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Case Series

Dosimetric comparison of rectal carcinoma radiation therapy using three dimensional conformal radiation therapy and intensity modulated radiation therapy: an analytical observational study

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ABSTRACT

Rectal cancer is the second most common cancer in large intestine. Recently, preoperative chemoradiotherapy has been generally used in the management of locally advanced rectal cancer on the basis of several benefits proven by clinical studies, in the aspect of better locoregional tumor control, reduced toxicity of normal organs, and an increased chance of preserving the anal sphincter, when compared with postoperative chemoradiotherapy. In this observational study, conducted between January 2017 and December 2021, pursuant to the recommendations of the radiation therapy oncology group (RTOG), all patients underwent CT simulation, a bladder protocol and target contouring. 10 patients were treated with intensity modulated radiotherapy (IMRT) and 10 with three-dimensional conformal radiation therapy (3DCRT). Planned target volume (PTV) coverage, homogeneity index (HI), conformity index (CI), and doses to organs at risk (OAR) were compared. Our findings showed that 3DCRT and IMRT have statistically significant differences in PTV coverage and dosages to OAR ($p<0.001$), proving that IMRT achieves improved target dose coverage and superior normal tissue avoidance (bladder and intestine) compared to 3DCRT.

Keywords: 3DCRT, IMRT, PTV

INTRODUCTION

The typical neoadjuvant therapy for patients with LARC (T3 and/or N+) is preoperative chemoradiation (CRT).[1] The German CAO/ARO/AIO 94 experiment established that preoperative CRT in LARC results in the reduced local recurrence rates, less acute and chronic toxicity, and the higher rate of the sphincter preservation when compared to the post-operative CRT.[2] The absolute rates of toxicity were nevertheless notable even if pre-operative treatment reduced both the short- as well as long-term adverse effects. Grade 3-4 diarrhoea rates with the pre-operative CRT were 12% while grade 3-4 diarrhoea rates with postoperative CRT were 18%. Preoperative chemoradiation resulted in a 27% reduction in all acute grade 3-4 toxicities (diarrhoea, hematologic, as well as dermatologic), compared to a 40% reduction with postoperative therapy. Similar rates of the acute toxicity have been observed when novel chemotherapy drugs, like capecitabine as well as the oxaliplatin, are administered simultaneously with the pre-operative radiation.[3-5]

With IMRT, the dosage absorbed by nearby dose-limiting structures is reduced while the target volumes receive highly conformal dose distributions. However, there aren't many dosimetric studies comparing IMRT and 3DCRT in LARC and comprise 5 to 8 tiny patient samples.[6-8] Regarding local control and survival for anal canal cancer, IMRT appeared equivalent to 3DCRT while lowering dermatologic, GI, and haematological toxicities and related treatment breaks.[9,10] Studies on dosimetry have shown that IMRT reduces the doses of irradiated small bowel used to treat rectal cancer.[11] A novel approach to planning and administering RT is the relatively recent treatment known as IMRT. In contrast to standard RT, IMRT tightly conforms radiation to tumours and high-risk locations while sparing nearby important normal tissues. This approach is frequently used to treat head and neck tumours as well as prostate cancer. Clinical studies using IMRT have reduced acute rectal toxicity and xerostomia. IMRT lessens hematologic and GI damage while preserving disease control in the treatment of pelvic malignancies.

Considering that IMRT will supposedly lessen the severity of acute toxicities during the preoperative treatment of rectal cancer, this study compares the clinical data and toxicity profiles of IMRT and 3DCRT for rectal cancer. In this work, the radiation to the anal sphincter in IMRT and 3DCRT was also examined. In patients receiving IMRT and 3DCRT, the association between dosage and sphincter function was examined.

CASE SERIES

This was an analytical observational study related to dosimetry, conducted in our hospital in which 20 patients with locally advanced histo-pathologically proven rectal carcinoma, were treated with chemoradiation from the period of January 2017 till December 2021. 10 patients were treated with IMRT and 10 with 3DCRT. Patients were simulated with 16 slices helical siemens somatom sensation computed tomography simulator. Following the bladder protocol, scans were performed when the patient felt the urge to urinate and was instructed to consume 700 cc of water. Target delineation was performed using slices with thickness of 3 mm. Target volumes contoured using the digital imaging and communication in medicine (DICOM) data that uploaded to Varian EclipseTM. The planning target volume (PTV) was recommended a dosage of 50.4 Gy over the course of 28 fractions, with following OAR constraints: Urinary bladder: UB V50Gy (Volume of UB in percentage getting more than 50 Gy) less than 50%; small bowel: SB V45Gy (Volume of SB in cc receiving more than 45 Gy) fewer than 195 cc. While 3DCRT technique was intended using beam angles of 0, 90, 180, and 270, IMRT technique used 7 field techniques and static beam angles of 0, 60, 100, 135, 225, 260, and 310 degrees using static multi leaf collimator (MLC).

Target coverage and dosages received by OAR were compared between the two approaches dosimetrically. PTV D2% (Dose received by 2% of the PTV), PTV D50% (Dose received by 50% of the PTV), PTV D98% (Dose received by 98% of the PTV), HI, and conformance index (CI) were compared for the evaluation of target coverage. SB V45Gy and UB V50Gy were the parameters that were used to evaluate OAR. The near-maximum and near-minimum dose differences normalised to the median dose were used to define HI.

HI= D2-D98/Dp

The mean dose to the anal sphincters in both procedures was also compared. Patients were instructed to lie on their backs with their full bladders, both arms resting on their chests. Physical examination, transrectal ultrasonography, CT, PET-CT, and/or MRI results were combined to evaluate the gross tumour volume (GTV) and enlarged regional lymph nodes. The perirectal, mesorectal, and presacral lymph nodes, along with the internal and external iliac (T3) and iliac (T4), were added to the GTV to create the clinical target volume (CTV). The rectal CTV featured the rectal GTV with a 1.5-2 cm radial expansion and 2.5-3 cm craniocaudal expansion, as opposed to the nodal GTV, which received a 1.5-2 cm uniform expansion. The unaffected iliac nodal regions expanded by 1.0 to 1.5 cm. The sacral promontory marked the start of the presacral lymph nodes, which continued to the base of S5. The PTV expanded by 0.5-1.0 cm. The research physicist used the EclipseTM (Version 13.2) treatment planning system to determine the dosimetric parameters after the expert radiologist helped shape the anal sphincters.

The mean (standard deviation) of the continuous measurements was reported. The Mann-Whitney 'U' test was employed for non-parametric data, and the paired student 't' test was utilised for statistical comparisons of parametric quantitative variables. All statistical analyses were performed using the social science statistical system (SPSS version 20, SPSS Inc, Chicago, IL, USA) and a $p=0.05$ or lower was regarded as statistically significant.

According to our findings, there is a significant difference in PTV coverage between IMRT and 3DCRT, with mean ± standard deviation values of D95% (50.12±0.32 vs 49.64±0.54), D98% (49.1±0.41 vs 48.04±0.52), D2% (52.4±0.56 vs 53.4±0.51), and D50% (51.2±0.42 vs 51.8±0.49), respectively. In IMRT, HI and CI were better than in 3DCRT, with mean and standard deviations of 0.102 and 0.042 vs. 0.109 and 0.051 and 0.86 and 0.034 vs. 0.72 and 0.041, respectively, with p values less than 0.001 (Table 1).

The results showed that IMRT was superior to 3DCRT in terms of mean PTV D95%, mean PTV D98%, PTV D2%, and mean PTV D50%, 3DCRT produced noticeably greater volumes of hot areas and smaller quantities of cold spots when compared to IMRT. Significantly lower doses to the entire OAR were achieved using IMRT (Table 1). This study showed that, in comparison to

3DCRT, IMRT achieves improved normal tissue avoidance (bladder and colon), with better target dose coverage (Figure 1 A and B). In addition to this, the mean dose to anal sphincter was significantly less in IMRT as compared to 3DCRT and is given in Table 1. During the routine follow-up of patients, it was found that patients whose mean dose to anal sphincter was ≥ 40 Gy had less sphincter control as compared to mean dose <40 Gy.

Table 1: Dosimetric comparison between IMRT vs 3DCRT in rectal cancer.

Parameters	IMRT		3DCRT		P value
	Mean	SD	Mean	SD	
PTV D95%	50.12	0.32	49.64	0.54	<0.001*
PTV D98%	49.1	0.41	48.04	0.52	<0.001*
PTV D2%	52.4	0.56	53.4	0.51	<0.001*
PTV D50%	51.2	0.42	51.8	0.49	<0.001*
HI	0.102	0.042	0.109	0.051	<0.001*
CI	0.86	0.034	0.72	0.041	<0.001*
Small bowel V45GY (CC)	112	28	172	39	<0.001*
Urinary bladder V50GY (%)	28.40	4	62	14	<0.001*
Anal sphincter (Gy)	35.24	0.54	42.65	0.42	<0.001*

*P<0.05 significant.

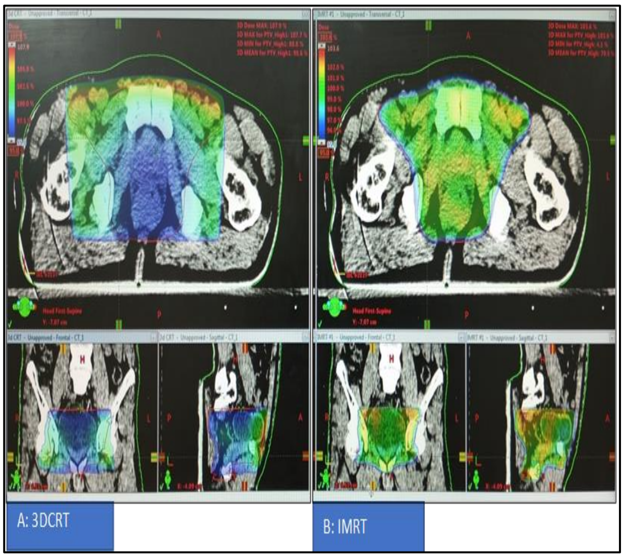

Figure (1 A and B): Dose colour wash to the PTV high for 3DCRT and IMRT in axial, coronal and sagittal view for rectal cancer.

DISCUSSION

Radiation doses to neighbouring healthy organs can be kept to a minimum while yet being given to the tumour and nearby lymph nodes at high doses with IMRT. It can decrease undesirable effects and possibly improve the toxicity profile by changing the dose in this way to avoid normal, unaffected tissues. Furthermore, the use of IMRT for rectal cancer might hasten the period until surgery, encourage a quicker recovery afterward, and improve the acceptability of adjuvant chemotherapy. IMRT for rectal cancer can lessen treatment-related toxicity as compared to traditional 3DCRT. In the NSABP R-03 trial, patients with rectal cancer were randomly assigned to receive preoperative (3DCRT) or postoperative (RT with concurrent 5-FU and leucovorin after one cycle of induction 5-FU and leucovorin before chemoradiation) treatment. The rate of grade 3 diarrhoea was 36% in the preoperative arm and 29% in the postoperative group.[12]

Duthoy et al evaluated the PTV coverage of 3DCRT and intensity-modulated arc treatment (IMAT) in LARC and found no differences.[7] Rectal cancer treatment with IMRT has drawbacks and potential issues that must be taken into account, including organ motion, volume fluctuation, dose inhomogeneity, and integral dosage. Treatment efficacy is more dependent on correct target location, shape, and size assessment than in 3DCRT due to the rapid dose drop-off beyond target volumes, internal target and organ at risk motion, and volume variability. Nearly all cases of rectal organ movements have been reported in patients receiving treatment for prostate and bladder cancer. In these studies, treatment-related rectal volume alterations were noted, particularly in the front wall and upper half of the rectum.[13-17] The variability of the CTV in rectal cancer caused by internal organ motion during adjuvant therapy was explored by Nuyttens et al but no information has been published on the variability of the tumor-affected rectal wall.[18] Due to the assumption that 88% of stage II and stage III tumours can have a digital rectal examination confirm, the variance of the rectal wall in individuals with LARC would likely be smaller.[19] Nuyttens et al investigated how little bowel motion affected IMRT treating rectal cancer.[20] The small bowel is situated in the superior pelvis in the preoperative situation, where the posterior, lateral, and anterior borders of the CTV are all highly stable. As a result, it is unlikely that the CTV is affected by small bowel motion and volume fluctuation. Realising the extent of internal organ motion is crucial for assuming a low level of variability to ensure clinical repeatability. Based on these findings, the IMRT treatment planning objective must be the 95% coverage of the PTV for the specified dose, and image verification becomes essential.

In our series, supine treatment was given to patients who got IMRT/3DCRT in order to increase setup repeatability and tolerability. A combination of prone positioning and bladder distention was found to be the most efficient technique for lowering irradiated small bowel volumes in preoperative rectal cancer patients in one research, but this was in a population of Asians who likely had smaller body habits than Americans.[21] In contrast, another study reported no difference in toxicity outcomes when endometrial cancer patients got IMRT when prone as opposed to supine.[22] Drzymala et al compared the supine position to the prone position in 19 patients with rectal cancer and found that, at low doses levels, the supine position resulted in a significantly higher volume of bowel being exposed to radiation. However, from 20Gy to 45Gy, with each 5Gy increase, the volume of bowel exposed to radiation did not alter noticeably. Because of this, getting concurrent CRT did not significantly increase the area of colon exposed at levels linked to bowel toxicity.[23] The evidence regarding the best patient placement for pelvic RT is conflicting, and further research is needed to determine whether the benefits of bowel sparing with each of these approaches (positioning, IMRT, and bladder distention) are cumulative or patient dependant.

CONCLUSION

This study showed that IMRT achieves greater target dose coverage and superior normal tissue avoidance (bladder and intestine) compared to 3 DCRT. So, it can be concluded that IMRT should be chosen as best technique for the radiotherapy of rectum carcinoma.

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