Original Article

Treatment Planning Evaluation of Sliding Window and Multiple Static Segments Technique in Intensity Modulated Radiotherapy for Different Beam Directions

Teyyiba Kanwal, Muhammad Khalid, Syed Ijaz Hussain Shah, Khawar Nadeem

Abstract

Objective: The demand of improved dose conformity of the tumor has been increased in Radiation Therapy with the advent of recent imaging facilities and efficient computer technologies. This study was focused to investigate more accurate dose conformity and delivery using intensity modulated radiation therapy (IMRT). **Material and Methods:** This study was conducted at department of Radiation Oncology Shaukat Khanum Cancer Hospital Lahore during January 2011 to July 2011. **Sample Size:** Thirteen patients were enrolled**.** Intensity modulated radiotherapy plans were explored for different beam directions in sliding window and step and shoot technique, using Eclipse Treatment Planning System with Linear Accelerator. Thirteen patients were planned on 15 MV X-ray for 5, 7, 9 and 13 fields making the dose constraints analogous. **Results:** The rival plans were scrutinized using D_{mean}, D_{max}, $D_{1\%}$, $D_{95\%}$, dose uniformity index (UI), dose conformity index (CI) and dose homogeneity index (HI). Better coverage for planning target volume was achieved using step and shoot (multiple static segments) technique and reduced the dose to surrounding healthy tissues and organs at-risk (OAR). **Conclusion:** Step and shoot technique has better results as compared to sliding window technique. Key words, Sliding window (SW), Step and Shoot (SS), IMRT, dose conformity index (CI) and dose homogeneity index (HI), Planning Target Volume (PTV), Dose Volume Histogram (DVH)

INTRODUCTION

Intensity-modulated radiation therapy (IMRT) is an advanced conformal method available to deliver external-beam radiation therapy (EBRT). The technique required the development of multileaf collimation. The improvement of inverse planning systems and methods in IMRT for delivering nonuniform radiation intensities have ushered in the epoch of intensity-modulated radiation therapy (IMRT), representing the state of the art in the treatment of many cancers.[1] IMRT modulates the beam to create a conformal dose distribution around the target while minimizing dose to the surrounding normal tissues and enables tumor dose escalation. There are multiple ways of modulating the beam intensity in traditional IMRT e.g. sliding-window (SW) and multiple static segment /step-shoot (SS) IMRT[2]. Different IMRT techniques were developed and clinically implemented, using different number of beams and orientation, different optimization methods (forward or inverse) and different delivery modalities of different complexity [3,4]. In spite of all pains in the conventional method of planning, the surrounding normal tissue of PTV and other critical organs at risk still receives considerable doses in the final plan. In IMRT it is possible to overcome this problem by achieving desired dose distribution in the target volume and adjoining critical organs. In this article the authors describe a systematic approach to compare different plans generated for different beam directions with two techniques of IMRT such as sliding window (SW) and step-shoot (SS). Authors also furnished DVH comparisons among several fields (5, 7, 9, and 13). DVH was exercised to calculate D_{mean}, D_{max}, $D_{1\%}$, $D_{95\%}$, dose uniformity index (UI), dose conformity index (CI) and dose homogeneity index (HI) for dose coverage of planning target volume (PTV) and D_{mean},

D_{max}, $D_{15\%}$, $D_{25\%}$, $D_{35\%}$, $D_{50\%}$ volume of the organ at risk were analyzed for the critical organ sparing.

MATERIAL AND METHODS

Setting: This study was conducted at department of Radiation Oncology Shaukat Khanum Cancer Hospital Lahore.

Duration: January 2011 to July 2011

Sample Size: Thirteen patients were enrolled**.**

Inclusion Criteria: Cancer patients with tumors in ECOG 0 and 1

Operational definitions:

1-PTV, Planning target volume,

2- 3DCRT Three Dimensional conformal radiotherapy

Procedure: Eclipse Radiation Treatment Planning System (RTPS) with Helios inverse planning software was utilized for treatment planning. High energy Medical Linear Accelerator 2100 C/D with 120 leaf millennium MLC was exercised for the delivery of treatments. Thirteen patients planned and treated at 15MV for five/ seven/ nine/ thirteen field with SW and SS IMRT technique for comparing the dose distributions in PTV and organs at risk.

Postoperative patients were chosen which were given in 25 fractions of 2 Gy to a total dose of 50 Gy in 5 weeks for whole bladder in conventional 3 DCRT and the boost is given by IMRT in 2 Gy of 8 fractions. CT images of 5mm thickness at different transverse sections away from the mid plane were taken to create a 3D image. Partial rectum and Partial bladder were created by subtracting bladder and rectum from PTV by using Boolean operator. All plans with SW and SS techniques of IMRT were generated on same CT images with structure. For five fields IMRT plan was generated for each patient both for SW and SS techniques and had gentry's arrangements 135^o, 75^o, 0^o, 285^0, 225^0. For seven fields IMRT plan both for SW and SS techniques had gentry's arrangements at 180^o, 105^o, 60^o, 30^o, 0^o, 330^o, 300^o, 255^o. For nine fields IMRT plan both for SW and SS techniques and had gentry's arrangements starting with 0^o and ended at 320^o with gentry angle difference of 40^o. For thirteen fields IMRT plan both for SW and SS techniques had gentry's arrangements at 160^o, 130^o, 110^o, 80^o, 60^o, 40^o, 0, 320^o, 300^o, 280^o, 250^o, 230^o, 200^o(IEC Convention. Wherever required and achievable, the constraints were changed to obtain possible minimum doses to critical organs without compromising the PTV coverage of at least 95% dose to 95% of PTV volume.

COMPARISON FACTORS

To asses the target coverage and normal tissue sparing the following factor were used.

1. A uniformity index was used and defined as, ratio of D_5 and D_{95}, Where D_5 and D_{95} are the minimum doses delivered to 5% and 95% respectively of the PTV [5-6].
2. A homogeneity index was used and defined as:

$$HI = \frac{D_{1\%} - D_{99\%}}{prescription.dose}$$

   Where $D_{1\,(\%)}$ and $D_{99\,(\%)}$ are the dose delivered to 1% and 99% volume respectively of the PTV[7-8]. Smaller HI corresponds to more homogenous dose distribution in PTV.
3. Conformity index is defined by, ratio of reference isodose volume to target volume of PTV. The 95% isodose volume was taken as reference volume of the PTV [9-10]. The value of CI varies between 0 and 1 and a value 1 is for ideal plan. In addition, the mean and maximum doses to PTV, percentage of target volume receiving at least 95% of the prescribed dose $D_{95\%}$ and the dose to 1% of target volume $D_{1\%}$ were calculated to appraise target coverage.
4. The sparing of organ at risk was evaluated by comparing of maximum and mean doses. Doses at 15%, 25%, 35% and 50% volume were calculated for organs at risk (OARs) receiving a dose more than tolerance limit and compared. Statistical analysis was performed with two tailed paired t-test. A p-value of $p<0.05$ was considered statistically significant.

RESULTS

Both the planning techniques formed tolerable dose distribution to the planning target volume. The isodose distribution in transversal, frontal and sagittal views obtained with SW IMRT and SS IMRT for 5-field, 7-Field, 9-field and 13-filed are given in figure 1-2**.**

Figure-1
Comparisons of Transversal, Frontal and sagittal views of 9F SS IMRT and 9F SW IMRT

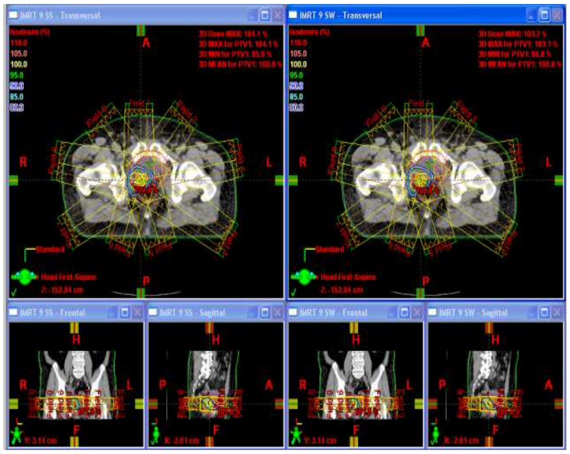


Figure-2
Comparisons of Transversal, Frontal and sagittal views of 13F SS IMRT and 13F SW IMRT.

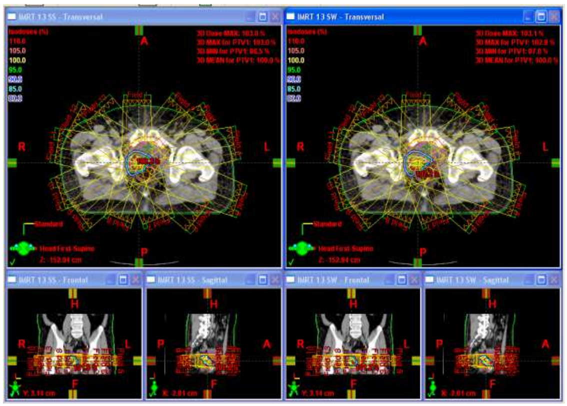


Figure-3
Comparison of DVH curves of PTV for all fields using SS IMRT and SW IMRT

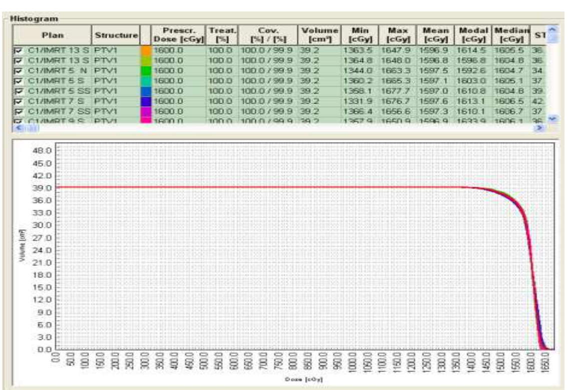
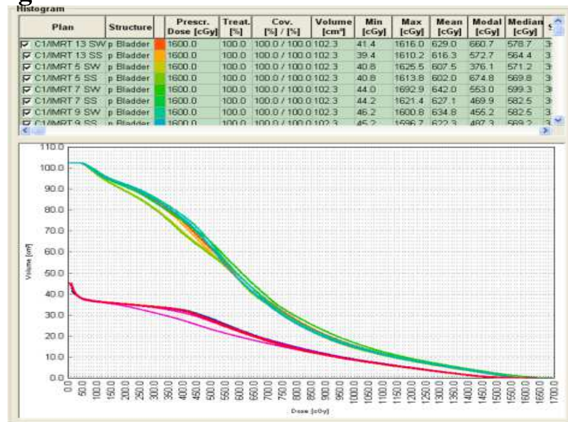


Figure-4
Comparison of DVH curves of OAR for all fields using SS IMRT and SW IMRT.



The dose volume histograms (DVHs) for the PTV, partial bladder and partial rectum of the representative patient using both techniques i.e. Sliding window (SW IMRT)and step and shoot (SS IMRT) techniques for 5-field, 7-Field, 9-field and 13-filed are shown in figure 3 and figure 4 respectively.

Table-1
comparison of average dosimetric parameters for irradiation of target volume using both techniques.

PTV	5F.SW	5F.SS	7F.SW	7F.SS	9F. SW	9F. SS	13F.SW	13F.SS	t-value	Prob.
D_{mean}	99.78±0.05	99.78±0.05	99.78±0.05	99.78±0.05	99.78±0.05	99.78±0.05	99.78±0.05	99.78±0.05	0.00^{NS}	1.000
D_{max}	107.08±2.5	107.55±2.3	106.05±3.6	106.62±3.5	105.20±1.6	106.00±1.4	106.15±2.4	105.57±2	0.98^{NS}	0.329
$D_{1\%}$	104.27±1.8	104.8±1.3	103.37±1.6	103.96±1.4	103.44±1.2	103.93±0.9	103.20±1.5	103.06±1.2	-1.24^{NS}	0.216
$TV_{95\%}$	95.40±0.9	95.11±1	95.88±0.9	95.33±0.8	95.95±0.9	95.43±0.8	95.93±1.2	95.74±0.7	2.15^{*}	0.034
U.I	1.07±0.02	1.08±0.01	1.05±0.01	1.07±0.01	1.05±0.01	1.06±0.01	1.06±0.01	1.06±0.01	-2.01^{*}	0.047
H.I	0.12±0.03	0.13±0.02	0.11±0.01	0.12±0.01	0.10±0.01	0.12±0.01	0.11±0.01	0.12±0.01	-2.05^{*}	0.043
C.I	0.95±0.01	0.95±0.009	0.96±0.01	0.95±0.009	0.96±0.009	0.95±0.009	0.96±0.01	0.96±0.005	1.72^{NS}	0.089

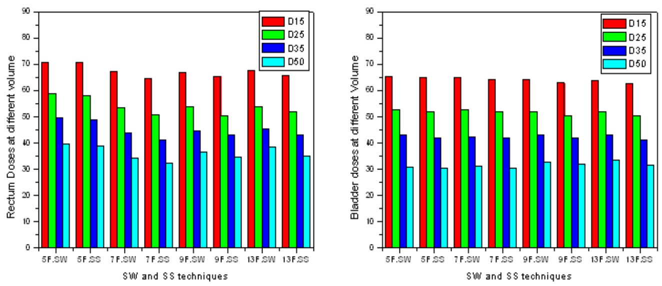
D_{mean} = Mean dose, D_{max} = Maximum dose, $D_{1\%}$ = dose to 1% of target volume; $D_{95\%}$= dose to 95% of target volume; UI = Uniformity index; CI = Conformity Index; HI = Homogeneity Index; NS = Non Significant

The evaluated data of thirteen patients with the mean doses to PTV and comparison of the dose coverage with sliding window and step and shoot treatment plans is given away in table 1. The results illustrate that mean doses to PTV remains same for both techniques. Commonly the PTV coverage was better in

SW IMRT. Statistically significant results appear for HI, UI and $TV_{95\%}$ for SW IMRT ($P<0.05$). The average lower values of UI, HI and higher or equal values of SW IMRT confirms the advantage of SW IMRT over SS IMRT.

Figure-5

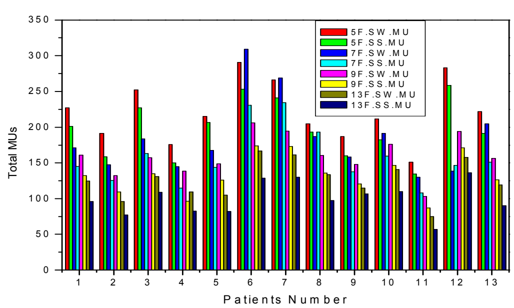
Comparison of both techniques for different volume of partial Bladder and partial Rectum



The dose coverage of organs at risk (OAR) with Sliding Window and Step & Shoot plans for 5-field, 7-Field, 9-field and 13-filed are shown in figure 5. The average mean dose values were less for SS IMRT than SW IMRT for partial bladder and partial rectum.

Figure-6

Average MU assessment of individual patient for different filed with SW IMRT and SS IMRT



For every patient under consideration SS IMRT delivers fewer MUs than SW IMRT it means SS IMRT takes less time to complete the radiation process.

DISCUSSION

The evaluation of SW IMRT and SS IMRT plans demonstrates that the dose coverage of PTV in both cases was analogous and comparable with significant differences. Either one of the plans can be preferred depending upon the shape and size of PTV by comparing DVH values. In this study, the PTV from SW IMRT plans showed systematic and significance better results in term of target coverage and homogeneity compared to SS IMRT plans. Conformity index is used to appraise the clinical verification of better treatment. Average Conformity index for both techniques is approximately 0.96. It is observed that conformity index is not much helpful to demonstrate the difference in both SW IMRT and SS IMRT while increasing number of fields. The value of Conformity index nearly 1 provides better conformity of dose to PTV.

The results explained that SW treatment plans give significant progress of dose conformity to PTV with higher values of CI than SS IMRT treatment plans. Better conformity may help to deliver higher doses to PTV without delivering additional doses to adjacent normal tissue. This was obviously confirmed by isodose distribution and DVH curves. The average uniformity index for Sliding Window method is 1.06 and for Step & Shoot method, it is 1.07. The greater uniformity index indicates higher heterogeneity. So SW IMRT is considered well. The uniformity index values calculated for the target volume also demonstrates considerable benefit of SS IMRT over SW IMRT plans.

Average Homogeneity index for SW IMRT is 0.11 and for SS IMRT is 0.12. The smaller Homogeneity index means more homogeneous dose distribution to PTV. So SW IMRT gives significant results than SS IMRT.

With respect to OARs SS IMRT is able to sustain the mean doses below their acceptance levels in contrast with SW IMRT. This dose reduction in critical organs without compromising the dose in target volume could lead to additional clinical advantages because side effects during or following treatment might be reduced. Figure 3 shows rectum and bladder doses at different volumes ($D_{15\%}$, $D_{25\%}$, $D_{35\%}$, $D_{50\%}$) and for different number of fields with appropriate angle selection verify that SS IMRT is better for sparing OARs than SW IMRT. Non significant results were found for OARs. The statistical analysis shows the response of IMRT techniques on different treatment parameters. t-value of different parameters describe the significance or non significance of a treatment plan using both techniques. It was scrutinized that results were significant for HI, UI and $TV_{95\%}$ and non significant for rest of the parameters. This type of research is not done in Pakistan so far and internationally very little work is available.

CONCLUSION

This study suggests a benefit of SW IMRT for target covering than SS IMRT and SS IMRT considered best for organ sparing than SW IMRT. IMRT plans improve the conformity and homogeneity of the dose distribution in the target volume. SW IMRT gives enhanced target coverage showing lower values of HI and UI than SS IMRT. Over all, it is suggested that SS IMRT is better than SW IMRT.

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AUTHORS

- **Teyyiba Kanwal**
  Health Physicist Department Oncology
  Allied Hospital Faisalabad
- **Dr. Muhammad Khalid**
  Assistant Professor Department Oncology
  PMC/Allied Hospital Faisalabad
- **Prof. Dr. Syed Ijaz Hussain Shah**
  Professor of Oncology
  PMC/Allied Hospital Faisalabad
- **Dr. Khawar Nadeem**
  Senior Medical Officer Oncology
  Allied Hospital, Faisalabad