RESEARCH ARTICLE

Simultaneous integrated boost-intensity modulated radiation therapy (SIB-IMRT) planning for pelvic tumours: dose coverage to target volume and normal tissue sparing

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Abstract

Objective: To evaluate the better radiotherapy plan for pelvic tumours that may achieve a high target coverage dose and low normal tissue tolerance dose using simultaneous integrated boost-intensity-modulated radiation therapy technique.

Method: The analytical, cross-sectional, descriptive study was conducted from October 2020 to March 2021 at Al-Amal National Hospital for Cancer Treatment, Baghdad, Iraq, and comprised male pelvic cancer patients aged 50-80 years. Computed tomography scans were randomly selected. For each patient, 4 treatment plans (phases I and Π) were generated using the simultaneous integrated boost-intensity-modulated radiation therapy technique while keeping all parameters constant except the number of beams, which were 5, 7, 9 and 11. The optimal and safe dose was defined as the one to cover 95% planning target volume. Homogeneity and conformity indices were used to assess the uniformity of dose distribution in the target volume, and various treatment plans in the same patient were compared. Data was analysed using SPSS 24.

Results: There were 15 males with mean age 67.12±2.84 years. There was a significant variance in the target volume dose and organ at risk in the 4 different plans generated using the simultaneous integrated boost-intensity-modulated radiation therapy technique ($p<0.05$). The 9-beam treatment plan was the best for coverage of tumours and protection of healthy organs assessed through homogeneity and conformity indices ($p<0.05$).

Conclusion: The 9-beam treatment plan showed significant tumour coverage, homogeneity and conformity values, and sparing dose for organs at risk.

Key Words: Pelvic, Tomography, Radiotherapy, Radiation

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Introduction

Radiation therapy (RT) significantly treats malignant pelvic cancers, such as endometrial, cervical, rectal, prostatic, blood blister and anal[1]. In recent years, intensity-modulated radiation treatment (IMRT) has been utilised to treat these tumours because it can reduce radiation exposure to adjacent normal tissues, such as the colon, bladder, rectum and bone marrow[2-5].

Simultaneous integrated boost (SIB) approaches give a larger dose to the primary tumour without increasing the total treatment time[6]. Moreover, the SIB technique improves the plan's quality compared to sequential techniques. The use of SIB strategies efficiently reduces cumulative process fragmentation. In sequence treatments, however, the daily dose in the boosting region is more significant than typical[7-10].

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The current study was planned to assess the optimal and safe dose to cover 95% of planning target volume (PTV) in pelvic tumour patients which could spare the normal tissue and organs at risk (OARs).

Patients and Methods

The analytical, cross-sectional, descriptive study was conducted at Al-Amal National Hospital for Cancer Treatment, Baghdad, Iraq, from October 2020 to March 2021, and comprised male pelvic cancer patients aged 50-80 years. The study was approved by the institution ethics review board of the College of Medicine, Al-Nahrain University, Iraq, and written informed consent was obtained from all the participants.

All parameters were kept constant except the number of beams. Four plans were created for each case using the SIB-IMRT technique with an X-ray energy of 6MV in Monaco treatment planning system (TPS) version 5.1 manufactured by Elekta company, Sweden. The planning process included acquiring computed tomography (CT) images. Multi-leaf collimator technique for IMRT photon beam delivery was employed for 5, 7, 9 and 11 fields.

Treatment plans with <5 beams and >11 beams were excluded.

Gantry angles differed according to the number of fields. Couch angle and collimator were 00 for all cases. The treatment plans were compared in terms of their dose-volume histograms (DVHs), PTV covered by 95% of the prescription dose (D95%), maximum dose (Dmax) and mean structure doses (Dmean), homogeneity index (HI) and conformity index (CI). HI was the ratio between Dmax in PTV and the reference isodose, while CI indicated the relation between the reference dose volume (VRI) and PTV.

Evaluation of planning was done by the oncologist on dose distribution for the target and OARs on the basis of DVH curves. CI and HI parameters were used to evaluate the plan for each patient and technique, and to check if it needed to be edited. Finally, if the plan was accepted, the oncologist approved the patient's treatment plan and prepared the patient for irradiation. Time of treatment indicated the time of all treatment fractions.

Data was analysed using SPSS 24. Data was presented as mean ± standard deviation. One-way analysis of variance (ANOVA) was used to assess the difference among treatment groups. $P<0.05$ was considered statistically significant.

Table-1: Demographic data.

Demography	
Age (years)	50 – 80 (67.12 ± 2.84)
Gender	Male
Type of tumour	Prostate cancer
Prescribed dose	74 Gy
Number of fractions	37 fractions
Time of treatment	7.4 weeks

Table-2: Comparison of dose coverage for the 2-planning target volume (PTV) cases for different beams (n=15).

	5-beam	**7-beam**	**9-beam**	**11-beam**	**p-value**
Phase I	75.11±27.27	72.24±31.21	90.80±30.48	66.90±33.96	0.036*
Phase 2	90.73 ± 4.84	95.96 ±7.03	96.41 ± 6.58	80.73 ± 8.15	0.059*

Table-3: The mean dose for each organ in different beams (n=15).

	5-beam	**7-beam**	**9-beam**	**11-beam**	***p-value***
Rectum	4695.48 ±1159.51	2452.90 ± 978.34	4586.05 ± 941.71	2374.53 ± 842.32	0.017*
Bladder	3849.46 ± 710.16	5104.83 ±1066.22	3982.96 ±828.91	5066.84 ± 938.92	0.0309*
Small intestine	906.47 ± 399.21	1956.13 ± 1005.81	1958.49 ± 999.35	1963.56 ±1044.66	0.049*

Table-4: Comparison of HI and CI values for phase I and Π phase with different beams (n=15).

	Homogeneity Index (HI)				
	5-beam	**7-beam**	**9-beam**	**11-beam**	***p-value***
Phase I	0.18±0.05	0.22±0.17	0.01±0.01	0.07±0.01	0.033*
Phase 2	0.28 ±0.02	0.37 ±0.03	0.32 ±0.02	0.39 ± 0.02	0.048*
	Conformity Index (CI)				
Phase I	0.94±0.27	0.72±0.31	0.97±0.30	0.66±0.34	0.046*
Phase 2	0.83 ± 0.03	0.89 ± 0.02	0.89 ± 0.03	0.88 ± 0.02	0.041*

*One-way analysis of variance (ANOVA).

Results

There were 15 male prostate cancer patients with mean age 67.12±2.84 years (Table 1). The 9-beam treatment plan was the best in terms of covering the tumour, as it was able to achieve good coverage of the tumour in both phases due to the shape of the tumour as well as the number of beams and their projections. This was followed by the treatment plan of 7, 5 and 11beams (Table 2).

The 9-beam and 5-beam treatment plans protected the bladder, small intestine and rectum, while the 7-beam and 11-beam plans protected the rectum and small intestine, but not the bladder (Table 3).

The 9-beam treatment plan gave good homogeneity of the dose in phase I and less homogeneity in phase 2, followed by the 11-beam, 5-beam and 7-beam plans (Table 4).

Discussion

The higher the number of beams, the greater is the need to plan, deliver success, verify and process dosimetry. In practice, the number of beams is required to be reduced to the lowest possible number without compromising treatment quality[11].

The advantage of SIB-IMRT is better conformity to the target, lower dose for critical structures, moderate treatment acceleration with reduced total treatment time, and the option for dose escalation in gross tumour volumes[12].

The current study showed a significant difference between the 4 treatment plans. The 5-beam plan was able to cover 2PTVs, but it did not deliver 95% of the prescribed dose to the tumour centre, and it was considered the most critical dose to be delivered. The 7-beam plan also gave results similar to the 5-beam plan, and did not deliver a sufficient dose to cover the tumour in phase I. This meant that the healthy organs near the tumour received the dose, which is not required in the treatment planning. As for the 9-beam treatment plan, the tumour coverage rate was 90.9% of the prescribed dose in phase I, and 96.4 % in phase 2. This plan gave the best results among the 4 treatment plans in terms of covering the tumour with the dose in the two phases. Finally, the 11-beam plan did not fulfil the condition or deliver a sufficient dose for the tumour in the two phases. The difference in the results was due to the number of beams and angles that were formed, as well as the shape and location of the tumour. The most critical factor, however, was the isocentre, which had to be in the right place.

The current study showed there was a significant difference in the results between the 4 treatment plans. Both 5-beam and 9-beam plans achieved better protection than the 7-beam and 11-beam plans, which was due to the number of beams and the correct angles used.

The ideal dose coverage for PTV should have HI=0 and CI=1.

HI ([D2%-D98%]/Dmean) values showed that 9-beam and 11-beam were the best treatment plans, which meant that the increase in the number of beams increased dose homogeneity in the tumour.

With respect to CI (V95/VPTV), all treatment plans gave good results, but the 9-beam and 5-beam plans gave the best results.

The number of beams needed to obtain an ideal treatment plan for coplanar IMRT has been investigated by several researchers[13-15]. Ehab M et al.[16] concluded that the minimum number of equilateral beams depended on the ratio of the prescription dose to the tolerance dose of critical structures. As this ratio increases, a large number of beams becomes necessary. They also noted that when the beam angles were improved for a small number of beams, <5, there was a significant dosimetric improvement relative to equiangular beams[16].

Treatment plans are less conformal when <7 fields are used, while >9 fields usually result in slight improvement. Mundt et al.[17] recommends using 9 evenly spaced beams placed at 40◦ intervals.

Samir et al.[15] compared the dosimetry outcomes and treatment delivery effectiveness of 4 different procedures to determine the most effective strategy for treating prostate disease. Patients with prostate cancer had low or moderate risk. Based on 2 distinct assessment methodologies, qualitative and quantitative evaluation was done of 7-field (7F)-IMRT and 9F-IMRT procedures. Compared to the current study, they found that 7F IMRT and 9F IMRT plans gave lower integral doses and exposed less normal healthy tissue to radiation in the low-dose area. However, the 9F IMRT plans were better than the 7F IMRT plans to irradiate less normal, healthy tissue in the high-dose zone and give lower integral doses[15].

Pirzkall et al.[18] evaluated the effect of beam energy and field number on photon-based IMRT for prostate cancer, and showed that the integral non-target dose variation was <5% with all plans.

The results of Inanc B. et al.[19] were consistent with those of the current study with respect to dose homogeneity within the tumour.

Zope MK et al.[20] concluded that the difference between the treatment plans of 5 and 7 beams gave close results, and the difference was minimal in terms of coverage and OAR protection as well as HI and CI.

Limitation: The current study has limitations as the sample size was not calculated, which could have affected the power of the study.

Conclusion

The 9-beam treatment plan showed significant tumour coverage, homogeneity and conformity values, and sparing dose for OARs.

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