66±8.96	<0.001[a)]
	ID (Gy×cm^3×10^3)	3.84±0.75	3.86±0.75	<0.001[a)]
Health tissues	D_{mean} (Gy)	3.05±0.87	3.08±0.88	<0.001[a)]
	D_{max} (Gy)	83.46±0.73	83.16±0.85	<0.001[b)]
	ID (Gy×cm^3×10^3)	147.68±27.38	148.95±28.34	0.002[a)]
Penile bulb	D_{mean} (Gy)	35.67±10.90	35.71±10.91	0.084
	D_{max} (Gy)	71.16±13.95	70.89±13.87	<0.001[b)]
	ID (Gy×cm^3×10^3)	0.11±0.06	0.11±0.06	0.062

A P-value < 0.05 is considered significant. The paired t-test was used to determine whether there was a statistically significant difference.

IMRT, intensity-modulated radiotherapy; SS, Step-and-Shoot; SW, Sliding Window; PTV_p, primary planning target volume; PTV_b, boost planning target volume; D_{mean}, mean dose; D_{max}, maximum dose received; V_{nGy}, the percentage volume of organ receiving n Gy; ID, integral dose; Gy, gray; cm^3, cubic centimeter.

[a)] (SS) IMRT significantly better than compared technique, [b)] (SW) IMRT significantly better than compared technique.

IV. Discussion

The dose distribution comparing through the plan evaluation of the patient volume (slice -by-slice) makes it possible to qualitatively study the different degrees of conformal avoidance, the expansion of the low-dose areas, the degree of uniformity of doses inside the PTVs, and the probableexistence of hot spots. The dose distributions obtained for every two plans compared in TPS plan evaluationwasindeed found to be similar with minor differences. All of the plans achieve similar dose coverage of the PTVs. It is also observed that although the dose distributions are similar, the MU forasimilar field can be different, depending on which technique is used,neverthelesspreserving a constant beam rate from the initialprocess of the planning, the number and arrangement of thebeams, dose-volume constraints, relative prioritydefined for the structures, and equal time of optimization represented by number of iterations[13].

The average value of MU/cGy observed in the present study was not significantly different from what was reported in Fogliata et al [26]which useddifferent TPS, including Eclipse TPS, a mean value of 3.37 ± 1.88 MU/cGy with range [1.62, 6.84]has been determined. Whereas our study showshigher mean values than the TPS used by Eldesoky et al. [27]but still were in the range due to the TPS type used. The use of a sliding window delivery, by Eclipse TPS, is not significantly worse than the segmented MLC (step and shoot) technique in this regard[26]. Kim et al.[24]observed MU/cGybetween prostate versus H&N plans with 2D gamma evaluation. Therefore, H&N plans were more highly-modulated than the prostate plans (MU/cGy of prostate and H&N plans = 3.48 *vs.* 5.43), which is similar to the results in this studybecause of the total number of MU increases with the max. MU/min of plans used[13,28].

The results of increased number of total MU/fxleads to radiation head leakage, internal scatter [29], and this would also increase the total body integral dose that can rise incidence of the radiation-induced secondary cancer [30,32]. Table 2 showed that MU/fx in SW is higher than SS technique, however table 1 showed that the plan quality in SWis better than that for SS. The SS mode is better than the SW mode when it comes to non-target tissues sparingas shown in table 3[12]. Increasing total MU/fx of IMRT delivery impacts the room shielding design due to the increased patient load[33].The determination of MU/fxdepends both on the degree of

intensity modulationneeded[9], and the type of algorithm of a TPS used to convert the intensity pattern into a leaf sequence for IMRTdelivery[34].These results in this study,MU/fx and total no. of segments,are adjacent to those found in Xio TPS byEldesoky et al.[27].

Other methods for reducing theNo. of MU is to reducethe treatment delivery time.Thetreatment delivery time of SW is averaging to 4.56 min. which is adjacent toOliver et al.[22]results (averagingto 4.8 min.) estimated fromboth 5-fieldsIMRT & 9-fields IMRT.

Figures 2& 3 and table 2represents the average number of MUs per segment (or control points) and the number of MUs (for the highest and lowestnumber of segments (or control points))in the calculated plans. The difference between the twotechniques is that the SS plans include segments with very small number of MUs, which may affect the amount of radiation leakage. The number of MUs, for the lowestnumber ofsegments,is greater than the number of MUs, for the highestnumber ofsegments, as shown in figure 3.This is adjacent to the findings by Wang et al.[25], however is contrary to the findings by Eldesoky et al.[27](who evaluated by using twoother algorithmsof three different TPS).

This study shows the integral doses of 6 MV photons, which are mostly used in IMRT. The comparison of integral dose for non-target tissues with IMRT (SS) andIMRT (SW) were also discussed. IMRT (SW) plans increased the integral dose to the non-target tissues and significant difference was found in the volume receiving 2 Gy and 5 Gyas opposed to IMRT (SS) plans. IMRT (SS) with low intensity levels such as 10 L slightly degraded the dose uniformity in the target volumes. In DMLC the beam is continuously switched on, which means that there is an increase the OARs dosage due to transmission and leakage through the leaves [19]. It has been reported that for deep-seated targets and coplanar plans, the integral dose (ID) is independent on the beam energy [35]. These results support the expectation from geometric considerations that the ID decreases with increasing tumor size for similar anatomic sizes and increases with increasing size of anatomical district for similar tumor size [36]. ID can be distributed among the various health tissues in a variety of ways, but cannot be reduced except for increasing the beam energy, or reducing the beam margins. Another possibility for reducing ID may involve changing the beam characteristics in some other way, such as fluence modulation. Therefore, plan optimization becomes essentially a process of moving dose around within the patient to find the most favorable distribution [36]. Moreover, integrated dose is dependent on the coplanarity of the plan, tumor depths, and number of beams [37].

V. Conclusion

The main obstacle of IMRT plans, on the EclipseTPS,is increase inthe number of MU per fraction and number of segments (or control points) however maintaining the treatment delivery time.The SWmodeshowed higher treatment efficiency values than SS mode, but betterplan quality &shorter treatment delivery time. At the same time, the SSmode showed the ability to save mean dose and integral dose to thenon-target tissues,in addition to the reduction in the volume of low doses.

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