

TECHNICAL NOTE

Impact of Different Beam Energies on The Incidence of Thyroid Cancer in Breast Cancer Radiotherapy

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Abstract

Purpose: During breast radiotherapy, the organs which are located out of the radiation field such as the thyroid are prone to secondary cancers. The present study aims to evaluate the risk of thyroid cancer in breast cancer radiotherapy in conventional and conformal radiation therapy.

Materials and Methods: The data related to the thyroid dose in radiotherapy of breast cancer from the study by Behmadi *et al.* were used. In their study, the thyroid dose was measured on the Alderson RANDO phantom for four different breast cancer treatment plans and two photon energies. Using the Biological Effects of Ionizing Radiation (BEIR) VII model, the risk of thyroid cancer was estimated in conventional and conformal plans with two photon energies (6 and 15 MV) in breast cancer radiotherapy.

Results: The Lifetime Attributable Risk (LAR) for thyroid cancer in the conventional technique was only 7.5% higher than that in the conformal technique. In the conventional treatment technique, LAR for thyroid cancer at 6 MV in all age groups was 17% higher than the 15 MV energy. However, the LAR for thyroid cancer in conformal technique at 15 MV energy was 50% higher than at 6 MV energy.

Conclusion: Applying high energy for radiotherapy of breast cancer, in the conventional technique, could reduce the risk of thyroid cancer. But at high energies, the risk of thyroid cancer in the conformal technique is considerably higher than that at low energy. Therefore, it is suggested that the impact of energies be evaluated to reduce the risk of thyroid cancer in breast cancer radiotherapy.

Keywords: Breast Cancer; Radiation Therapy; Thyroid Cancer; Biological Effects of Ionizing Radiation VII Model; Secondary Cancer Risk.

1. Introduction

Breast cancer is one of the most frequent malignancies among women and is the second cause of death among women with cancer. Radiotherapy following surgery and chemotherapy has an important role in the treatment management of these patients [1]. Recently, advanced treatments such as Intensity-Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) have been used to treat breast cancer. Regarding IMRT and VMAT, dose distribution in the target volume is more uniform, and damage to Organs At Risk (OAR) which are located in the radiation field, and mortality rate in these patients is reduced compared to previous radiotherapy techniques [2]. However, the normal organs which are located out of the field may be irradiated due to leakage and scattered radiation, emitted from the head of the Linear Accelerator (LINAC) and patient's body, which increases the risk of secondary cancer in patients who undergo radiation therapy [3]. Evaluation of the secondary cancer risk in radiation therapy of breast cancer in different treatment techniques showed that the thyroid dose, despite being out of the field, was in the range of 0.01-0.16 Gy in various treatment techniques, and due to this irradiation secondary cancer risk of thyroid was increased by up to 0.02% [4].

In the clinic, the received dose of organs outside the radiation field is calculated using Treatment Planning Systems (TPSs). Studies have shown that the amount of dose calculated with the help of TPS compared to the amount of dose measured by using dosimeters has significant discrepancies. Therefore, using the dose calculated by TPS for out-of-field organs is resulted to have uncertainties in estimating the dose received in these organs. Hence, estimating the risk of secondary cancers for organs outside the radiation field using the dose calculated by TPS is not accurate enough [5, 6].

The risk of thyroid cancer in radiation therapy for breast cancer has been investigated in several studies,

the results of which have revealed that in different radiotherapy techniques such as Three-Dimensional Conformal Radiation Therapy (3DCRT) and IMRT as well as different radiation fields, the risk of secondary thyroid cancer is different [4, 7, 8]. Previous studies have examined the risk of thyroid cancer in breast cancer radiotherapy in various modalities and treatment fields. However, based on our knowledge, the risk of secondary thyroid cancer at different energies in radiation therapy of breast cancer has not been studied before. The aim of this study is to evaluate the risk of thyroid cancer in breast cancer radiotherapy in two-Dimensional (2D) conventional radiation therapy and 3DCRT in two beam energies of 6 and 15 MV.

2. Materials and Methods

2.1. Measurement of Thyroid Dose

This study used the thyroid received dose from the study by Behmadi *et al* [9]. In that study, four different plans in conventional and conformal techniques and two photon energies (6 and 15 MV) were evaluated on an Alderson RANDO phantom (Male phantom with medium woman breast size, 73.5Kg weight and 175cm height, Radiology Support Devices (RSD), United Kingdom) for radiotherapy of breast cancer. To measure the thyroid dose, ThermoLuminescent Dosimeters (TLD), MTS-700 (TLD, Poland, Krakow, Poland) was positioned at special points on the thyroid. The volume of the thyroid and OAR's were counterered on the Alderson RANDO phantom's Computed Tomography (CT) scan on ISOgray TPS (DOSISoft Company, Paris France) by Radiation oncologist to determine the position of TLDs in OAR. To increase the accuracy measurements were repeated three times for each technique- and energy. The measurements of thyroid point doses for four techniques in irradiation phantom are demonstrated in Table 1.

Table 1. Measured mean dose (mGy) of thyroid in phantom by ThermoLuminescent Dosimeters (TLD) in conventional and conformal techniques and 6 and 15 MV energies [9]

	Technique	Conventional	Conformal	Conventional	Conformal
		(2 Tangential)	(2 Tangential)	(2 Tangential)	(2 Tangential)
		6 MV		15 MV	
Organ	Thyroid dose (mGy)	450.5±97.00	271.25±78.75	437.77±22.62	394.22±93.73
		593.5±48.25	299.75±91.75	441.74±13.62	410.56±36.31
	Mean thyroid dose (mGy)	522.00	285.50	439.75	402.39

2.2. Treatment Planning

Elekta Precise Treatment SystemTM (Precise Digital Accelerator, Stockholm, Sweden) was applied for irradiation of a RANDO phantom (Figure 1.a). The prescribed dose in this study was 50 Gy in 25 fractions, also the applied plans were 2 opposed tangential fields using two different energies and techniques. Figure 1.b illustrates the simulation of the RANDO phantom and one of the plans in ISO gray TPS [9]. There was a significant difference, almost 83%, between the conventional technique and the conformal technique for 6 MV, but at 15 MV, the difference of thyroid dose between the two treatment techniques was slight, almost 9 %.

2.3. Calculation of Thyroid Cancer

This study used the Biological Effects of Ionizing Radiation (BEIR) VII model to estimate the risk of thyroid cancer [10]. This model is based on the analysis of atomic bomb survivors and is used for doses below 1 Gy. In order to estimate the risk of cancer, this model introduces Lifetime Attributable Risk (LAR), which means the probability of death from cancer due to the radiation exposure of a population (Equation 1):

$$LAR = \int_{e+l}^{80} ERR(D, e, a) \cdot \lambda \cdot \frac{S(a)}{S(e)} da \quad (1)$$

Where the Excess Relative Risk (ERR) is the incidence of a disease in the exposed population minus that in the unexposed population. D , e , and a represent the mean organ dose, the age at which the patient has been exposed to radiation, and the age at which the incidence of cancer is calculated, respectively. λ is the baseline cancer risk, $S(a)$ is the probability of surviving until age a , and $S(a)/S(e)$ is the probability

of surviving to age a conditional on survival to age e . ERR is calculated using the following Equation:

$$ERR(D, s, e, a) = B_s D \exp [\gamma(e - 30/10)] \left(\frac{a}{60}\right)^\eta \quad (2)$$

Table 2. Parameter values for Excess Relative Risk (ERR) in Biological Effects of Ionizing Radiation (BEIR) VII model

	B_{male}	B_{female}	γ	η
Thyroid	0.53	1.05	-0.4	None

Table 2 indicates other parameters, including B_s , γ , and η which depend on the type of model. In this study, the risk of thyroid cancer was calculated for patients aged 20 to 70 years undergoing radiotherapy of breast cancers.

3. Results

Thyroid LAR is shown in Figure 2 for patients undergoing breast cancer radiotherapy in their 20s and 60s. According to the results, in breast cancer radiotherapy, the highest thyroid LAR was related to the conventional technique at the energy of 6 MV. At 6 MV, the thyroid LAR in the conventional technique was almost twice that in the conformal technique. But at 15 MV, the thyroid LAR in the conventional technique was only 7.5% higher than that in the conformal technique. In the conventional treatment technique, the risk of secondary thyroid cancer at 6 MV energy in all age groups was 17% higher than that of 15 MV energy. However, the LAR for thyroid in conformal technique at 15 MV energy was 50% higher than at 6 MV energy (Figure 2).

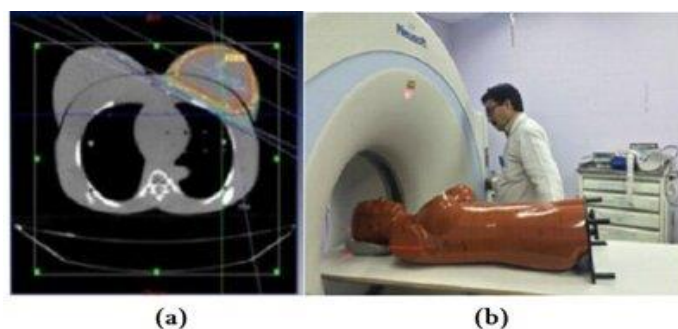


Figure 1. One of the treatment plans in Treatment Planning System (TPS) (a), Computed Tomography (CT) simulation of the RANDO phantom (b) [9]

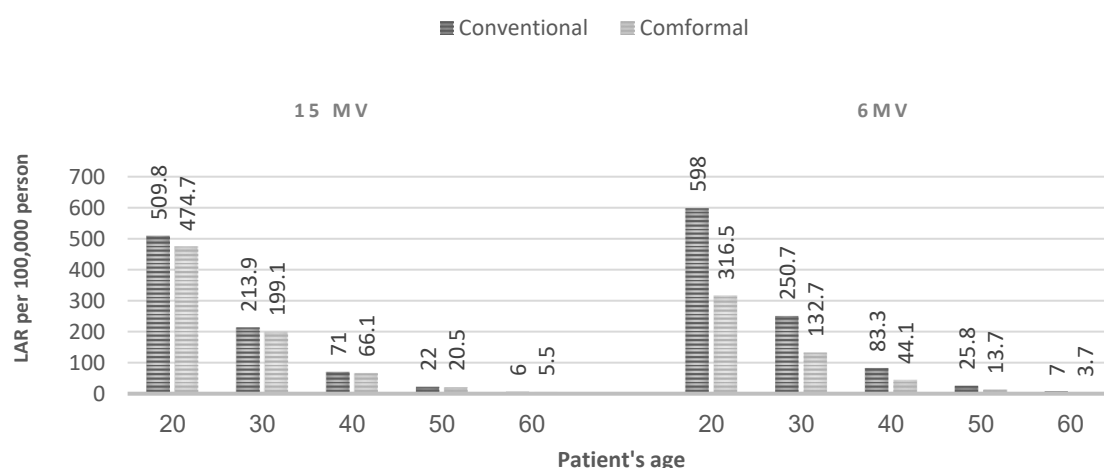


Figure 2. Lifetime Attributable Risk (LAR) of thyroid for breast cancer radiotherapy in different techniques and energies

4. Discussion

In this study, the impact of different energies on the LAR of the thyroid, out of the radiation field was evaluated in patients who underwent breast radiation therapy. Results have revealed that at 6 MV energy, the LAR of the thyroid in the conventional plan was twice that in the conformal plan. These results can be due to a wider treatment field in the conventional plan rather than that in the conformal plans. Moreover, the increasing width of the radiation field leads to producing more scattered radiation by Multi Leaf Collimators (MLCs). However, at 15 MV energy, the LAR of the thyroid in the conventional plan was slightly more than that in the conformal plan. This slight difference is due to the greater penetration of 15 MV photons and production of less scattered radiation. Based on the results obtained from the study conducted by Behmadi *et al.* [9], due to an increase in the photon energy, neutron contamination will be imposed on the treatment plan, but the plan has a reasonable dose distribution. The use of energies and techniques was dependent on breast volume, the number of lymph nodes involved and the depth of chest wall. They recommended the use of 6 MV for treatment plan reduces the scattered radiation without having neutron contamination [9].

Lee *et al.* calculated secondary cancer risk in breast cancer radiation therapy in different treatment techniques such as 3DCRT, IMRT, and VMAT. They found that LAR of the thyroid was almost equal in IMRT and VMAT techniques and LAR of the thyroid in 3DCRT technique

was close to one-fifth of IMRT and VMAT techniques, while the homogeneity index in 3DCRT was far less than that in the other two techniques [8]. Estimation of thyroid cancer risk after nasopharyngeal radiotherapy showed that the LAR of the thyroid as an organ, which is located in the radiation field, increased up to 2.7% in radiotherapy of nasopharyngeal cancer. Therefore, using new techniques to reduce thyroid cancer risk and performing follow-ups annually in terms of thyroid changes is necessary [11]. Mazonakis *et al.* have evaluated the impact of applying different energies on the incidence of secondary cancers in radiotherapy of prostate cancer in VMAT technique. They found that at 10 MV energy, the LARs of the bladder and rectum were 0.7% and 2.6% greater than 6 MV energy, respectively. The differences between the incidence of developing secondary bladder and rectal cancers with the low and high energies were found to be minor. Therefore, they recommended that for prostate cancer treatment, the use of high energy such as 10 MV photons, may be considered as the optimum choice. The reason for this choice is the reduction of the treatment time [12]. Also, estimating secondary thyroid cancer risk after radiotherapy of glioma showed that mean thyroid dose in 18 MV-3DCRT, 15 MV-3DCRT, and 6 MV-IMRT techniques was 6.8 ± 0.3 , 3.7 ± 0.5 , 9.5 ± 0.4 cGy. The ERR for thyroid cancer in the 6MV-IMRT technique was higher than in the 15 and 18 MV-3DCRT techniques. On the other hand, the ERR of thyroid cancer in 18 MV-3DCRT was nearly two times more than 15 MV-3DCRT [13].

In breast cancer radiotherapy, using the Schneider model [14]- this model estimated cancer risk based on extracted data from Dose Volume Histogram (DVH) by considering parameters such as dose fractionation and the ability for tissue repair and proliferation after each treatment session- the risk of secondary cancers for incidence of contralateral breast and lung cancers has been investigated for different treatment methods such as 3DCRT, IMRT, and VMAT [15-18]. The highest Excess Absolute Risk (EAR) was related to the ipsilateral lung, but the lowest EAR is changing between the contralateral lung and the contralateral breast. Among studies that used 50 Gy in 25 fractions [16-17]. Among 3DCRT, VMAT and IMRT techniques, the lowest EAR belonged to 3DCRT technique. However, there was no significant difference between IMRT and VMAT in these studies, but in some of them EAR of organs at risk in VMAT was lower than IMRT.

It was found that in radiation therapy of breast cancer by applying supraclavicular field, the position of the neck has a significant effect on thyroid dose, and the mean dose of the thyroid was significantly lower in patients with tilted necks as compared to those with straight necks [19]. Therefore, in addition to treatment techniques and position of the neck during radiotherapy, performing low and high energies can affect the incidence of thyroid cancer in radiotherapy of breast cancer. Limitations of this study include lack of access to an advanced therapeutic technique such as IMRT, also we could not find more published papers that have evaluated the impact of different energies on the incidence of secondary cancer risk.

5. Conclusion

According to the present study, the use of high beam energy for radiotherapy of breast cancer, especially in the conventional technique, could reduce the risk of thyroid cancer due to the reduction of scattered radiation, but at high beam energies, the risk of thyroid cancer in the conformal technique is considerably higher than low beam energy. Hence, it is recommended that in the treatment planning, in addition to the treatment technique, the impact of energies be evaluated to reduce risk of secondary cancers such as the thyroid cancer in radiotherapy of breast cancer.

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