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Original Research Article

Comparison of dosimetric parameters between intensity modulated and three-dimensional conformal radiotherapy planning for adjuvant therapy of gastric cancer

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ABSTRACT

Background: Adjuvant chemoradiotherapy is the standard treatment for gastric carcinoma, but the optimal radiation modality remains uncertain. This study aimed to compare intensity-modulated radiotherapy (IMRT) and three-dimensional conformal radiotherapy (3D-CRT) in terms of dosimetry for adjuvant gastric cancer treatment.
Methods: 21 patients with stage IIB-IIIC gastric cancer, treated between January and June 2021, underwent surgery followed by adjuvant chemoradiation with both IMRT and 3D-CRT plans. Dosimetric parameters were calculated for the planned target volume (PTV) and organs at risk (OAR).
Results: Both IMRT and 3D-CRT provided comparable PTV coverage. However, IMRT significantly improved kidney sparing, reducing the mean V20 value by 23% (p=0.01) for the right kidney and 26% (p=0.02) for the left kidney compared to 3D-CRT. IMRT also decreased the mean irradiated volume for both kidneys and the liver, as well as the V30 value for the liver, although these differences were not statistically significant. The dosimetric parameters for the spinal cord were comparable between IMRT and 3D-CRT plans.
Conclusions: IMRT demonstrated better kidney sparing compared to 3D-CRT in adjuvant radiotherapy for gastric cancer, while PTV coverage was similar. Long-term follow-up is necessary to assess clinical outcomes and local recurrence rates for both treatment plans.

Keywords: Dosimetric, Intensity, Conformal, Radiotherapy, Gastric, Cancer

INTRODUCTION

Stomach cancer is the 5th most common cancer in 2020 worldwide. About 10,89103 new cases (5.6% of total cancer incidence) and 76,8793 deaths (7.7% of total cancer mortality) in 2020 are due to cancer.[1] In 2020, new cases of stomach cancer in our country were 7,599 (4.8%) and it was ranked 6th (4.8%) among the whole cancer patients group and 5th (5.8%) among the male patients.[2] Patients with gastric cancer post-operative chemo-radiation have become the standard of care after the publication of intergroup 0116 trial.[3] In that trial, demonstrated adjuvant chemoradiotherapy not only improved relapse-free survival but also overall survival (OS) over surgery alone.[4] However, several studies revealed a favorable outcome with adjuvant chemoradiotherapy for post-operative cases and recommended chemoradiotherapy as the standard adjuvant therapy for patients with resected gastric adenocarcinoma.[5,6] The reported loco regional recurrence rate was 23% to 38% which was strongly emphasized the need for adjuvant radiotherapy.[7] Considering the probability of harboring micro metastatic disease larger radiation fields are necessary to adequately cover the resection bed and regional lymph node regions. Whereas the target volume has to be large and often not be irradiated in its entity to a sufficient dose because of the high toxicity of adjuvant chemo-radiotherapy.[8] Thus there is a need to improve standard treatment therefore, conformal radiotherapy has been used to overcome the disadvantage of conventional techniques, such as under-dosage of target regions and high radiation to neighboring normal structures. One such technique is intensity modulated radiation therapy (IMRT), which utilizes intensity-modulated ‘‘beamlets’’ to conform dose departed from vital organs and more nearly towards tumor. In comparison, three-dimensional conformal radiotherapy (3DCRT) uses beams of uniform intensity, offering less freedom in sculpting dose around the tumor. Still, there is disputation which conformal technique (3D-CRT or IMRT) is better for gastric cancer radiotherapy.[9,10] In this study the radiation prescribed dose was 45 Gray for both treatment plans. In adjuvant radiotherapy, it is not possible to increase dose beyond 45 Gray because tolerance doses of some critical organs can be even exceed with this standard target dose.[11] The purpose of this study, analyzed the which radiation technique achieved the doses of organ at risk (OAR) within the tolerance limit and provided the accurate dose coverage to target volume by comparison of dosimeter parameters between 3DCRT and IMRT techniques among postoperative gastric cancer patients. Nevertheless, clinical outcome of these dosimetric analyses is an area of current research.

METHODS

This retrospective analysis was conducted at the clinical oncology department of Bangabandhu Sheikh Mujib Medical University (BSMMU) from January to June 2021. A total of 21 patients diagnosed with locally advanced gastric carcinoma (stage IIB-IIIC) were enrolled in the study. These patients underwent postoperative radiotherapy with the intention of curative treatment, and a prescribed dose of 45 Gray in 25 fractions. Prior to simulation, patients were required to have an empty stomach for 3 hours. During simulation, patients were positioned in a supine posture with their arms raised above their head and immobilized using a wing board, knee, and footrest. CT simulation was performed with oral and intravenous contrast, employing one anterior and two lateral lasers to ensure precise patient alignment. Serial CT images with 3mm slices and contrast were obtained from the carina to the iliac crest for each patient. The clinical target volume (CTV) for adjuvant post-operative radiotherapy encompassed the residual stomach (subtotal gastrectomy), anastomotic stump, and regional draining lymph nodes. The CTV for lymph nodes was contoured based on vessel contrast, with a 5 mm margin around the corresponding vessels. To account for setup variation and organ motion, the planning target volume (PTV) was created by expanding the CTV by 1 cm in all directions. The OAR, including the liver, both kidneys, and the spinal cord, were delineated. Ethical approval for the study was obtained, and descriptive statistics were used to analyze the dosimetric parameters. The volumes received minimal, maximal, 95% (V95%), and 107% (V107%) of the prescribed dose for PTV were compared, and the homogeneity index (HI) was calculated to assess dose uniformity within the PTV. Statistical analysis was performed to compare the dosimetric parameters between the IMRT and 3D-CRT plans. It is important to note that the small intestine was not included in the evaluation of OAR due to its variable position and inconsistent delineation.

RESULTS

Characteristics of the 21 patients were summarized in Table 1. The median age at diagnosis was 51.52±8. 8 years (range, 35-65 years). Out of the total of 21 patients in this study, 16 patients were male and 5 patients were female. Pathological stage IIB was the most prevalent pathological stage in the study among 21 patients and stage IIIC was the least common. This table showed that most of the tumor grade was moderately differentiated it was about 42.8%. Dose volume histogram (DVH) data were detailed in Table 2. The mean maximum dose of the PTV was 48.41±1.1 Gray for 3DCRT and 49.30±1.3 Gray for IMRT plan (p=0.35). In the PTV for 3DCRT the average minimum dose was 40.83±1.1 Gray and 41.78±1.0 Gray for IMRT (p=0.10). The maximum and minimum dose in the PTV was higher for IMRT plan in comparison to 3DCRT but there was no significant variation was observed. Subsequently, the median volume received 107% of prescribed dose for 3DCRT and IMRT plan was 0. 27%±0.3 and 0. 35%±0.3 respectively (p=0.52). Additionally, the median volume received 95% of prescribed dose in the PTV was 96.86%±1.7 in IMRT plan and 97.76%±1.9 in 3DCRT plans. Regarding target uniformity, within the PTV the IMRT plans was superior in HI (1.02±0.02) compared to 3D-CRT (1.12±0.14) but statistically no significance was observed (p=0.08). Each of these volumes were indicated that PTV coverage was comparable between both techniques. Figures 1 and 2 showed isodose color wash for 3D-CRT and IMRT plan and revealed that more homogeneous isodose distribution was acquired by IMRT technique on plan PTV45. However, in terms of doses taken by PTV45 there was no significant difference observed between two plans. DVH data were also obtained for organ at risks by both IMRT and 3D conformal planning. It was seen that IMRT planning was more advantageous than 3D conformal planning accordant to organ at risk dose. DVH data for left and right kidneys in terms of V20 was found to be statistically significant on IMRT ($p<0.05$). Median V20 was found as 28% at 3D conformal radiotherapy planning while it was 23% at IMRT planning for right kidney (p=0.01). Median V20 dose of left kidney was found as 29% at 3D conformal radiotherapy planning while it was 26% at IMRT planning (p=0.15). Mean dose of right and left kidney was found comparable between two treatment plans. IMRT decreased the mean dose (21 Gray versus 23 Gray) and the median V30 of the liver (25% versus 26%) in compared to 3DCRT plan.

Table 1: Clinicopathological characteristics of patients (n=21).

Variables	Number of patients (%)
Age (years)	
Range: 35-65	Mean: 51.52±8.8
Gender	
Male	16 (76.1)
Female	5 (23.8)
Grade	
I	5 (23.8)
II	9 (42.8)
III	7 (33.3)
AJCC (American Joint Committee on Cancer) pathological stage	
IIA	4 (19.0)
IIB	7 (33.3)
IIIA	5 (23.8)
IIIB	4 (19.0)
IIIC	1 (7.6)

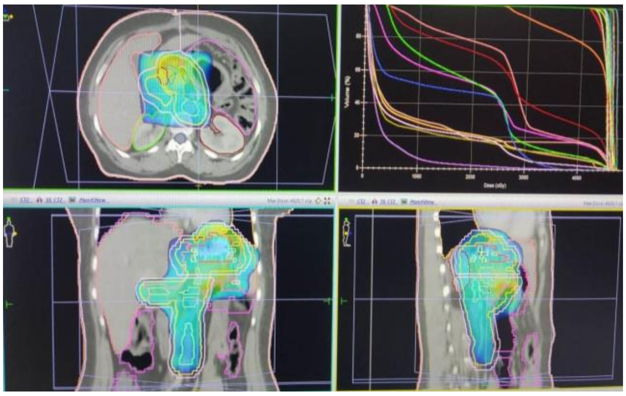

Figure 1: Isodose color wash on CT image (3DCRT plan).

Table 2: Dose constraints used for organ at risk in IMRT and 3DCRT planning.

Organs at risk	Constraints
Liver	V_{30Gray} <33%
	Mean <25 Gray
Right kidney	V_{20Gray} <33%
	Mean <18 Gray
Left kidney	V_{20Gray} <33%
	Mean <18 Gray
Spinal cord	Max <45 Gray

V_{20Gray}=Volume receiving 20 Gray, V_{30Gray}=volume receiving 30 Gray

However, both mean dose and median V30 of the liver were found to be statistically not significant (p>0.05). Maximum mean dose for spinal cord was insignificantly higher in IMRT when compared to the 3DCRT technique (40.06 Gray versus 39.17 Gray respectively) with no statistical difference (p=0.26). They were shown on Table 3.

Table 3: Dosimetric parameters of the planning target volume.

Dosimetric parameters	3DCRT (n=21)	IMRT (n=21)	P values
Maximum dose (Gray)	48.41±1.1	49.30±1.3	0.35
Minimum dose (Gray)	40.83±1.1	41.7±1.0	0.10
$V_{95\%}$	97.76±1.9	96.86±1.7	0.13
$V_{107\%}$	0.27±0.3	0.35±0.3	0.52
Homogeneity index	1.12±0.14	1.02±0.02	0.03

IMRT: Intensity modulated radiotherapy, 3DCRT: 3 – dimensional conformal radiotherapy, V95%: volume received 95% of prescription dose, V107%: volume received 107% of prescription dose

Table 4: Dosimetric parameters of IMRT and 3DCRT for the organ at risk.

Dosimetric parameters	3DCRT (n=21)	IMRT (n=21)	P values
Liver			
Mean dose	23 Gray	21 Gray	0.19
V_{30} (%)	26	25	0.11
Right kidney			
Mean dose (Gray)	17.75±1.0	16.75±1.4	0.56
V_{20} (%)	28	23	0.01
Left kidney			
Mean dose (Gray)	17.78±0.8	16.02±1.3	0.15
V_{20} (%)	29	26	0.02
Spinal cord			
Maximum dose	39.17	40.06	0.26

V_{20Gray}=Volume receiving 20 Gray, V_{30Gray}=volume receiving 30 Gray

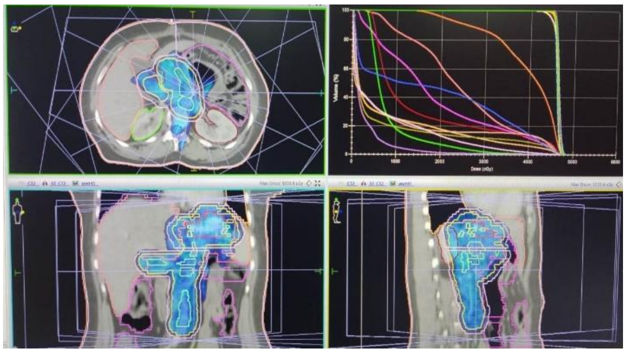

Figure 2: Isodose color wash on CT image (IMRT plan).

DISCUSSION

This study compared the dosimetric parameters of PTV coverage and doses of OAR in IMRT versus 3DCRT radiation technique for gastric cancer patients treated with adjuvant radiotherapy. In the present study total 21 patients were included. The patients age ranges from

35-65 years. The mean age of the patients at diagnosis was 51.52 ±8.8 years. The male patients were found predominant in this study. The number of male patients was 16 and 5 patients were female. Among 21 patients 7 patients were in stage IIB and only 1 patient in stage IIIC. Moderately differentiated tumors were more common in this study. This differs from the findings in Zhou et al where poorly differentiated histology was predominant.[13] This might be due to genomic variation of the study population. At the adjuvant stomach cancer radiotherapy target volumes determined extensive treatment field with stomach bed and regional lymphnode. However, due to the large irregular target area to cover and the vicinity of many vital organs to this region, it was challenging to achieve satisfactory dose distribution with 3D-CRT and treatment interruption was noticed in 25% patients because of the toxicity.[14] Therefore, various dosimetric studies compared 3D-CRT to IMRT in adjuvant gastric cancer radiotherapy and concluded that IMRT provided better sparing of critical structures.[15-17] The most DVH parameters for kidneys were mean dose and V20 that predict the renal toxicity.[18-20] Therefore, in this study, mean dose and V20 values were selected to evaluate the irradiated kidneys. The most significant finding in this research was that, IMRT had lowered the meanV20 value of the right kidney by 23% (p=0.01) and of the left kidney by 26% (p=0.02). This observation was correlated with the study Wieland et al, where IMRT technique was statistically more beneficial against 3D conformal radiotherapy technique in terms of right and left kidney V20.[21] Similarly, in the study of Milano et al, was also reported that the volume of right and left kidney V20 had been decreased by IMRT technique.[22] In this study mean dose for kidneys were observed similar in both techniques. The mean liver dose and V30 these were the dosimetric values used as predictors for enhanced toxicity risk during partial liver radiation.[23] The incidence of radiation-induced liver disease (RILD) was significantly associated with the mean dose to normal liver (MDTNL). Dawson et al reported that when the mean liver dose was <31 Gray no RILD was detected where each 1-Gray-increase in MDTNL, increased the frequency of RILD by 4%.[22] Meanwhile, Liang et al also demonstrated that the occurrence rate of RILD was 6% when the MDTNL was 23 Gray.[24] Therefore, in this study, mean dose and V30 parameters were selected to estimate the dose distribution in liver. IMRT improved sparing of the mean irradiated volume of the liver by 21 Gray (p=0.19) and the median V30 by 25% (p=0.11) compared to mean irradiated volume by 23 Gray and median V30 value by 26% in the 3D-CRT plan but statistically non-significant. The higher radiation dose in spinal cord can causes radiation-induced spinal myelitis. The frequency of spinal myelitis was found to be <0.2% at a radiation dose 45 Gray/25 fractions.[25] In this study, the median maximum dose of spinal cord was nearly similar in both techniques. In 3DCRT it was 39.17 Gray while it was 40.06 Gray in IMRT technique. Subsequently in this study, statistically no significant differences were observed in the maximum, minimum dose, V107%, and V95% of target volume between 3DCRT and IMRT radiation techniques. These results correlated with the Zhang et al and Chopra et al studies where median radiation was almost similar to the plan PTV in both the technique.[26]

Limitations

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

CONCLUSION

In conclusion, this dosimetric analysis revealed that the IMRT technique was a statistically more effective treatment method and decreases the dose on critical organs over the 3D conformal radiotherapy technique in terms of right and left kidney-V20 for patients who had adjuvant radiotherapy for stomach cancer. The DVH parameters of liver V30, mean dose of right, left kidney, and liver was arithmetically decreased at the IMRT technique but statistically insignificant. However, these results need longer follow-ups and further trials with a large number of patients for evaluation of clinical and toxicity outcomes.

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