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Comparison of Three Dimensional Conformal, Intensity Modulated and Hybrid Intensity Modulated Planning Techniques for Thoracic Esophageal Cancer

Torasik Özofagus Kanserinde Üç Boyutlu Konformal, Yoğunluk Ayarlı ve Hibrit Yoğunluk Ayarlı Radyoterapi Planlama Tekniklerinin Karşılaştırılması

Hatice ERDEM[a], Timur KOCA[b], Nina TUNÇEL[b], Aylin Fidan KORCUM[b]

[a]Department of Medical Services and Techniques, Hatay Mustafa Kemal University Hatay Vocational School of Health Services, Hatay, TURKEY
[b]Department of Radiation Oncology, Akdeniz University Faculty of Medicine, Antalya, TURKEY

ABSTRACT Objective: The aim of this study is dosimetric comparison of 3-D conformal radiotherapy (3D-CRT), intensity modulated radiotherapy (IMRT) and hybrid IMRT (h-IMRT) planning techniques above the recommended standard treatment doses for esophageal cancer patients in terms of target volume dose distribution and critical organ protection. The routine applicability of the h-IMRT technique have also been evaluated. **Material and Methods:** Totally 42 treatment plans for 59.4 Gy dose were designed for 14 esophageal cancer patients with 3D-CRT, IMRT and h-IMRT techniques. Dosimetric evaluation and comparison of the techniques were performed according to the parameters of dose volume histogram (DVH), homogeneity index (HI), conformity index (CI) and monitor unit (MU) calculations. The quality control of the dose distributions was calculated by treatment planning system (TPS) and, 2-dimensional dose distributions and point absolute doses were measured with MatriXX and ion chambers respectively. **Results:** In all regions of the esophagus, IMRT technique was found to be more successful than the 3D-CRT and h-IMRT techniques in terms of PTV coverage. HI was in accepted limits for all techniques but, IMRT and h-IMRT techniques were better for CI. As expected, treatment duration and MU parameters were found to be high in IMRT technique. **Conclusion:** Although all plans were within acceptable limits, dosimetric comparison of different planning techniques, revealed that 3D-CRT had statistically significant differences from IMRT planning technique in terms of planned target volume (PTV) coverage, OAR protection, HI, CI, MU and treatment duration above the standart doses. From the aspect of treatment duration and MU parameters, h-IMRT technique can be considered as an alternative planning option.

Keywords: IMRT; esophageal cancer; radiotherapy

ÖZET Amaç: Bu çalışmanın amacı özofagus kanserli hastalarda, hedef hacim doz dağılımı ve kritik organ korunması açısından, üç boyutlu konformal radyoterapi (3-DCRT), yoğunluk ayarlı radyoterapi (IMRT) ve hibrit IMRT (h-IMRT) planlama tekniklerinin dozimetrik olarak karşılaştırılmasıdır. H-IMRT tekniğinin rutin kullanımı da ayrıca değerlendirilmiştir. **Gereç ve Yöntemler:** Özofagus kanserli 14 hastaya, 3D-CRT, IMRT ve h-IMRT tekniklerinin her biri ile 59,4 Gy total doz için toplam 42 plan yapılmıştır. Dozimetrik değerlendirmeler ve tekniklerin karşılaştırılması, doz hacim histogramları (DVH), homojenite index (HI), konformite indexi (CI) ve monitör ünite (MU) hesaplama parametrelerine göre yapılmıştır. Doz dağılımlarının kalite kontrolleri tedavi planlama sistemi (TPS) yardımıyla yapılmıştır, iki boyutlu doz dağılımları ve nokta dozlar sırasıyla MatriXX ve iyon çemberleriyle ölçülmüştür. **Bulgular:** Özofagusun tüm bölgelerinde IMRT tekniği PTV kapsaması açısından 3D-CRT ve h-IMRT tekniklerinden daha başarılı bulunmuştur. HI, tüm tekniklerde kabul edilebilir limitlerdedir, ancak CI açısından IMRT ve h-IMRT teknikleri daha iyi bulunmuştur. Beklenildiği üzere, tedavi süresi ve MU, IMRT tekniğinde yüksek bulunmuştur. **Sonuç:** Tüm tekniklerle yapılan planlamalar kabul edilebilir sınırlarda olsa da, farklı planlama tekniklerinin dozimetrik karşılaştırmaları, standart tedavi dozlarının üstündeki dozlarda 3D-CRT planlama tekniğinin PTV sarımı, riskli organ korunması (OAR), HI, CI, MU ve tedavi süresi bakımından belirgin istatistiksel farklılıkları olduğunu ortaya koymuştur. Tedavi süresi ve MU parametreleri açısından, h-IMRT tekniği alternatif planlama tekniği olarak değerlendirilebilir.

Anahtar Kelimeler: IMRT; özofagus kanseri; radyoterapi

Esophageal cancer is a relatively common gastrointestinal cancer and associated with higher mortality rates.[1] According to Surveillance, Epidemiology, and End Results (SEER) data, the 5-year survival rate is 19.9%, the number of deaths is 16.080 in 2019, and it was consisting 2.6% of all cancer deaths.[2]

Correspondence: Timur KOCA
Department of Radiation Oncology, Akdeniz University Faculty of Medicine, Antalya, TURKEY/TÜRKİYE
E-mail: timurkoca3@gmail.com

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Despite advances in diagnosis and multimodal treatments (surgery, radiotherapy, chemotherapy), esophageal cancer is still associated with poor prognosis.[3-5] Radiation techniques are stated to be important to maximize tumor control and minimize morbidity.[3,6-8] In the non-surgical definitive treatment of esophageal cancers, total radiotherapy dose was determined as 50.4 Gy in the phase III study of RTOG 94-05 and it was reported that higher doses did not contribute to overall survival and local/regional control.[9] But in some studies, and recent meta-analyses, the use of treatment doses of 59.4 Gy or higher in radiotherapy has been reported to contribute to overall survival, progression-free survival and local/regional control.[10-12]

In esophageal cancer radiotherapy the h-IMRT approach is may be an additional alternative planning technique for radiotherapy clinics. In this technique, primary contribution to treatment plan doses is provided by 3D-CRT, while IMRT technique is used to add higher doses to PTV and to protect critical organs in the meantime. This reduces the uncertainty of very high and very low doses due to thorax movement in non-respiratory assisted therapies. Also it is reported that errors in dose calculation algorithms due to tissue heterogeneity can be reduced in small areas. For these reasons, it is envisaged that h-IMRT technique can be used for tumors located in the thoracic region.[13]

In this study 3D-CRT, IMRT and h-IMRT techniques were compared for above the recommended standard treatment doses of esophageal cancer radiotherapy plans in terms of target volume dose distributions and critical organ protection. It is aimed to obtain optimal treatment plans by using the advantages of these planning techniques while minimizing their disadvantages. Also, the applicability of the h-IMRT technique in the routine manner was evaluated by these comparisons.

METERIAL AND METHODS

This study was conducted in Akdeniz University Department of Radiation Oncology between the years 2012 and 2019, and based on the data of totally 14 patients (seven males and seven females) aged between 46 and 74 years (median: 64). Computed tomography (CT) data obtained for planning purpose of patients with intrathoracically located and hystopathologically confirmed esophageal squamous cell cancer were used in the study. Live material was not used and ethical permission was obtained for the study. The location of the disease was at the upper esophagus in 6 patients, the middle esophagus in 6 patients and the lower esophagus in 2 patients. Due to the limited number of patients in each group, it could not be possible to divide into subgroups. The patients with gastric junction located disease were excluded. The mean PTV volume was 432 cc and the PTV volume range was between 141.6 -855.0 cc.

All patient's CT (Computerized Tomography; General Electric (GE) brand LightSpeed ™ RT model) sectional data were taken from the archive and transferred again to the TPS. Target volumes and dose-limiting normal tissues at-risk were contoured by radiation oncologists on CT images obtained from the GE brand Adwire™ model contouring and virtual simulation computer. Treatment plans were designed with Elekta brand Precise 2.15™ model treatment planning system for totally 33 fractions with a 180 cGy daily fraction dose. This TPS uses "Full Area Integration" algorithm for 3D-CRT and "Aperture Based Inverse Planning" algorithm for IMRT dose calculations. For the quality control of the 3D-CRT and IMRT plans, the Elekta brand Synergy and Synergy Platform model linear accelerator devices with the same collimator structure and field widths were used in dose measurements.

For all patients with upper esophageal cancer, totally six portals with 30°, 60°, 160°, 200°, 300° and 330° gantry angles were selected for plans designed with the 3D-CRT technique. The same gantry angles were used for all patients and 6 MV photon energy was selected for all fields and then treatment plans were established. In the 3D-CRT plans designed for patients with middle esophageal cancer, 0°, 180° and two oblique fields were used. The gantry angles of the two oblique fields varied between angles of 110°-130° and 230°-250°. The fields were modified according to the patients' anatomy and tumor size. Photon energy of 6 MV was used at an angle of 180°, while the photon energy of 10 MV was used for the other three fields. In the plans for lower esophageal patients with 3D-CRT technique, 4 fields were used. Gantry angles of 0° and 180° were the same for both patients. However, the lateral angles varied according to the patient anatomy, tumor size and immobilization. Lateral gantry angles were 70°-300° for the first patient and 90°-270° for the second patient. Ten MV photon energy was used for all fields.

For the IMRT (step and shoot) plans of the upper and lower esophageal cancer patients non-coplanar 9 portals were used. Selected gantry angles were 0°, 40°, 80°, 120°, 160°, 200°, 240°, 280° and 320°. For the patients with middle esophageal cancer, plans were created by using the same angles with the IMRT technique without change in angles of 3D-CRT plans. Treatment plans were created by using TPS 'Aperture Based Inverse Planning' algorithm and 6 MV photon energy was used in all areas. Dose definitions of PTV and OAR were made by "the dose volume optimizer" calculation algorithm. The OAR protections were based on the QUANTEC and NCCN criteria. By giving weight values to the definitions according to the importance, at least 95% of the PTV were ensured to receive 95% of the desired dose. The OAR were tried to be provided with optimum protection. With this algorithm, repetitions were made to obtain desired dose distributions, thus appropriate segment number and densities were determined. After the plan reached the desired criteria, the segments under the 2 MU were deleted and the plans were completed.

For the hybrid treatment plans 2/3 of the prescribed dose was planned with 3D-CRT technique and the remaining 1/3 planned with IMRT in the TPS. Hybrid plans were created separately for each sections of the esophagus. For the upper, middle and lower esophagus, unified 3D-CRT and IMRT planning techniques were used. The gantry angles and energy choices used for the both techniques were not changed. Plans were combined in TPS and analyses were made on the total plan.

PTV and organs at risk (OAR) doses of the designed treatment plans were calculated with TPS and evaluated separately for each technique by the DVHs. For the target volume, plans were evaluated with D2, D50, D95, D98, Dmin, Dmax and Dmean parameters. Dose limits for OAR were determined by QUANTEC (Quantitative Analyses of Normal Tissue Effects in the Clinic) and NCCN (National Comprehensive Cancer Network) dosimetric plan evaluation protocols. HI and CI data evaluations were made for all plans.

In the calculation of HI, the correlations specified in the ICRU 83 and RTOG protocols were used (equation 1 and 2 respectively).[14,15]

$$HI = \frac{D_2 - D_{98}}{D_{50}} \quad (1) \qquad \text{and} \qquad HI = \frac{I_{max}}{RI} \quad (2)$$

CI data were calculated by using the equations specified in the ICRU 62 and RTOG protocol (equation 3 and 4 respectively).[15,16]

$$CI = \frac{TV}{PTV} \quad (3) \qquad \text{and} \qquad CI = \frac{V_{RI}}{TV} \quad (4)$$

MU values and treatment durations for each technique were also compared. For all non-target healthy tissues, the percent volume values occupied by 50 percent (2970 cGy) of the treatment dose were analysed for each technique.

Statistical analyses of the planning data obtained from the three different planning techniques was supported by Akdeniz University Statistical Consultancy Application and Research Center. In the comparison of 3D-CRT, IMRT and h-IMRT plans in terms of PTV and critical organ doses, Friedman's Two Way Test was applied.

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Akdeniz University (Date: 24.04.2019/No: 369/Code: 2012-KAEK-20).

RESuLTS

For all patients the statistically significant results of the dosimetric comparisons of PTV and risky organ dose data of the applied 3 different treatment planning techniques were shown in Table 1 and Table 2 in pairs of binary comparisons depending on tumor location.

Findings of upper esophageal cancer patients are presented in Table 1.

When the statistical binary comparisons of all three techniques for PTV doses were evaluated; statistically significant differences were found between 3D-CRT and IMRT plans in terms of D2, D95, Dmin, Dmax, and Dmean parameters in favour of IMRT technique. There was no significant difference for the same parameters between binary comparisons of the other planning techniques.

In the evaluation of CI data results according to ICRU 62 recommendations, statistically significant differences were found between 3D-CRT and IMRT planning techniques (p=0.004). The closest CI value to 1 was achieved with the 3D-CRT technique. As a result of separate evaluations according to RTOG and ICRU 83, HI data of the plans for all techniques were found to be in accordance with the protocol recommendations but, there was a significant difference between 3D-CRT and IMRT plans from the aspect of HI (p=0.002 and p=0.002, respectively). Dose distribution in PTV was more homogeneous in plans obtained by the IMRT technique. In other binary comparisons of the techniques, no significant differences were found between CI and HI values for different planning techniques.

When all three planning techniques were compared in terms of lung doses V10Gy, V13Gy, V20Gy, V30Gy, V40Gy and Dmean, there was no statistical significance between techniques, but only total lung V5 dose was significantly higher in h-IMRT technique compared to 3D-CRT technique (p<0.05). When heart doses were evaluated with binary comparisons of 3D-CRT and IMRT techniques, a statistical significance was observed in favour of IMRT in terms of Dmean. The Dmean of the heart was significantly lower in the plans of the IMRT technique (p=0.005). When the planned risk volumes (PRV) of the spinal cord were evaluated, it was found that, Dmax was significantly different between the IMRT and h-IMRT plans, and was higher in the IMRT technique plans (p=0.028).

In the whole body structure covered by the external contour of the patient, the volume values enclosed by 2970 cGy, which is 50% of the treatment dose, was evaluated as normal tissue integral dose.

TABLE 1: Statistically significant PTV and OAR dose parameters between three different planning techniques for upper esophageal cancer patient plans.

Mean ±SD	3D-CRT	IMRT	h-IMRT	p value 3D-CRT & IMRT	IMRT & h-IMRT	h-IMRT & 3D-CRT
PTV						
D_2 (cGy)	6724.05±198.52	6282.55±77.72	6431.00±142.95	0.002	0.250	0.250
D_{95} (cGy)	4975.70±123.50	5722.67±113.02	5278.38±87.00	0.002	0.250	0.250
D_{min} (cGy)	4212.17±137.95	5022.33±424.14	4548.33±246.66	0.002	0.250	0.250
D_{max} (cGy)	7095.67±205.80	6476.33±207.13	6756.83±140.80	0.004	0.745	0.130
D_{mean} (cGy)	5829.83±128.13	5995.00±29.77	5884.83±88.48	0.002	0.250	0.250
CI (ICRu62)	1.32±0.31	1.60±0.18	1.38±0.26	0.004	0.745	0.130
HI (RTOG)	1.29±0.08	1.15±0.05	1.21±0.05	0.002	0.250	0.250
HI (ICRu83)	0.34±0.02	0.12±0.05	0.23±0.04	0.002	0.250	0.250
Total Lung						
V_{5Gy} (cc)	983.17±366.17	1005.33±364.31	1019.68±352.24	1.000	0.182	0.042
Heart						
D_{mean} (cGy)	75.00±44.09	60.60±32.49	70.20±40.09	0.005	0.342	0.342
PRV-Spinal Cord						
D_{max} (cGy)	4287.67±573.73	4640.50±171.80	4488.33±100.67	0.250	0.028	1.000
NTID (cc)	1499.52±506.78	1321.87±565.29	1295.72±567.88	0.028	1.000	0.028
Mu	235.50±7.58	309.17±19.99	263.33±8.45	0.002	0.250	0.250
Treatment duration (minute)	0.39±0.01	0.52±0.03	0.44±0.02	0.002	0.250	0.250

h-IMRT: Hybrid IMRT, CI: Conformity index, HI: Homogeneity index, D_X (Gy)= Dose (Gy) absorbed by certain percentage (%) or absolute volume (cm^3) of the contoured structure; V_X= Percentage of organ volume exposed to certain radiation dose, PRV: Planned risk volume NTID: Normal tissue integral dose, Mu: Monitor unit.

TABLE 2: Statistically significant PTV and OAR dose parameters between three different planning techniques for midle and lower esophageal cancer patient plans.

Mean ± SD	3D-CRT	IMRT	h-IMRT	p value 3D-CRT & IMRT	p value IMRT & h-IMRT	p value h-IMRT & 3D-CRT
PTV						
D_{95} (cGy)	5371.60±651.70	5771.39±91.66	5694.84±143.37	0.008	1.000	0.073
D_{min} (cGy)	4946.50±625.55	5361.25±145.82	5276.38±186.04	0.001	0.401	0.073
CI (RTOG)	0.90±0.11	0.98±0.02	0.95±0.07	0.001	0.184	0.184
HI(RTOG)	1.03±0.37	1.00±0.36	1.01±0.37	0.037	1.000	0.137
HI ICRu83	0.22±0.23	0.22±0.38	0.24±0.37	0.008	0.401	0.401
Total Lung						
V_{30Gy} (cc)	875.46±609.38	559.22±312.88	908.29±915.76	0.008	0.073	1.000
V_{40Gy} (cc)	498.74±420.58	379.85±192.57	436.21±223.04	0.003	0.137	0.634
PRV-Spinal cord						
D_{max} (cGy)	4156.00±692.00	4478.50±577.32	4387.50±438.56	0.008	0.401	0.401
Mu	221.00±9.29	266.88±12.53	236.25±9.82	0.000	0.137	0.137
Treatment duration (minute)	0.37±0.02	0.44±0.02	0.39±0.02	0.000	0.137	0.137

h-IMRT: Hybrid IMRT, CI: Conformity index, HI: Homogeneity index, D_X (Gy) = Dose (Gy) absorbed by certain percentage (%) or absolute volume (cm^3) of the contoured structure; V_X= Percentage of organ volume exposed to certain radiation dose, PRV: Planned risk volume NTID: Normal tissue integral dose, Mu: Monitor unit.

3D-CRT versus IMRT and h-IMRT versus 3D-CRT binary comparisons showed that integral doses were significantly lower in the plans created by the IMRT and h-IMRT techniques.

In the evaluation of the monitor unit (MU) data, it was found that, it was higher for IMRT technique and statistically significantly different from 3D-CRT planning. Treatment duration were evaluated between the planning groups and it was determined that treatment duration was significantly longer than the 3D-CRT in IMRT technique (p=0.002).

Findings of middle and lower esophageal cancer patients are presented in Table 2.

In the evaluation of 59.4 Gy PTV doses used for patients with middle and lower esophageal tumors, there were differences between the plans in terms of D95 and Dmin parameters. Although these two parameters were higher in IMRT plans when compared to other tehniques but only the difference with 3D-CRT plans were statistically significant (Table 2). In terms of dose conformity and homogeneity indexes (RTOG and ICRU-83), in the two-group comparison of the planning techniques, the plans made by IMRT technique showed a statistically significant supperiority to those made with 3D-CRT technique.

When the total V30 and V40 doses for lung were examined; in the IMRT plans these volumetric doses were statistically significantly lower than 3D-CRT plans. PRV Dmax doses for spinal cord were significantly lower in 3D-CRT plans than IMRT and h-IMRT plans. It can be said to be there is a better spinal cord protection in favour of 3D-CRT planning technique. Binary comparisons between IMRT and h-IMRT plans for spinal cord doses was evaluated as insignificant. The MU values were significantly higher in the IMRT plans and the treatment duration was significantly longer than the 3D-CRT plans.

DISCuSSION

Generally in the planning of radiation therapy, the defined dose is intended to encompass the predetermined PTVs as well as possible. Also it is aimed to ensure that the tissues and organs considered critical and risky receive the minimum dose as possible. In their dosimetric comparisons of 3D-CRT versus IMRT for cervical esophageal cancer Fenkell et al. reported that IMRT provides superior PTV coverage.[17] In another study of 20 patients who received radiotherapy for esophageal cancer, 4 field box technique (4FB) and in-field-field (FIF) technique were compared in terms of dosimetric and radiological parameters. The FIF technique has been reported to be advantageous in terms of PTV coverage over the 4FB technique.[6] In a study comparing dosimetric IMRT plans for 4, 5 and 7 portals in 15 patients receiving radiotherapy for upper thoracic esophageal cancer, similar results were obtained for PTV doses (mean and maximum values) and PTV coverage.[18] In the current study, for all regions of the esophagus found to be very difficult to fully cover PTV with 3D-CRT technique and the technique produced very high and low dose regions in the target volume.

Dose conformity is indicating the degree of which the high dose region complies with the target volume, while dose homogeneity is the data of absorbed dose distribution within the target volume. Conformity (CI) and homogeneity indexes (HI) are used as two analysing tool for treatment plans.[19] It has been reported that FIF technique is close in terms of dose suitability compared to 4FB technique, but it is statistically significantly superior in term of homogeneity.[6] For upper thoracic tumors, conformity index results were found to be similar for IMRT plans with 4, 5 and 7 fields.[18] Values of CI above 1 indicates that, the tumor and a portion of the healthy tissue are exposing to an overdose. The value of CI below than 1 indicates that the target volume cannot be adequately covered and this is not desirable. When we look at the CI index results of our study, someone can say that, the IMRT and h-IMRT techniques covers the tumor more appropriately in all regions of the esophagus.

For the HI (ICRU) values of the PTVs, although for all techniques the values found were close to zero but; the IMRT technique was found to be the planning technique providing the closest value to zero. According to RTOG, if the homogeneity index is above 2, treatment is considered to be in accordance with the protocol.[15] In our study, for all plans made with different techniques, HI values were found to be below 2.

For the lungs V5 is an important parameter for the development of radiation pneumonia, and V5Gy $\leq$ 70 is considered as the limit value for lungs.[20] In a study, considering only dosimetric factors, when the lung volume receiving 5 Gy or above exceeds 60% of total lung volume was considered as an important factor for the development of symptomatic pneumonia.[21] In their study, Fu et al. compared 4, 5 and 7 field IMRT plans and reported that in multiple evaluations of 4-field IMRT plans, mean V5Gy, V13Gy, V20Gy and total lung doses were significantly reduced compared to 5 and 7 field plans.[18]

In their study investigating h-IMRT in the treatment of patients with lung and esophageal cancer, Mayo et al. stated that they had given 2/3 of the total dose by static rays and remaining 1/3 by IMRT. They had created four plans for each of the 18 patients by using h-IMRT, 3D-CRT, 5-field IMRT and 9-field IMRT techniques. They reported that the highest value of V5 parameter of the lung was belong to h-IMRT with 84%.[13] In our trial the highest V5 value was been observed in h-IMRT plans designed for upper esophageal patients. When the dose data of middle and lower esophageal patients were examined, it was seen that, total lung area volume receiving 3000 and 4000 cGy was decreased with IMRT technique.

In a trial investigating the dosimetric differences among 3D-CRT, IMRT and VMAT techniques for esophageal cancer, investigators decided that, IMRT and VMAT techniques provided better heart protection than 3D-CRT by the means of V20, V30 and Dmean parameters.[22] In a dosimetric comparison study Choi et al. had obtained 19.85 ± 15.00 Gy and 10.71 ± 8.72 Gy dose values in static IMRT technique for V30 and V40 heart doses, respectively. Considering these dose parameters, they had been reported better heart protection in favour of IMRT compared to other techniques ($p<0,039$ and $p<0,040$ respectively).[1] Similarly, in our study, it was observed that IMRT technique provided better results in heart protection. Besides, the h-IMRT technique includes the 3D-CRT technique and does not able to provide sharp dose transitions such as IMRT.

The spinal cord is a serial organ and the Dmax dose is important. In a study of Allaveisi and Moghadam, the maximum dose value of the spinal cord was being found 32,80 Gy with FIF technique and it was emphasized that FIF technique was better for spinal cord protection than the 4FB technique.[6] In another study, the maximum value for the three field IMRT technique was found as 56.9 Gy in 4 out of 5 patients for the spinal cord and it was stated that this technique was unacceptable because of this value was well above the limit.[18]

In a study where dosimetric comparisons of IMRT and VMAT techniques were performed in patients with esophageal cancer without intrathoracic localization differences, it was shown that IMRT technique were increased the spinal cord Dmax dose in plans of middle and lower esophageal tumors.[23] In our study, Dmax below 45 Gy parameter for spinal cord was provided with all techniques, but it was observed that the 3D-CRT technique was better in spinal cord protection. However, this difference was found to have statistical significance only for middle and lower esophageal tumors. When the value of healthy tissue in the irradiated area was analysed except for critical organs it was observed that, normal tissue volume exposed to low radiation doses increased with IMRT compared to conventional radiotherapy. Numerous beams used in IMRT had been reported to cause an increase in integral doses. Since the increase of the integral dose increases the likelihood of normal tissue damage, the integral dose should be kept to a minimum to ensure that the tumor receives sufficient radiation and that critical organs are protected. However, it was emphasized that, the total energy accumulated in a patient during irradiation is quite independent of treatment planning parameters.[24-26] In this study, volume values receiving 2970 cGy, which is 50% of the dose applied in the whole body structure covered by the external contour of the patient (NTID), were obtained for 3D-CRT, IMRT and h-IMRT planning techniques and h-IMRT technique had provided the lowest volume value for NTID.

In a study comparing dosimetric methods of IMRT and VMAT (single and double arc) techniques in thoracic esophageal cancer, Abbas et al. reported that they had provided higher MU values with IMRT.[7] In another study, it was stated that MUs were 25% lower in FIF technique.[6] In our current study, when we compare MU values among three techniques in all regions of esophagus, the highest MU value was found in IMRT technique. As a result of the analysis of treatment periods, the longest treatment duration among the planning techniques for all regions of the esophagus emerged in the IMRT technique. In clinical practice, h-IMRT can be considered more advantageous in terms of treatment time because it includes two seperate techniques.

CONCLUSION

Above the standard recommended doses there is a statistically significant difference between the 3D-CRT and IMRT planning techniques in terms of PTV dose coverage and risky organ doses. On the other hand, the PTV coverage and critical organ doses obtained by h-IMRT technique are very close to the dosimetric results obtained by IMRT. In terms of MU and duration of treatment, 3D-CRT and h-IMRT techniques have similar results. Although the 3D-CRT planning technique is still being used in clinics, considering the chronic toxicities of radiotherapy, it may be advisable not to prefer it over the routine doses. In addition to the standard radiotherapy planning techniques, it is possible to use hybrid IMRT technique in patients with esophageal cancer. In clinics with high patient number with limited facilities, for treating the patients above the standard treatment doses h-IMRT planning technique could be evaluated as an option.

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Hatice Erdem, Nina Tunçel, Timur Koca; Design: Hatice Erdem, Nina Tunçel; Control/Supervision: Aylin Fidan Korcum, Timur Koca; Data Collection and/or Processing: Nina Tunçel, Hatice Erdem; Analysis and/or Interpretation: Nina Tunçel, Hatice Erdem;Literature Review: Timur Koca, Aylin Fidan Korcum; Writing the Article: Hatice Erdem, Timur Koca; Critical Review: Nina Tunçel Nina Tunçel; References and Fundings: Aylin Fidan Korcum, Timur Koca; Materials:Timur Koca, Hatice Erdem.

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