Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2022 Aug 27; 10(B):2118-2123.
https://doi.org/10.3889/oamjms.2022.10760
eISSN: 1857-9655
Category: *B - Clinical Sciences*
Section: *Oncology*

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Evaluation the Impact of Changing Patient Thickness on Treatment Dose Amount Given to Injured Area

Musherah Al-Suhbani[1]*, Saif Serag[2], Nor El Houda Baghous[1], Chakir El Mahjoub[1]

[1]*Department of Physics, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco;* [2]*Laboratory of Electronics Treatment Information, Mechanic and Energetic, Ibn Tofail University, Kenitra, Morocco*

Edited by: Ksenija Bogoeva-Kostovska
Citation: Al-Suhbani M, Serag S, Baghous NE, El Mahjoub C. Evaluation the Impact of Changing Patient Thickness on Treatment Dose Amount Given to Injured Area. Open Access Maced J Med Sci. 2022 Aug 27; 10(B):2118-2123. https://doi.org/10.3889/oamjms.2022.10760
Keywords: Radiation therapy; XIO; Computed tomography; Chemotherapy; Tumor
***Correspondence:** Musherah Al-Suhbani, Department of Physics, Faculty of Sciences, Ibn Tofail University, Kenitra, 14000, Morocco, North Africa.
E-mail: mushirahnaji@gmail.com
Received: 31-Jul-2022
Revised: 14-Aug-2022
Accepted: 17-Aug-2022

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: Radiation therapy provides an appropriate radiation dose to tumors. The proportion of this dose varies according to the injured part and its location. Targeting the part affected by the tumor with an appropriate radiation dose requires high accuracy in measuring from the radiation source to the patient and the amount of dose. This treatment was applied using digital linear accelerators and computers to treat the tumor with radiation. In most cases, it is used chemotherapy, one of the standard cancer treatments. However, those doses affect the patient as it leads to loss of appetite, which negatively affects the patient's weight. The patient loses weight during treatment, and the affected area's thickness changes during a computed tomography (CT) scan of the body for treatment planning. This led to changes in dose distribution to the target area and adjacent organs (organs at risk).

AIM: This study examines the impact of changes in the patient's treatment area thickness on both dose and source surface distance.

METHODS: In this study, we apply five different parts of cancer (lung, prostate, uterus, rectum, and vulva) that were treated by the traditional method using a linear accelerator and using a one-dimensional beam. Furthermore, CT takes images of the affected area to locate the tumor and plan treatment. Furthermore, XIO device is used to track the patient's thickness during treatment and take a three-dimensional (3D) image of the patient during daily treatment sessions.

RESULTS: The obtained results showed that the changing in treatment area thickness between 0.5–2.3 cm, led to a change in the distance from the source to the patient's body, where the percentage of change was from 0.43 to 2.67%. Furthermore, the results showed that the dose increase of the planning target volume (PTV) by 1.54%, prostate 0.13%, rectum 0.38%, and bladder 0.83%, when the treatment area decreased thickness to 1.47 cm for prostate cancer. Moreover, the clinical target volume (CTV) dose by 0.40%, PTV 3.65%, rectum 3.84%, and bladder 3.19% decrease when the treatment area thickness increase by 3.16 cm in cervical cancer.

CONCLUSION: Thus, the dose changed for the affected organ significantly more than the reference dose.

Introduction

Cancer is the world's and the United States' second most significant cause of death. In 2020, 10 million people died from cancer worldwide. Each year, over 600,000 cancer fatalities occur in the United States and approximately 80,000 in Canada. The rest takes place in nations all around the globe. Seven out of ten deaths due to the illness occur in low- and middle-income nations [1]. There are four phases of worry, defined by various characteristics such as the tumor's size and location: (I) Cancer has been contained to a limited location and has not spread to lymph nodes or other tissues, (ii) cancer has progressed but not spread, (iii) cancer has progressed and may have migrated to the lymph nodes or other tissues, and (iv) your cancer has spread to other organs or parts of your body, a condition known as metastatic or advanced cancer. Several methods and medications are available to treat cancer, with many more under investigation. Some therapies are "local," such as surgery and radiation therapy, and are used to treat a specific tumor or body part. However, because drug therapies (such as immunotherapy, chemotherapy, or targeted therapy) can influence the entire body, they are commonly referred to as "systemic" treatments [2].

The radiotherapy principle is to treat tumors with high-energy ionizing radiation (photons or electrons) whose biological effects lead to cancer cells death. More than 67% of patients are treated with primarily radiotherapy [3]. It is important to reduce the rays absorbed from normal tissues adjacent to the tumor, because it is hard to focus the rays on the tumor directly without exposing the tissues near to it, it is critical to limit the rays absorbed from normal tissues adjacent to the tumor. To achieve this goal, various treatment techniques are constantly being developed, and the simplest changes or effects that may occur during treatment are studied [4]. A change in depth and spatial modifications in the target volumes and thickness of the treatment area are among the simplest changes that might occur. According to the previous studies, patients' physical appearance changes from what was expected in the treatment plan when they lose weight during the treatment, resulting in a change in dose distribution to target tumor regions and organs at risk [3], [4], 5]. Furthermore, chemotherapy accompany with radiotherapy may affect weight during treatment sessions [6]. Because the dose needs to be concentrated within the tumor area during radiotherapy, slight changes in the body's outward appearance might impact dose distribution, treatment effectiveness, and negative treatment impacts. Furthermore, several studies have demonstrated that even when body thickness is identical, there is a difference in dose distribution for multiple and arc conduction approaches [7], [8], [9]. In addition, the essential organs are close together and may contain tumors, the authors of indicated that the volume changes during radiation to the head and neck required a specific dose concentration in particular organs [10]. Therefore, the accuracy of dose determination around target volumes and organs at risk is a characteristic of intensity-modulated radiation therapy (IMRT). Moreover, computed tomography (CT) scans provide a single image of the targeted volumes, and IMRT is described using data from CT scans. Furthermore, the slight change in patient weight is caused by losing weight, reducing the tumor size, or reducing organ size at risk. Therefore, the changes in patient weight lead to the target volumes receiving less treatment while the organs at risk receive a high dose during radiotherapy [10], [11], [12], [13], [14], [15], [16]. James *et al*. [7] compared IMRT and volumetric modulated arc therapy (VMAT) regarding patient volume reduction during radiotherapy for patients with prostate tumors. Due to lack of appetite or dehydration, the patient loses volume resulting in a decrease in the depth surrounding the abdomen, but the bone architecture stays intact throughout radiation. When a patient's volume is reduced, the dosages in the rectum, bladder, and thigh are increased. The effects of radiation doses on important targets and organs depend on the in-depth reduction technique used to deliver doses to organs [17].

Study by James *et al*. Chow at Princess Margaret Hospital in Canada demonstrated why doses differ in target and organs at risk when patients lose weight in prostate cancer using the VMAT plan was used Eclipse treatment planning system and Varian 21 EX linear accelerator. The results showed that increase in doses when patient weight changes might not constitute a problem in target organs because the doses correspond to target. However, increase thickness of treatment area may pose a problem for organs at risk [8]. Another study in Princess Margaret Hospital, which did it by James *et al*., compared IMRT and VMAT in dose parameters changes for target organs and at-risk organs. In addition, comparing dose graph and volume when patient thickness changed, this study used a heterogeneous virtual human male pelvis phantom, Siemens SOMATOM Sensation Open CT-simulator, ArcCHECK 4D cylindrical detector array, and Varian 21 EX linear accelerator [8]. The study concluded that VMAT is preferred instead of IMRT for patients with prostate. Because doses for at-risk organs when the patient loses weight was increased in IMRT more than in VMAT In Suzuka General Hospital, Hiroya Ito checked through a dose-volume graph (DVH) the extent of dose changes for target organs and organs at risk when the patient's thickness changed, using an imaginary bladder tumor model. Moreover, tools such as CT, Pinnacle, Tomotherapy Planned Adaptive software, Matrixx Evolution system, OmniPro-I'mRT software, and MULTICube Lite Phantom then found helical delivery model are less affected by changes in a patient's body weight than the direct delivery model. Therefore, it is preferable to use spiral conduction for prostate patients [18].

Motivation and contributions

Changing the treatment area's thickness might lead to changing the tumor position. Furthermore, adding more radiation doses might lead to an impact on the tumor and surrounding organs. In previous studies, different techniques and treatment methods were used to study the effect of changing the thickness of the treatment area on the distribution of radiation dose in the prostate [7], head, and neck [10]. However, there is no work done to evaluate the changing thickness of (i.e., Vulve, lung, rectum, and cervical). Therefore, it motivates us to evaluate the impact of the change thickness for the Vulve, lung, rectum, cervical, and prostate. The contributions of this paper are summarized as follows:

1. We examine and evaluate the change in the thickness of the treatment area (increase or decrease) for five different organs (i.e., Vulve, lung, rectum, cervical, and prostate), and its effect on the distance from the source to patient.
2. We evaluate the effect of change in treatment area thickness on monitor unit (MU).
3. We evaluate the change in the dose applied to CTV, PTV, and surrounding organs (the organ at risk) using a conventional treatment technique.

Paper structure

The rest of the paper is organized as follows. Section 2 discusses materials and methods. Section 3 provides description of results and discussion and finally, the conclusions are discussed in Section 4.

Methods

Data collection

The study included ten individual participants whose ages varied from (40 to 61). The Vulve, Lung, Rectum, Cervical, and Prostate were chosen as the primary regions for treatment. The doctor decided on the dosage and the number of treatment sessions. The patients were treated in the Oncology Center in Sheikh Zayed Hospitals. To further examine the impact of changing the thickness of the treatment area on the PTV, CVT, and organs surrounding the tumor, two cases (Patients) with tumors in the pelvic region were taken into the consideration (prostate cancer and cervical cancer). The field size is 10 cm × 10 cm. Furthermore, the classic treatment technique is used for treatment.

Treatment plane

The study was split into two parts, including (i) thickness with distance and (ii) effect of the thickness on the dose of tumor and organs surrounding. In cone beam CT (CBCT), a volumetric imaging tool for diagnostic imaging in radiotherapy, was used to track the patient's thickness during treatment sessions. The change in thickness was calculated by contrasting the CT scan image of the patient's tumor obtained before the treatment sessions with the image taken during the therapy. In a CT scan, a patient is exposed to a focused beam of X-rays, which quickly rotates around the body and produces signals. Then, a computer processes the data to produce transverse images, or "slices," of the body. It is possible to create a 3D image of the patient using digital "assembly" make it easier to identifying tumor location and other organs when many subsequent slices are gathered by computer. This study used only one beam field, and photon field energies varied from patient to patient. when taking the difference between these two images (i.e., CBCT and CT), the patient's data are entered into an XIO device after thickness change then is measured source surface distance (SSD) and MU when treatment area thickness change.

The second part covers the effect of increasing the patient's thickness on the dose ratio absorbed by CTV, PTV, and surrounding organs. For this investigation, two instances were collected (prostate cancer and cervical cancer). We noticed a change in the external circumference of the patient's body. In prostate tumor shrinks the outer body circumference in the front and side directions are shown in Figure 1a. In the case of cervical tumor, the body circumference increased in the front direction, as shown in Figure 1b. The change in the treatment area thickness was investigated by the patient's body contour obtained from kilovoltage CBCT scan and compared with the body contour of planning CT. The same dose was re-applied in the original treatment plan for patients with prostate and cervical cancer when the thickness of the treatment area was changed using CT. The maximum dose for the tumor and the organs at risk was calculated and compared with the reference dose (there was no change in the treatment area thickness).

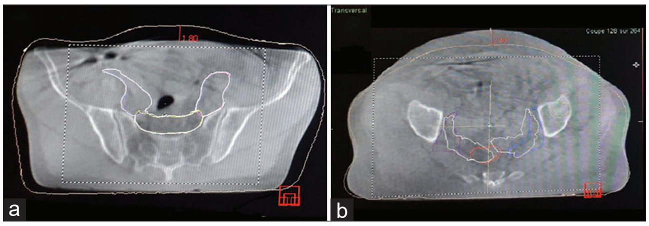

Figure 1: CT view. (a) Shows a cross-sectional image of a decrease in the treatment area thickness by 1.80 cm during treatment sessions for a Prostate Cancer. (b) Shows CT images of an increase in treatment area thickness of 2.40 cm during treatment of cervical cancer

Results and Discussion

All percentage changes of doses and SSD were compared with those for the patient thickness equal to zero as a reference point which had not changed in it the thickness of the patient (Normal thickness). In the case of Vulva, when the treatment started, the tumor was inside and outside the Vulva. The treatment area's thickness changes throughout multiple sessions. We observed that the thickness of the treatment area in the 1st week changed (0.5–2.3 cm). Therefore, the distance from the source to the treatment area changed accordingly. In other words, increasing the SSD over the reference value was between (0.43 and 2.67%) as shown in Figure 2. Furthermore, this change in treatment area thickness led to MU dose decrease by (1.36–8.5)% in Figure 1.

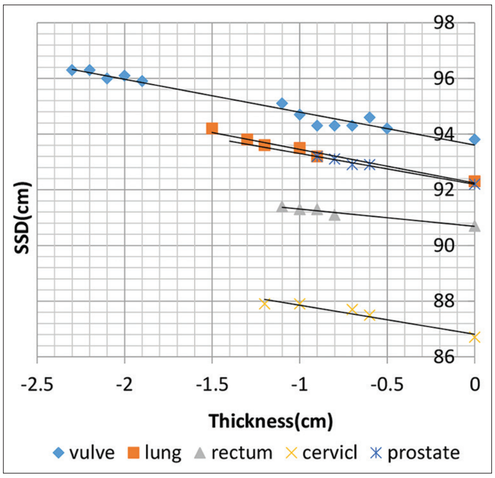

Figure 2: Variations in SSD points with reduced thickness of the treatment area ranged from 0 (normal thickness) to 2.5 cm for five patients

In the case of the lung, we observed that lung tumor patients' treatment area thickness varied from 0.9–1.5 cm over the reference range, and the thickness decrease led to an increasing SSD between 0.98–2.06%. An increase in SSD inversely affected MU where it decreased over the reference value by (1.76–3.77)%. The rectum had the smallest change in patient thickness, with the treated area's thickness falling by 0.8–1.1 cm. This resulted in a slight rise in

SSD between 0.44 and 0.77%, although this change was slight it resulted in a decrease MU by 0.7–1.08% as shown in Figure 3. The decrease in the treatment area thickness in the cervical tumor by an amount (0.6–2 cm) resulted in a change in the amount of radiation reaching the tumor, with SSD increasing by (0.92–2.54)%. Accordingly, the MU decreased by 0.94–2.76%. Furthermore, treatment area thickness for prostate patients changed by an amount of 0.6–0.9 cm, and this change led to an increase in SSD from the reference value in the range of 0.76–1.08%.

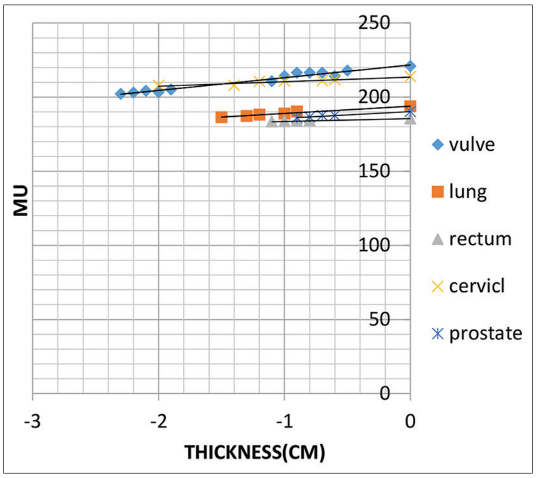

Figure 3: Variations of dose with reduced thickness ranging from 0 to 3 cm for the five patients

The same applies to the prostate, although the change was slight in the treatment area thickness, it affected SSD and MU. Treatment area thickness changed between (0.6–0.9) cm, and this change in thickness led to a decrease in MU by 1.42–2.26%. It can be said that slight change in the treatment area thickness (increase or decrease) affects the distance from the radiation source to the patient's skin, and this plays a clear role in changing dose deposited in tumor and surrounding organs.

Table 1 presents the values for dose max before the changing the patient's thickness and after changing the patient's thickness in the case of prostate cancer.

Table 1: Presents the values for dose max before the changing the patient's thickness and after changing the patient's thickness in the case of prostate cancer

$Dose_{max}$	Status	PTV	Prostate	Bladder	Rectum
	Before change (Gy)	45.49	71.96	51.57	46.19
	After change (Gy)	46.19	72.05	52	47.89

Table 1 presents the reference dose values for prostate, PTV, bladder, and rectum; before the patient underwent treatment sessions, there was no change in thickness of the patient. These values were compared with the dose values obtained for these organs when treatment area thickness decreased by 1.47 cm during treatment. As shown in Figure 1a, a clear decrease in the treatment area thickness and changes the target organ position and the organs at risk. The dose maximum is higher than the patient thickness reference dose by prostate 0.13%, PTV by 1.54%, bladder 0.83%, and rectum 0.38%.

Table 2 displays the values of dose max before changing the patient's thickness and after changing the patient's thickness in each treatment field for cervical cancer.

Table 2: Displays the values of dose max before changing the patient's thickness and after changing the patient's thickness in each treatment field for cervical cancer

$Dose_{max}$	Status	CTV	PTV	Bladder	Rectum
	Before change Gy	44.83	44.95	47.70	41.17
	After change Gy	44.65	43.31	46.18	39.59

Table 2 shows the dose values prescribed for CTV and PTV. Furthermore, dose of organs at risk like the bladder and rectum was compared with the results of dose change for tumors and organs at risk after a patient increased 3.16 cm in thickness during treatment. Figure 1b shows an increase in the treatment area thickness. These results were obtained by inserting the change in patient thickness into the XIO device. This device showed a decrease in dose received by tumor and organs at risk, where the percentage of CTV received after thickening change of the patient's prescribed dose was 0.40%, and PTV was 3.65%. For organs at risk, Table 2 shows that the rectal dose is 3.84% lower than the reference dose, and the bladder dose is 3.19% lower than the dose reference to the patient. There is a high possibility that changing the patient thickness (increasing or decreasing) will effect of absorbed dose. The results concluded that any increase in the patient thickness increases ionization, leading to an increase in the attenuation factor and an increase in the dose absorbed by the tumor and surrounding organs, a change in the organs at risk dose from the dose determined by the doctor for each organ. Results also showed that the radiation intensity decreased when treatment area thickness decreased and the distance from the radiation source to patient's skin increased; this reduces the amount of radioactive ionization inside patient's body and affects the amount of deposited energy in the organs, so the deposited dose in the tumor is less than the prescribed dose for treatment.

The previous cases conclude that despite difference in tumor positions between (lung, rectal, prostate, vulvar, and cervical), the values show that any change in patient thickness increases or decreases affects MU and SSD. When a decrease in patient thickness, the source-to the patient SSD increases intensity of beam decreases, and this leads to a decrease in deposited energy, which reduces the absorbed dose in the treatment area, in this case, tissue attenuation rate is small, and the tumor volume will receive a lower radiation dose than prescribed dose. In addition, surrounding edges and healthy tissue will receive a dose greater than the prescribed dose, and this complication may lead to cancer in healthy organs.

Therefore, it is necessary to repeat the CT scan when the patient suffers from loss or gain of weight during radiotherapy, also must be considered whether variable dose is acceptable within criteria for evaluating the therapy dose.

Conclusions

This research focuses on the study of changing patient thickness during radiotherapy sessions and thus achieving the desired results of this treatment. The work presented is based on factors knowledge that influences the absorbed dose, which changes doses with a change in patient thickness. Decrease and increase in the thickness of treatment area were examined in five patients who have cancer in different body organs such as lung, prostate, cervix, rectum and vulva. We found that the absorbed dose is affected by the treatment area thickness change (increasing or decreasing). This affects the dose of the organs surrounding the tumor. Results show that there is a need to monitor patient thickness during the Radiotherapy treatment sessions by taking 3D verification images and recording daily SSDs on patients in the treatment room. In case of thickness change, must send pictures from XIO to treatment planning systems to be recalculated the dose which the tumor must receive. In addition, this would improve to find patients weight gain or loss immediately and improve the location of target to deliver high radiation dose safely and spare the organ at risk being irradiated unnecessarily. As well, it will improve the target location to deliver high radiation dose safely and avoid the organ at risk of being unnecessarily irradiated. Changes in SSD, or patient thickness noticed in CBCT scan, can help clinicians to decide to re-CT scan the patient for re-planning purposes or will allow medical physics to run the dosimetry check for accurate dose distribution within the treatment area, improve the treatment outcome, and to reduce the incidents of disease recurrence.

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