DERLEME REVIEW

Investigation of the Effects on Dose Distributions of Contrast Agents Used in Stomach Cancer Radiotherapy

Mide Kanseri Radyoterapisinde Kullanılan Kontrast Maddelerin Doz Dağılımlarına Olan Etkilerinin İncelenmesi

Serhat ARAS,[a]
Meryem AKTAN,[a]
Mehmet KOÇ[a]

[a]Department of Radiation Oncology, Konya Necmettin Erbakan University Meram Faculty of Medicine, Konya

Geliş Tarihi/*Received:* 20.05.2017
Kabul Tarihi/*Accepted:* 28.07.2017

Yazışma Adresi/*Correspondence:*
Serhat ARAS
Konya Necmettin Erbakan University Meram Faculty of Medicine, Department of Radiation Oncology, Konya,
TURKEY/TÜRKİYE
serhataras1985@gmail.com

ABSTRACT The aim of this study is to investigate the effects of contrast agents used during planning CT scans on the radiotherapy treatment planning dose calculations in a stomach cancer radiotherapy with regard to dosimetry. Taken into account the cases which included the presence of contrast medium (500-HU) and the absence of contrast medium (0-HU) for stomach radiotherapy, Planning Target Volume (PTV) and the Dose Volume Histograms (DVH) of the critical organs like liver and right and left kidneys at risk were compared as dosimetrically. For the 5 stomach patients involved in the study, the PTVs of patients with radiotherapy treatment plans and the DVH of the critical organs liver and right and left kidneys at risk were compared, and the dosimetric differences between 1-2% were calculated. In addition, a dose difference of 2-2.5% was calculated since the left kidney is close to the anatomic area in which the contrasting substance takes place.

Keywords: Contrast agents; stomach cancer; radiotherapy

ÖZET Bu çalışmanın amacı, mide kanseri RT'sinde planlama BT çekimi sırasında kullanılan kontrast maddelerin, RT tedavi planlama doz hesaplamalarına olan etkilerini dozimetrik olarak incelenmesidir. Aynı Pencil Beam Convulation (PBC) doz hesaplama algoritması ile Modified Batho doz düzeltme algoritması (Heterogeneity Correction Factör) kullanıldı. Mide radyoterapisi için kontrast maddenin olduğu (500-HU) ve olmadığı (0-HU) durumlar dikkate alınarak, planlanan hedef hacim (PTV) ile risk altındaki karaciğer, sağ ve sol böbrek kritik organlarının Doz Hacim Grafikleri (DVH) dozimetrik olarak karşılaştırıldı. Planları yapılan hastaların PTV'leri ile risk altındaki karaciğer, sağ ve sol böbrek kritik organlarının DVH'leri karşılaştırıldı ve %1-2 arasında dozimetrik farklılıklar hesaplandı. Ayrıca sol böbrek, kontrastlı maddenin yer aldığı anatomik bölgeye yakın olduğundan %2-2,5 arasında doz farklılığı hesaplandı.

Anahtar Kelimeler: Kontrast madde; mide kanseri; radyoterapi

Surgery, radiotherapy and chemotherapy are the major treatment ways for stomach cancer. A number of factors such as tumor size, location, spread, lymph node involvement, and patient performance impact on the treatment approach for stomach cancer. Through using high-energy x-rays, it is aimed to irradiate tumor beds and lymphatic areas after surgery in radiotherapy. In radiotherapy of stomach cancer, when a total dose of 45-50.4 Gy is delivered to the planning target volume (PTV), critical organs such as liver, spinal cord, heart, lungs, kidneys around the target volume are planned to be exposed to the least radiation.[1,2] Computed tomography is used for radiotherapy treatment planning in patients with stomach cancer and in order to be able to image the remaining stomach volume, barium sulphate ($BaSO_4$) contrast medium is administered orally to patients during the examination. It is of most importance for the patient volume to make sure the dosimetric effects of contrasting agents used for imaging purposes in radiotherapy treatment planning. For this reason, in the literature there is a hot discussion on the determination of the effects of the contrast agents used for imaging the tumor volume in stomach radiotherapy on dose distributions.[3,4] Used in CT imaging, high-density barium-contrasted contrast agents increase the Hounsfield Unit (HU) value and makes it a high-density tissue. As a result of this, while the organs can be visualized anatomically, radiotherapy differs in dosimetry during the treatment planning.[5,6] The aim of this study is to investigate the effects of contrast agents used during planning CT scans on the radiotherapy treatment planning dose calculations in a stomach cancer radiotherapy with regard to dosimetry.

In the present study, we used a linear accelerator (Siemens Primus) which can make three dimensional (3D) conformal radiotherapy, Pencil Beam Convolution (PBC) dose calculation algorithm and Modified Batho dose correction algorithm (Heterogeneity Correction Factor) through which the data is transferred.[7] Five patients with stomach cancer were underwent a CT of 5 mm. The Planning CT images of the patients were taken and the contrast medium volume (500-HU) was contoured. The same volumes were also recognized and recorded as water-tissue equivalents (0-HU) (Figure 1).[8]

In the treatment planning systems (Eclipse, $V_{8.9.08}$ Varian, USA) in which 6 MV and 18 MV photon energies were used, the treatment planning were conducted for the data defined in both ways. Taken into account the cases which included the presence of contrast medium (500-HU) and non-contrast medium (0-HU) for stomach radiotherapy, Planning Target Volume (PTV) and the Dose Volume Histograms (DVH) of the critical organs like liver and right and left kidneys at risk were compared as dosimetrically.

Moreover, in our study, we constructed a 25x25x25 cm^3 cubic rectilinear phantom center including 500-HU barium sulfate ($BaSO_4$) and 0-HU water equivalent, and 4x4x4 cm^3 cubic phantoms for two different cases in the Eclipse treatment planning system (Figure 2).

Following the calculations which were made for 6 MV photon energy on virtual phantoms, Gantry 0° irradiation angle, cubic dose calculation voxels with 0.25 cm^3 volume, 10x10 cm^2 beam area and dose calculation plans for skin source distance (SSD)= 100 cm for both cases, the dose distribution profiles at lateral depth were compared.

For the 5 stomach patients involved in the study, the PTVs of patients with RT treatment plans and the DVH of the critical organs liver and right and left kidneys at risk were compared, and the dosimetric differences between 1-2% were calculated (Table 1). In addition, a dose difference of 2-2.5% was calculated since the left kidney is close to the anatomic area in which the contrasting substance takes place.

When the dose profiles of the lateral axis in the contrast and non-contrast cubic phantom placed in the 25x25x25cm^3 cubic rectilinear phantom center were compared, the dosimetric difference below 1% (Figure 3) and the measurement difference of 2% in the Monitor Unit (MU) values were calculated.

It is of very important to determine the location and volume of the tumor for the treatment planning in stomach cancer radiotherapy. The administration of contrast medium during the tomographic imaging for planning allows for relative separation of normal and tumorous tissue from each other. For radiation oncologists, the determination of the tumor boundaries is a supporting feature in creating a treatment plan.[9] With the advancements in

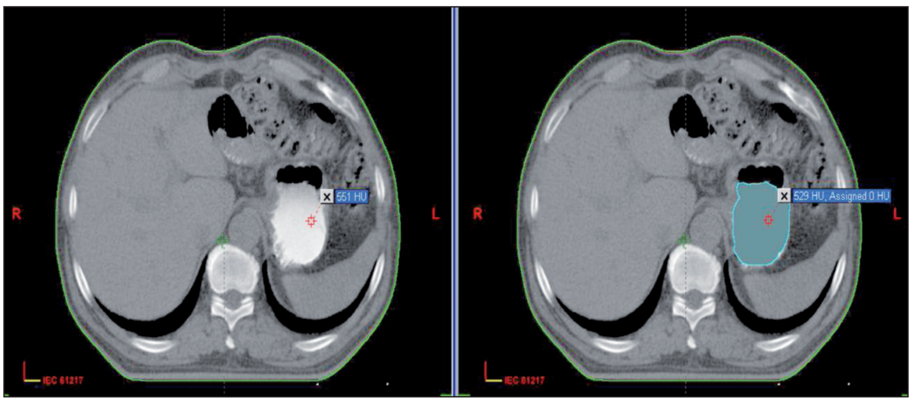

FIGURE 1: Volume image of contrast material (500-HU) and volume image defined as water-tissue equivalent (0-HU)/

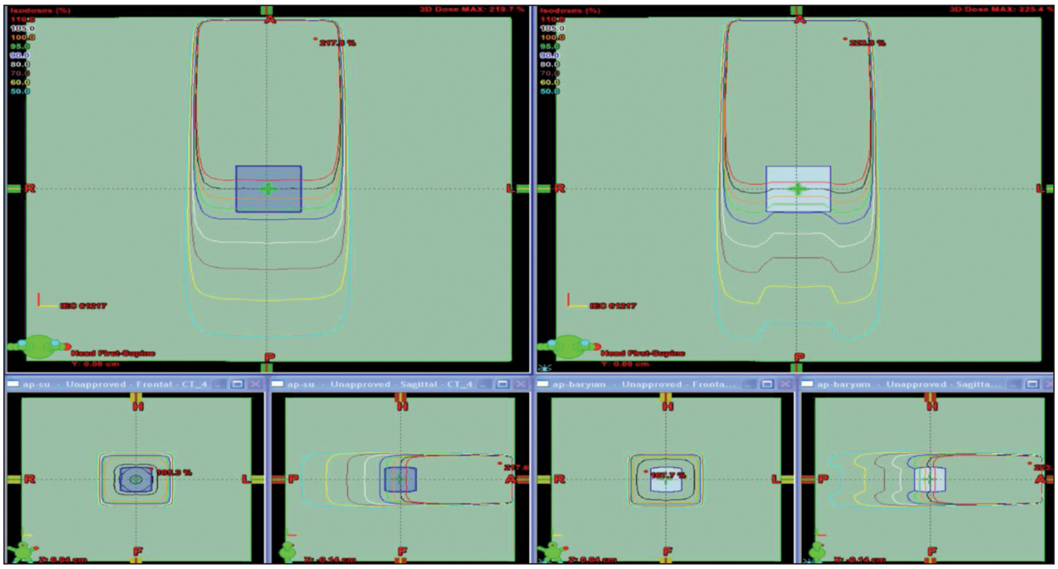

FIGURE 2: Barium sulfate (BaSO4) with 500-HU value (right) cubic phantom and water equivalent of 0-HU (left) cubic phantom.

the computer technology, there exist dose calculation programs which are used both as research and for simulation purposes in clinics. There are studies based on different tissue and heterogeneous environments for dose calculation programs such as Monte Carlo (MC), Pencil Beam (PB), AAA and CC which are used in treatment planning systems especially in clinics.[10] Through using the dose calculation algorithms such as Monte Carlo, Pencil Beam, AAA and CC, Fogli-

TABLE 1: % dose differences for PTV and liver at risk, right and left kidney critical organs.

	Min. Dose Difference %	Max. Dose Diffrence %	Mean Dose Diffrence %
PTV	2.26	1.97	1.69
Liver	2.74	1.75	1.88
Right Kidney	1.20	1.05	1.12
Left Kidney	2.54	2.24	2.02

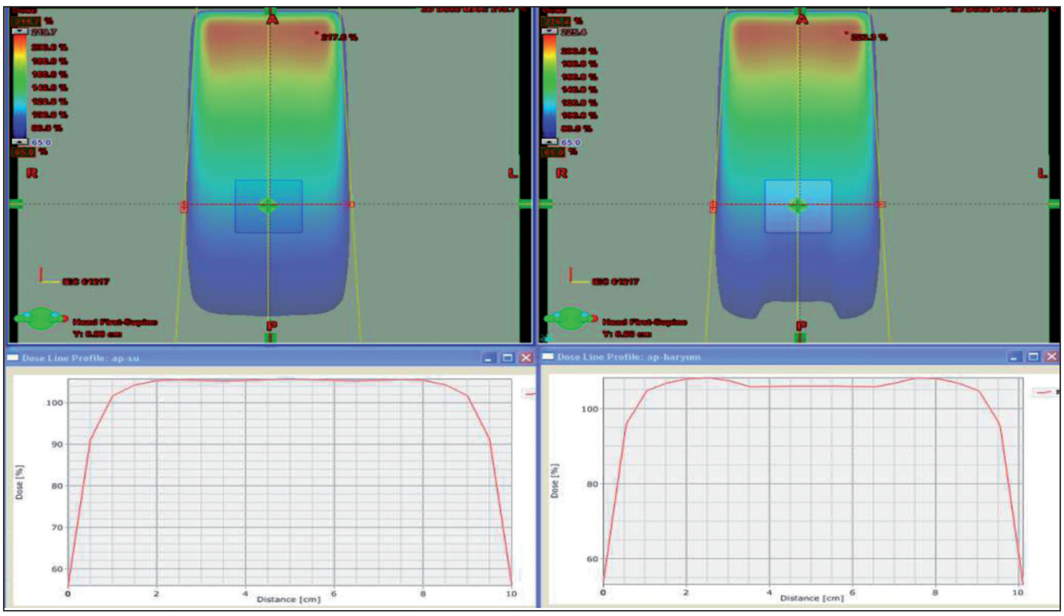

FIGURE 3: Dose distribution profiles of lateral axis obtained with contrast and uncontrasted cubic phantom.

ata et al. evaluated the measurements they obtained in the special heterogeneous phantom prepared at different densities as well as the water-tissue equivalent (HU=0). The conclusion drawn was that the dose values obtained through this particular heterogeneous phantom are directly related to the sensitivity of the dose calculation algorithms which are used.[11] Choi and Lee et al. pointed out that the dose differences were below 1% which were obtained as a result of contrast agent used in head and neck cancers and this value can be disregarded.[12] Fayda et al. studied on the effects of intravenous contrast agents on different treatment planning systems in the planning of treatment of lung cancer. They examined the changes in doses calculated by different algorithms of two different treatment planning systems of the use of intravenous contrast agent in the planning of three dimensional conformal radiotherapy of lung cancer.

As a result of the study, though it is thought that three-dimensional radiotherapy planning can be done through contrast-enhanced CT scans, they thought that target volumes should be determined on contrasted sections and then making fusion and planning with non-contrasted sections on non-contrasted sections would be the most appropriate approach.[13] The current dose inhomogeneity correction algorithms cannot address all the interactions involved in the complex geometry as in Monte Carlo methods.[14] The studies conducted previously have shown that it is the convolution/superposition algorithm that gives the closest result to the Monte Carlo calculations.[15]

In anatomic regions, in which the PBC dose calculation algorithm is used, with inhomogeneity such as stomach cancer filled especially with contrast medium, the Modified Batho correction-based algorithm is insufficient in dose calculations of treatment plans for inhomogeneous structures. In addition to the PBC dose calculation algorithm, together with the dose calculation algorithms such as Monte Carlo, Anisotropic Analytical Algorithm (AAA), Collapsed cone convolution, and convolution/superposition compared as dosimetrically and used in the correction-based algorithms, the adoption of the most optimal patient dose plan will yield better results.

In the dose volume histograms developed for the two cases with and without contrast agents used for imaging purposes in stomach cancer, Planning Target volume (PTV), liver exposed to radiation, right and left kidney and total MU and dose distribution profiles in lateral axis, which result in higher dosimetric differences can be calculated in the studies in which it is reproduced with Monte Carlo, were predicted.

REFERENCES

1. Khan FM. The Physics of Radiation Therapy. 3rd ed. Department of Therapeutic Radiology University of Minnesota Medical School Minneapolis; 2002. p.467-75.
2. Yovino S. Intensity-Modulated Radiation Therapy Significantly Improves Acute Gastrointestinal Toxicity in Pancreatic and Ampullary Cancers 2011;79(1):158-62.
3. Lees J, Holloway L, Fuller M, Forstner D. Effect of intravenous contrast on treatment planning system dose calculations in the lung. Australas Phys Eng Sci Med 2005;28(3):190-5.
4. International Commission on Radiation Units and Measurements. ICRU Report 62. Prescribing, recording, and reporting photon beam therapy. Bethesda, MD: ICRU; 1999.
5. Choi Y. Influence of intravenous contrast agent on dose calculations of intensity modulated radiation therapy plans for head and neck cancer. Radiotherapy and Oncology 2006;81:158-62.
6. International Commission on Radiation Units and Measurements. ICRU Report 50. Prescribing, recording, and reporting photon beam therapy. Bethesda, MD: ICRU, 1993.
7. Engelsman M, Damen EM, Koken PW, van 't Veld AA, van Ingen KM, Mijnheer BJ. Impact of simple tissue inhomogeneity correction algorithms on conformal radiotherapy of lung tumours. Radiother Oncol 2001;60(3):299-309.
8. Carrasco P, Jornet N, Duch MA, Panettieri V, Weber L, Eudaldo T, et al. Comparison of dose calculation algorithms in slab phantoms with cortical bone equivalent heterogeneities. Med Phys 2007;34(8):3323-33.
9. Shibamoto Y, Naruse A, Fukuma H, Ayakawa S, Sugie C, Tomita N. Influence of contrast materials on dose calculation in radiotherapy planning using computed tomography for tumors at various anatomical regions: a prospective study. Radiother Oncol 2007;84(1):52-5.
10. Robar JL, Riccio SA, Martin MA. Tumour dose enhancement using modified megavoltage photon beams and contrast media. Phys Med Biol 2002;47(14):2433-49.
11. Ramm U, Damrau M, Mose S, Manegold KH, Rahl CG, Böttcher HD. Influence of CT contrast agents on dose calculations in a 3D treatment planning system. Phys Med Biol 2001;46(10):2631-5.
12. Fogliatta A, et al. On the dosimetric behaviour of photon dose calculation algorithms in the presence of simple geometric heterogeneities: comparison with Monte Carlo calculations. Phys Med Biol 2007;52:1363-85.
13. Lee FK, Chan CC, Law CK. Influence of CT contrast agent on dose calculation of intensity modulated radiation therapy plan for nasopharyngeal carcinoma. Journal of Medical Imaging and Radiation Oncolog 2009;53:114-8.
14. Fayda M, Yıldırım A, Tarpıcı N, Aksu G, Çakır A. Akciğer kanserinin tedavi planlamasında intravenöz kontrast ajanların farklı tedavi planlama sistemleri üzerindeki etkileri, Türk Onkoloji Dergisi 2008;23(3):126-31.
15. Bazalova M. Tissue segmentation in Monte Carlo treatment planning: A simulation study using dual-energy CT images. Radiotherapy and Oncology 2008;86:93-8.