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Research Article

Examination of the Dosimetric Effects of the Headrest Used in Radiotherapy by Different Algorithms

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Abstract

INTRODUCTION: The use of immobilization devices is imperative in radiotherapy to ensure proper positioning of the patient and correct application of the treatment. Headrests are frequently used to restrict the movement of a patient and to provide comfortable laying during the treatment. The aim of the present study was to examine the effect of a headrest on dose distribution by including the headrest in the body structure using two different algorithms. METHODS: The body structures on seven patient images were contoured with and without headrest. Dose distribution within the body was calculated for each patient using both Collapse Cone (CC) and Monte Carlo (MC) algorithms for cases where the headrest was included in the body structure and removed. The obtained results were compared with the gamma analysis method. RESULTS: The headrest has some effect on the dose distribution. Specifically, the results of the gamma analysis indicate that when the headrest was included in the body structure doses to the body were somewhat reduced. Since the CC algorithm does not allow calculation of secondary photons and scattered radiation sufficiently accurate in a low density environment, the similarity results of the CC algorithm were higher in the gamma analysis than those of the MC algorithm. DISCUSSION AND CONCLUSION: In order to accurately calculate the radiation dose, all the materials through which the radiation passes during the treatment must be specified in a treatment planning system. It is concluded that even if the immobilization devices are of low-density material, they have some effect on the dose distribution within a patient and should be included in the treatment planning system.

Keywords: Radiotherapy, immobilization devices, headrest, treatment planning system.

Radyoterapide Kullanılan Baş Yastığının Dozimetrik Etkisinin Farklı Algoritmalarla İncelenmesi

Öz

GİRİŞ ve AMAÇ: Radyoterapide immobilizasyon cihazlarının kullanılması hastanın doğru pozisyon alması ve tedavinin doğru uygulanması için zorunludur. Tedavi sırasında hastanın hareketini kısıtlamak ve rahat bir şekilde yatışını sağlamak için baş yastıkları sıklıkla kullanılmaktadır. Bu çalışmanın amacı, baş yastığının doz dağılımı üzerindeki etkisini iki farklı algoritma kullanarak incelemektir. YÖNTEM ve GEREÇLER: Yedi hasta görüntüsündeki vücut konturları, baş yastıklı ve baş yastıksız olarak şekillendirildi. Baş yastığının vücut konturuna dahil edilip çıkarıldığı durumlarda hem Collapse Cone (CC) hem de Monte Carlo (MC) algoritmaları kullanılarak her hasta için vücut içindeki doz dağılımı hesaplandı. Elde edilen sonuçlar gama analizi yöntemi ile karşılaştırıldı. BULGULAR: Spesifik olarak, gama analizinin sonuçları, baş yastığı vücut konturuna dahil edildiğinde hastaya ulaşan dozların bir miktar azaldığını göstermektedir. CC algoritması, düşük yoğunluklu bir ortamda ikincil fotonların ve saçılan radyasyonun yeterince doğru hesaplanmasına izin vermediğinden, CC algoritmasının benzerlik sonuçları gama analizinde MC algoritmasına göre daha yüksektir. TARTIŞMA ve SONUÇ: Hastaya ulaşan radyasyon dozunun doğru bir şekilde hesaplanabilmesi için tedavi sırasında radyasyonun geçtiği tüm materyaller bir tedavi planlama sisteminde belirtilmelidir. Radyoterapide kullanılan immobilizasyon cihazlarının düşük yoğunluklu materyalden oluşsa bile hasta üzerindeki doz dağılımı üzerinde etkilerinin olduğu ve tedavi planlama sistemine dahil edilmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimeler: Radyoterapi, immobilizasyon cihazları, baş yastığı, tedavi planlama sistemi.

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1. Introduction

The use of immobilization devices in radiotherapy is indispensable to ensure the proper positioning of a patient and the correct application of the treatment. Immobilization devices are available in different brands and models. While determining the usability of such immobilization devices, factors such as robustness, time required during application, storage and easy use must be taken into consideration (Pang et al. 2017; Melancon et al. 2013).

Intensity modulated radiation therapy (IMRT) and 3-dimensional conformal radiation therapy are the treatment modalities typically used in head and neck cancers radiotherapies. These treatment modalities are preferred to ensure local control of the tumour and to reduce the side effects that may occur in the patient, due to scattered radiation. Geometric errors that may occur in the setup of the head and neck region can significantly affect the treatment (Outhwaite et al. 2013). In the treatment of patients with head and neck cancer, thermoplastic masks and headrests are frequently used to restrict the movement of a patient and provide comfortable laying during the treatment (Oulhouq et al. 2019; Kang et al. 2011).

Treatment Planning Systems (TPSs) are very important for the success of a radiotherapy modality. Consequently, the accuracy of the materials and structures included in the TPS is very important for the quality of treatment. Many TPSs calculate radiation doses only for the tissues indicated within the body structure (Chen et al. 2018; Vanetti et al. 2009; Pulliam et al. 2011). It is argued that to contour immobilization devices in a TPS is not necessary, because these devices consist of low-density material. However, many studies have shown that immobilization devices may influence the dose distribution in a patient (Chen et al. 2018; Tuğrul 2018; Gerig et al. 2010; v et al. 2002; v et al. 2017; Wu et al. 2006). However, studies examining this effect using different algorithms are limited in the literature. Consequently, in the present study, the effect of using different algorithms was studied in detail. It is emphasized that the American Association of Physicists in Medicine (AAPM) Task Group 176 recommends that immobilization devices be included in dose calculations (Olch et al. 2014).

The aim of the present study was to examine the effect of immobilization devices on dose distribution by including a headrest in the body structure of a patient using two different algorithms. The obtained results are compared with those obtained with the method of gamma analysis.

2. Material and Method

Dose distribution changes that may occur in the brain region due to the use of a headrest were investigated for seven patients treated for cancer in the head region. Four of the patients were male and three were female, with ages between 40 and 62. All patients were selected from patients with glioblastoma multiforme (GBM) cancer. In this study, the Monaco TPS (v5.1, Elekta AB, Stockholm, Sweden) was used to examine dose distributions. Patient images taken with a Siemens Sensation 4 brand computed tomography device were used and transferred to the TPS. In the TPS, body contours for each patient were drawn with or without headrest. Two different treatment plans were developed in the TPS, including and not including the interaction of the headrest with radiation. In each patient, the isocenter of the radiation field was positioned in the middle of the brain, and the source-skin-distance (SSD) was set at 88 cm. Monaco TPS consists of three different algorithms; these algorithms are called Pencil Beam (PB), Collapse Cone (CC) and Monte Carlo (MC) MC using the XVMC based MC algorithm. The PB algorithm was not used in this study because it is not preferred in complex treatments such as Stereotactic Body Radiation Therapy (SBRT) and intensity modulated radiotherapy (IMRT) today, and because there have already been many studies published involving the PB algorithm. The Monaco TPS calculates any dose distribution considering only tissues and structures within the body. For this reason, in the present study the Monaco TPS was used, and the body structures of seven patient images were contoured without headrest and with headrest.

An exemplary headrest used for patient treatment is shown in Fig. 1. The headrest considered is a CIVCO Timo Headrest size B (MTTIMOBL) made of durable polyurethane foam (Civco Radiotherapy 2020). The reason for employing the B headrest in the present study is that it is used very frequently in radiotherapy.

Fig 1: CIVCO Timo Headrest size B (MTTIMOBL) used in the present study (Civco Radiotherapy 2020).

In the TPS, the radiation field was created to cover the entire lateral area of the headrest (10x10 cm2). In order to understand the effect of the headrest on dose distribution, the same radiation dose (100 Monitor Unit (MU)) was given from the gantry 180° for each case in planning. The dose distribution was calculated for each patient using both the CC and the MC algorithm.

The CC algorithm, which considers the dose contributions of primary photons including photon and electron scattering, is one of the convolution-superposition algorithms. The CC algorithm also calculates kernel energies with lateral scattering and finally allows calculation of the total absorbed dose (Ulmer et al. 2005; Reis et al. 2019; Fogliata et al. 2007; Bragg et al. 2006).

MC algorithms nowadays used by some TPSs offer the most accurate dose calculations including dose contributions from scattered radiation, even for inhomogeneous materials (Chen et al. 2018; Reis et al. 2019). Using random numbers MC algorithms estimate interaction probabilities for various physical processes describing the interaction of ionising radiation with matter. Because an MC algorithm takes into account every interaction of photons and electrons in air and other matter present, it creates reliable dose distributions (Reis et al. 2019;

Fogliata et al. 2007; Bragg et al. 2006; Chow et al. 2009). The MC algorithm included in the Monaco TPS uses an XVMC-based MC algorithm (Monaco 5 Comprehensive treatment planning 2014). Because the effect of all parts of the headrest on the radiation dose should be investigated in the present study, the dose distributions along the coronal axis were calculated with the TPS.

In radiotherapy, the gamma analysis method is typically used to compare the dose distribution values of the two plans. Consequently, the dose distributions obtained in the present study were also compared using the gamma analysis method. The PTW VeriSoft software (PTW, Freiburg, Germany) was utilized to calculate the results of the gamma analysis. Specifically, the 3% dose difference and the 3mm distance to agreement evaluation criteria commonly used in clinic applications were applied. Fig. 2 shows the sample interface of the PTW VeriSoft program.

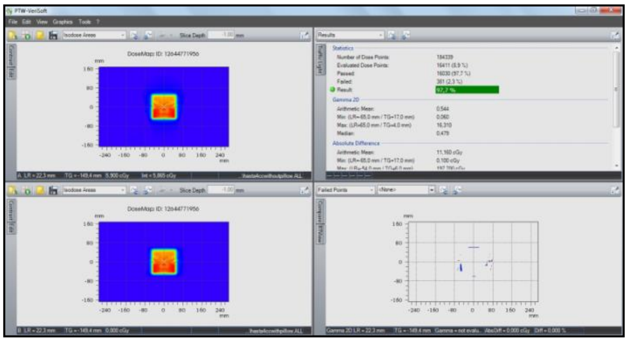

Fig 2: The interface of the PTW VeriSoft program.

3. Results and Discussion

For the seven investigated patients, the radiation dose distributions were calculated using the MC algorithm along the coronal axis in the isocenter point (SSD=88 cm) for cases with the headrest included or not included in the body structure. For the same cases, the radiation dose was also calculated using the CC algorithm.

The doses obtained in cases where the headrest was and was not included in the body structure were compared for each algorithm using the gamma analysis method. In addition, doses obtained in cases where headrests were included in the body structure using the MC and CC algorithms were compared with each other.

To give an example, for patient #3, after applying the gamma analysis criteria, the dose points that passed and failed the evaluation criteria are shown in Fig. 3. For all patients, the results of the gamma analysis are shown in Table 1.

Table 1: Gamma analysis results; second column (MC): comparison of MC results with and without headrest; third column (CC): comparison of CC results with and without headrest; fourth column (MC+CC, headrest included): comparison of MC and CC results when headrest was included.

	Results of Gamma Analysis (%)		
Patient	MC	CC	MC and CC, headrest included
1	90.5	99.7	82.1
2	88.6	95.7	80.1
3	88.2	91.3	79.7
4	88.6	97.7	76.9
5	88	92.2	80.6
6	88.1	95.5	79.3
7	88.5	95.3	80.2

The second column of Table 1 shows the results of the gamma analysis when the dose distributions were calculated with the MC algorithm with and without headrest, the third column shows those when the CC algorithm was used, and the fourth column shows the results of the gamma analysis when the dose distributions obtained using the MC and CC algorithm were compared when the headrest was included.

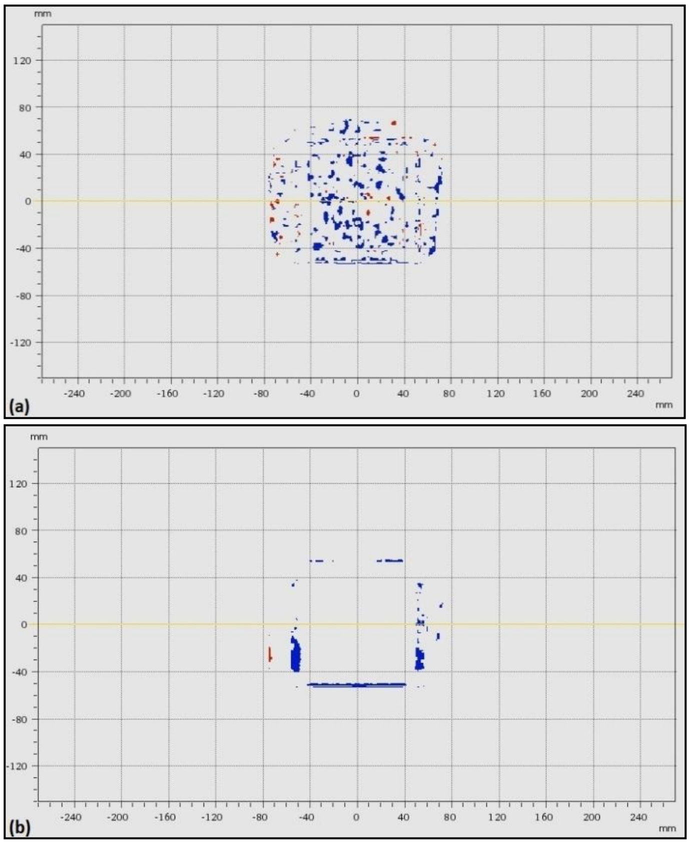

Fig 3: The result of comparison for patient #3 (see Table 1) which passed and failed the evaluation criteria in the gamma analysis. (a): For the dose distribution calculated using the MC algorithm. (b) For the dose distribution calculated using the CC algorithm. The blue and red dots indicate the regions that failed the comparison result. Blue dots show regions with lower dose values, red dots show regions with higher dose values.

A correct calculation of the radiation dose to be applied in cancer therapy is of great importance for both treatment success and avoidance of undesired side effects. For this reason, it has become imperative to examine any algorithm used by TPSs in radiotherapy. Because in the treatment of head and neck cancer, immobilization devices are used to ensure that the patient lies comfortably and does not move. The effect of these immobilization devices on dose distribution has been investigated many studies and the greatest effect of these devices on dose distribution was shown to be their absorption of radiation. Consequently, if these devices are not defined in a TPS during treatment planning, the dose calculated for the patient may not be calculated correctly and even higher skin doses may result because some immobilization devices may show a bolus effect.

In the study, the effect of a headrest typcially used in radiotherapy on dose distribution was investigated using two different dose calculation algorithms. Table 1 shows the differences in the results obtained after applying a gamma analysis. The percentage values given in Table 1 express the agreement value of the dose values of the two plans compared, within the specified criteria, as a percentage. As can be seen, the headrest has an effect on the dose distribution. It is noted that the headrest used as an immobilization device is made low-density material. Since the MC algorithm calculates the radiation dose that may occur in low-density materials more accurately than the CC algorithm, the gamma analysis results of the MC algorithm are lower.

Beside the percentage result of the gamma analysis it is also important to see where the employed headrest when included in the body structure absorbed radiation. These regions are indicated in Fig. 3 as red and blue dots. Fig. 3 demonstrates that for the CC calculations the cold points occurred only at the edges of the radiation field. This is due to the fact that radiation passes through the air environment due to the oval shape of the head (the area of the head that is not in contact with the headrest), and because the CC algorithm does not take into account the effect of the headrest in the middle parts of the radiation field. This is because the CC algorithm does not calculate secondary photons and scattered radiations accurately enough, in a low-density environment. In contrast, the MC algorithm does accurately calculate the scattered and absorbed secondary photon and electron doses, especially in low-density environments.

5. Conclusion and Recommendations

In order to accurately calculate the radiation dose reaching a patient in radiotherapy, all the materials through which the radiation passes during the treatment must be specified in the TPS. Even if the immobilization devices used in radiotherapy are of low-density, they have some effects on the dose distribution within the patient. Therefore, in order for the patient to receive the prescribed radiation dose correctly and to reduce any unwanted side effects that may occur, immobilization devices used must be defined in TPSs and the dose distribution results obtained must be controlled with appropriate quality control equipment. It is emphasized in the study that if there are immobilization devices such as headrest in the treated area and if we want to accurately measure the effect of immobilization devices on the dose distribution in a patient, the MC algorithm should be used.

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