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COMPRASION OF DOSE DISTRIBUTION FOR CRITICAL ORGANS WITH INTENSITY MODULATED RADIOTHERAPY AND 3D CONFORMAL RADIOTHERAPY FOR GASTRIC CANCER

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ABSTRACT

Objective: Early and late complication may occur depending on the radiation dose in patients receiving gastric radiotherapy (RT), especially in the liver and kidneys. With the development of modern RT techniques, many planning techniques have been developed to reduce side effects. This study compared 3-dimensional conformal radiotherapy (3DCRT) and intensity-modulated radiation therapy (IMRT) planning techniques to determine which is superior in clinical use for postoperative planning of gastric cancer patients.

Material and Method: The target volumes drawn on Oncentra 4.3 planning system for 3DCRT were transferred to Monaco 5.0 IMRT planning system without any change. The total dose of 50.4 Gy (1.8 Gy/fraction) was delivered to 95% isodose of planning target volume (PTV). The analyses of doses of the target volumes and critical organs were performed. Independent-Samples T and Mann-Whitney U tests were used to compare the doses of PTV and critical organs in both techniques. P value <0.05 was considered statistically significant.

Results: When 3DCRT and IMRT techniques were compared according to the 95% isodose of PTV, a statistically significant difference was not found (p=0.909). Considering % doses of liver and spinal cord exposed to 30 Gy and more in both planning techniques; the IMRT technique was found to be statistically superior to 3DCRT (p<0.05).

Conclusion: IMRT is recommended to protect critical organs better for gastric cancer patients receiving abdominal radiotherapy.

Keywords: Conformal radiotherapy, gastric cancer, intensity modulated radiotherapy

INTRODUCTION

The main treatment method of clinically resectable gastric cancer is surgery. Despite the improvement in surgical techniques, local and regional recurrence rates after surgery alone in gastric cancers are reported to be high in randomized studies (1-3). Better outcomes in local recurrence and survival were obtained with the addition of radiotherapy (RT) and chemotherapy to surgical treatment.

As RT techniques developed, clinical results and toxicity assessments began to be made according to the technique used. A meta-analysis showed that the intensity modulated radiotherapy (IMRT) was associated with a slight increase in the 3-year OS rate and a significant increase in the local control rate, without affecting the DFS rate or increasing the clinical toxicity rate, compared with three-dimensional conformal radiotherapy (3DCRT) (4).

Early and late side effects may occur depending on the radiation dose in patients receiving abdominal RT, especially in the liver, spinal cord and kidneys. With the development of modern RT techniques, various planning techniques have been developed to reduce late complications. The volume of irradiated liver, kidney and spinal cord can potentially be reduced in plans made with IMRT technique (5,6).

In this study, we compared the radiation doses received by the critical organs in the treatment area using the 3DCRT and the IMRT techniques in patients with gastric cancer who underwent surgery, and analyzed which technique is superior to other.

MATERIAL AND METHOD

The study was approved by the local ethics committee (Date: 14.12.2015, Decision No: 2015-344) and conducted by principles of the Declaration of Helsinki. Ten patients who underwent total gastrectomy for gastric cancer and had regional lymph node metastases were evaluated within the scope of the study. Clinical target volume (CTV) and planning target volume (PTV) were defined by a radiation oncologist. CTV was obtained by adding celiac, splenic, portohepatic, pancreaticoduodenal lymph nodes according to the localization of the tumor to the postoperative gastric bed. Internal target volume (ITV) was created by adding 1.5 cm margin to CTV. Then PTV was created by adding 0.5 cm margin to ITV. Kidneys, spinal cord, liver and heart were defined as critical organs. A dose of 50.4 Gy with fraction dose of 1.8 Gy was administered with a linear accelerator to the 95% isodose of PTV by changing the beam intensities according to the tumor location in the 3DCRT.

In this study, a new RT plan was created using the IMRT technique on the CT simulation images of ten patients with operated gastric cancer who had standard 3DCRT plans. Within the scope of the study, an IMRT plan was also created for the same target volumes.

Oncentra 4.3 treatment planning system was used for the 3DCRT technique, and the Monaco 5.0 treatment planning system was used for the IMRT technique. In order to compare the two techniques under the same conditions, images of the patients in the Oncentra planning system were transferred to the Monaco planning system without changing the contours of the CTV, ITV, PTV and critical organs. The superiority of the plans to each other was tested by analyzing their dose volume histograms (DVHs).

The minimum, maximum, average dose received by the target volume, the volumes corresponding to $V_{50,4Gy}$ (percentage of volume receiving 50.4 Gy or more) and the dose received by the D95 volume (volume that receives 95% of the dose) were analyzed statistically. In addition, the volumetric dose of critical organs was calculated, recorded and analyzed.

Statistical analysis

Statistical Package for Social Sciences 20 (SPSS 20) for Windows 10 program was used for statistical analysis of the findings. While evaluating the data in our study, Independent-Samples T and Mann-Whitney U tests were used to compare the doses of PTV and critical organs received by the patients in both techniques. P value <0.05 was considered statistically significant.

RESULTS

The conformity index (CI) value was found to be 1.62 (1.56-1.79) and 0.92 (0.91-0.93) in the 3DCRT and IMRT techniques, while the homogeneity index (HI) value was 0.94 (0.83-1.08) and 1.08 (1.07-1.08), respectively. CI and HI values were found to be statistically superior in IMRT technique ($p<0.04$). When the dose received by 95% of the PTV volume was compared in both plans, no statistical difference was found (p=0.9). While the liver V_{40Gy} value was found to be 29.63 (± 6.86) and 19.26 (± 4.18) in 3DCRT and IMRT, respectively, it was found to be superior in the IMRT technique (p=0.001). The volumetric radiation dose received by critical organs such as kidney, spinal cord and heart was statistically lower in the IMRT technique (Table 1).

DISCUSSION

Today, in addition to 3BCRT, the use of IMRT is increasing due to the fact that it delivers a higher effective dose to the tumor, as well as better protection of the normal tissues nearby the tumor (such as spinal cord, liver, kidney) and better dose distribution correction capability. The basis of the IMRT technique may be defined as that it is a planning system that makes non-uniform beams effective with many commands to give the appropriate dose to the target area, together with the maximum dose limitation for the normal tissues adjacent to the tumor. Comparisons of plans using IMRT and 3DCRT techniques show that IMRT is more suitable for the reduction of maximum dose in critical organs and homogeneous distribution of target dose in different treatment areas (7-9).

In our study, RT planning of ten patients with gastric cancer who underwent surgery was performed using two different planning techniques (3DCRT and IMRT), and the superiority of these plans over each other was tested by examining their DVHs. With the IMRT technique, a more homogeneous dose distribution was obtained in the target volume in the RT field. While there was no statistically significant difference between the two techniques in terms of target volumes, lower volumes of critical organs were exposed to radiation with IMRT which resulted in better protection of adjacent organs.

In studies up to now, better dose distribution has been obtained with the IMRT technique in the target volume compared to 3DCRT. Accordingly, CI and HI values are statistically reduced in organ volumes receiving high doses and this change has been shown to reduce acute toxicity (7-9). In our study, when the CI and HI values were examined, IMRT was found to be superior in accordance with the literature. In addition, in our study, there was no difference between the IMRT and the 3DCRT plans in terms of 95% dose coverage of PTV and it is compatible with the literature (10).

Tolerance doses are limited by the risk of radiation-induced liver disease, and the $Dose_{mean}$ and V_{30Gy} for the liver are considered important dosimetric parameters associated with increased toxicity risk (11). Although a lower dose was calculated with the IMRT technique, the mean liver dose was found to be statistically similar between the two techniques in previous studies (7-9). Similarly, in this study, there was no statistically significant difference between the two techniques with respect to the percentage of liver volume that received doses 30 Gy or below. However, IMRT was found to be superior to the 3DCRT technique in terms of liver volume percentage that received more than 30 Gy doses.

Kidney tissue is radiation-sensitive, and previous studies have reported that total doses of 18–23 and 28 Gy are associated with 5 and 50% risks of injury in 5 years, respectively (12). Previous studies have reported that the IMRT technique reduces the volume of kidneys receiving higher doses and increases the volume of kidneys receiving lower doses when compared to 3DCRT. In these studies, it was reported that renal doses decreased in most of patients, but this dose reduction was not reflected in statistical significance (7, 9). Alaa Ahmed Nour et al. (8), in the IMRT technique, it was reported that the kidney volume that received only 28 Gy doses for both kidneys was statistically lower than 3DCRT. In our study, while the IMRT technique was found to be statistically superior for both kidneys for low doses (20, 28, 30 Gy), no difference was found between the two techniques in kidney volumes receiving doses over 40 Gy.

While no statistical difference was reported between the two techniques for the spinal cord and heart doses in patients who underwent gastric RT, statistically lower doses were calculated for the IMRT technique in both organs in our study. Lower dose distribution was calculated with IMRT for the heart and spinal cord with V45 and below (7-9).

Conclusion

In radiotherapy applications, protection of critical organs in the neighborhood of the target region can be of great importance in order to prevent acute and late complications. In addition, homogeneity of the dose coverage and obtaining a sharp dose decrease around the target volume is one of the desired treatment planning goals. In this study, a more homogeneous dose distribution in the target volume was obtained with the IMRT technique in patients with resected gastric cancer. In addition, it is seen that the IMRT technique is statistically more advantageous than the 3DCRT technique in terms of protecting critical organs. As result, the IMRT technique is an effective and safe treatment method in gastric cancer patients who need adjuvant RT.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Gaziantep University, Clinical Research Ethics Committee (Date: 14.12.2015, Decision No: 2015-344).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The author has no conflicts of interest to declare.

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Table 1. Critical organ doses according to RT techniques

Variable	3DCRT	IMRT	*P value*
Liver V_{30Gy}	39.32 ± 6.82	36.12 ± 5.72	0.27
Liver V_{40Gy}	29.63 ± 6.86	19.26 ± 4.18	0.001
Liver V_{50Gy}	19.58 ± 2.8	12.53 ± 3.01	0.001
Liver Mean	29.25 ± 2.5	27.87 ±1.62	0.16
Right Kidney V_{30Gy}	19.05 ± 8.76	4.59 ± 3.8	0.004
Right Kidney V_{40Gy}	4.97 ± 3.64	0.16 ± 1.1	0.1
Right Kidney Mean	12.34 ± 3.2	10.32 ± 1.7	0.04
Left Kidney V_{30Gy}	16.26 ± 12.2	8.61 ± 2.7	0.2
Left Kidney V_{40Gy}	10.24 ± 8.64	5.56 ± 5.56	0.17
Left Kidney Mean	13.69 ± 7.2	12.3 ± 5.1	0.6
Heart V_{30Gy}	23.54 ± 9.24	13.5 ± 7.3	0.01
Heart V_{45Gy}	12.9 ± 4.1	7.14 ± 3.7	0.02
Heart Mean	16.1 ± 4.7	13.2 ± 2.73	0.1
Spinal Cord V_{30Gy}	27.5 ± 12.6	7.84 ± 5.7	0.001
Spinal Cord Maximum	42.12 ± 7.81	34.9 ± 5.9	0.001

V_{xGy}; Percentage of volume receiving x Gray
3DCRT, three-dimensional conformal radiotherapy; IMRT, intensity modulated radiotherapy