Volume 23, No 3 | International Journal of Radiation Research, July 2025

The absorbed dose of the thyroid among patients with breast cancer following irradiation to the supraclavicular field

M. Bahador[1], S. Soltani Nejad[1], S. Yazdani[2]*

[1]Department of Radiation Oncology, Afzalipour Hospital, Kerman University of Medical Sciences, Kerman, Iran
[2]Department of Medical Physics, Afzalipour Hospital, Kerman University of Medical Sciences, Kerman, Iran

► *Short report*

***Corresponding author:**
Samira Yazdani, Ph.D.,
E-mail:
yazdani_ph70@yahoo.com

Received: October 20243
Final revised: September 2024
Accepted: September 2024

Int. J. Radiat. Res., July 2025; 23(3): 819-822

DOI: 10.61186/ijrr.23.3.40

Keywords: *Breast neoplasms, radiotherapy, thyroid gland.*

ABSTRACT

Background: The aim of this study was to determine the radiation dose to the thyroid and spinal cord using different gantry angles for the supraclavicular field in breast cancer patients. ***Materials and Methods:*** Fifty patients treated with opposing tangential fields for chest wall and ipsilateral supraclavicular (SCV) field were enrolled. On the planning computed tomography (CT) scans of patients receiving 50 Gray (Gy) of radiation in daily fractions of 2 Gy, the volumes of the thyroid, spinal cord, and supraclavicular (SCV) nodes were contoured. A comparison of the dosimetric parameters between three different gantry angles (0°, 5°, and 10°) of the SCV field was performed. Moreover, the percentage volumes of absorbed dose by the thyroid at low (V15) and high (V45) doses were compared. The maximum dose to the spinal cord was also compared between the angles. ***Results:*** Differences between mean dose (Dmean) of thyroid, spinal cord, V15, and V45 values using different gantry angles were statistically significant ($p < 0.05$). When the gantry angle increased, the Dmean of the thyroid and spinal cord significantly decreased. ***Conclusions:*** Gantry angle adjustment can reduce the dose to the thyroid. Therefore, contouring the thyroid as an organ at risk and utilizing an appropriate gantry angle during radiation is beneficial in minimizing the dose received by the thyroid. Nevertheless, the dose distribution of SCV lymph nodes and SCV field should be considered.

INTRODUCTION

Breast cancer ranks as the most prevalent cancer among women, posing a critical mortality risk. Among Iranian women, breast cancer stands as the second most prevalent malignancy, surpassed only by skin cancer. This cancer accounts for 23% of cancer-related mortalities among Iranian women [1, 2]. Surgery and radiation therapy (RT) are the common medications for these patients to control the disease in the breast [3].

So far, limited research has explored the potential link between RT and the development of hypothyroidism in individuals diagnosed with breast cancer [4]. The thyroid is a butterfly-formed endocrine organ within the neck that produces the hormone triiodothyronine [5]. RT to the supraclavicular field incorporates a portion of the thyroid gland; in this manner, there is concern about the impact on thyroid function in these patients [6]. Furthermore, it seems inevitable that portions of the thyroid gland will be exposed to radiation, particularly when targeting the ipsilateral supraclavicular fossa. A few other reports show that thyroid function was reduced because of irradiation to the supraclavicular region after breast surgery [7].

According to recommendations of the Radiation Therapy Oncology Group (RTOG), the maximum radiation dose absorbed by the thyroid gland should not exceed 3% of the total prescribed dose during breast RT [8]. Using thermoluminescent (TLD) dosimetry techniques, Farhood and colleagues determined that the thyroid's average skin entrance dose (SED) was nearly 7% of the prescribed radiation dose for the supraclavicular region. In another study, Suleiman *et al.* used TLD-100 chips to measure the thyroid dose and reported that the thyroid gland received an average dose of 3.7% of the total radiation prescribed for the breast [9]. Another study reported that thyroid exposure measurements varied significantly, registering 8.0±2.0% of the prescribed dose when supraclavicular field irradiation was included but only 2.0±0.8% without it [10].

To ensure adequate safeguarding measures, it's crucial to precisely calculate and monitor the radiation exposure to the thyroid and other vital organs at risk (OARs) during breast RT. Factors determining the dose absorbed by the thyroid include the specific RT approach employed, the dimensions of the treatment field, and the proximity of the thyroid to the irradiated area's boundary [11]. However, it has not been explored which gantry angle for the supraclavicular field improves dose uniformity in treatment plans. According to our surveys, a limited number of research has been conducted on the thyroid dose in several gantry angles in breast RT. In this study, we aimed to quantitatively analyze the radiation dose delivered to the thyroid during RT for breast cancer treatment.

MATERIALS AND METHODS

This study aimed to assess the association between thyroid dose parameters and angles of the supraclavicular field. Patients with invasive breast cancer who received one-sided supraclavicular irradiation in Afzalipour Hospital, Kerman, Iran, were entered between October 2021 and April 2023. Any patient with irregular thyroid glands or irregular thyroid nodules was excluded. The Ethics Committee of Kerman University of Medical Sciences approved the present study (Registration number; IR KMU.AHREc 1400/106).

Simulation and treatment planning

All patients were treated with 3-field RT, where the target volume encompassed the breast (after breast-conserving surgery (BCS)) and the same supraclavicular fossa. The RT planning was based on a transverse computed tomography (CT) scan, which included the area from the sixth cervical vertebra down to the mid-abdomen. CT slice thickness was 5 mm utilizing Neosoft (*Neosoft Medical Solutions, Hun Nun Industrial Area, and Shenyang, China*). The CT simulation procedure was conducted with the patient lying on their back, arms stretched overhead and secured on a specialized board (*Omni Board, Macro Medics, Netherlands*) for immobilization. The clinical target volume, heart, lungs, thyroid gland, supraclavicular lymph node, and spinal cord were delineated when planning CT images. The thyroid gland is placed in the middle of the neck at the cervical–thoracic junction. The bulk of the gland is located just in front of and inferior to the thyroid cartilage. The Eclipse treatment planning system (Version 15.5) and Anisotropic Analytical Algorithm (AAA) were employed for treatment planning and dose calculation.

The beam setup included three half-beams consisting of two tangential beams targeting the caudal part of the target volume, complemented by a single forward field (0°). Figure 1 shows two other designs with portal angles of 5 and 10 degrees (figure 1). The design was optimized by the forward field-in-field technique. A 6 MV photon beam was used through a Varian vital beam linear accelerator (*Vital Beam- SN3011, Varian Medical Systems, USA*). The breast target received a total dose of 50 Gy, and the regional lymph nodes received 46-50 Gy. The thyroid gland was marked by the radiation oncologist on the CT scan images, and the volume of the gland was calculated. The percentages of thyroid volume absorbing 15 and 45 Gy (V15 and V45), respectively, were then calculated from each patient's DVH. In addition, we calculated the mean dose to the thyroid gland and spinal cord from the supraclavicular field at different portal angles.

Statistical analysis

The SPSS V.20 was used for analyses. The doses for thyroid and spinal cord, V15 and V45, were expressed as mean and range. Statis-tical significance was considered as a $p<0.05$.

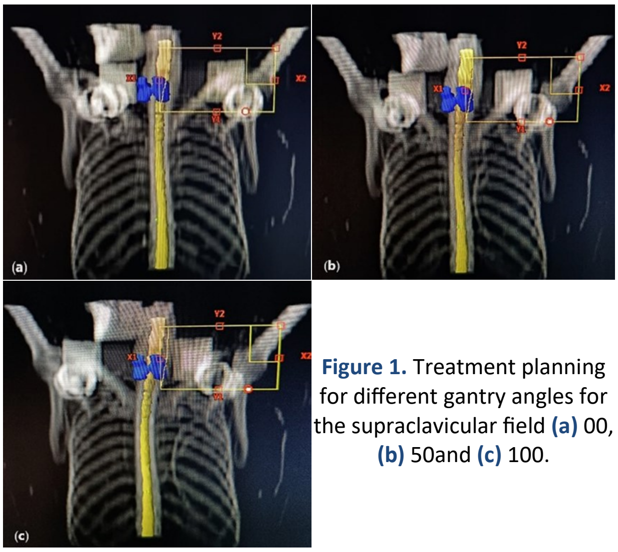


Figure 1. Treatment planning for different gantry angles for the supraclavicular field **(a)** 00, **(b)** 50and **(c)** 100.

RESULTS

Fifty breast cancer patients were evaluated. The mean age of the participants was 50.65±11.81 years (age range: 29-68). The mean volume of the thyroid gland was 10.79 cc (3.9-27.6). Thyroid dose distributions are shown graphically as isodose lines in figure 2. Dose distributions for one patient at different gantry angles are shown in figure 3. The dose to the thyroid for 3D-conformal radiotherapy of the breast using the field-in technique was 873, 661.9, and 556.2 cGy at 0^0, 5^0, and 10^0 degrees, respectively, which account for about 17%, 13%, and 11% of the breast dose, respectively. In Figure 4, dose -volume histograms were plotted and compared at three different angles. The maximum spinal cord dose was measured for each plan, and the mean was 3349.2, 1701.9, and 541.7 cGy at 0^0, 5^0 and 10^0 degrees, respectively. The average thyroid absorption volumes in percentage were as follows: in low dose (V15) at 0^0, 5^0, and 10^0 degrees, the values were 15.88%, 11.62%, and 9.11%, and in high dose (V45) the values were 6.65%, 4.03%, and 2.81%, respectively. Overall, the mean percentage volume of thyroid uptake was V15= 12.2% and V45= 4.5%. Moreover, smaller field angles were found to be associated with higher mean volumetric absorption percentage of radiation doses (figure 4).

[DOI: 10.61186/ijrr.23.3.40]

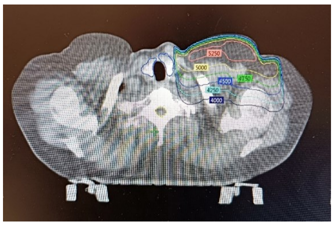
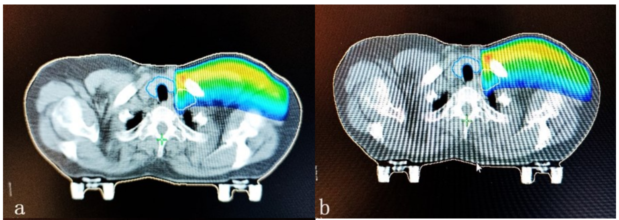


Figure 2. Thyroid dose distribution as isodose lines. The location of the thyroid in the supraclavicular beam is described. The thyroid gland is shown in blue.

Table 1. Dose and volume parameters of thyroid and spinal cord with supraclavicular field at different angles.

Indexes	0^0 (Mean ± SD)	5^0 (Mean ± SD)	10^0 (Mean ± SD)
Thyroid dose (cGy)	873.06 ± 5.22	661.95 ± 4.47	556.24 ± 4.00
Spinal cord dose (cGy)	3349.2 ± 9.83	1701.9 ± 12.54	541.7 ± 4.63
V15 (low dose)(%)	15.88 ± 1.25	11.62 ± 1.10	9.11 ± 1.01
V45 (high dose)(%)	6.65 ± 0.76	4.03 ± 0.56	2.81 ± 0.48

V15: percentage of thyroid volume that received a radiation dose of 15 Gy; V45: thyroid volume percentage that received radiation doses of 45Gy; SD: standard deviation.



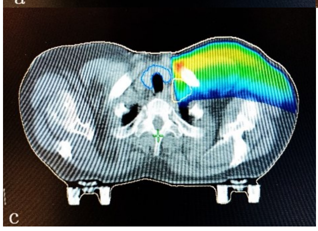


Figure 3. Isodose distribution for three plans of the axial plane for a representative breast cancer patient. The Color-wash threshold was set at 4500 cGy **(a)** 00, **(b)** 50and **(c)**100.

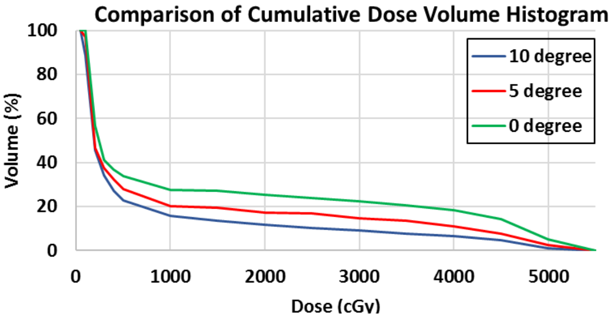


Figure 4. Comparison of thyroid dose-volume histograms (DVH) using different gantry angles.

DISCUSSION

The thyroid gland is a radiation-sensitive organ [12]. Radiation-induced thyroid dysfunction most frequently manifests as primary hypothyroidism, which affects 20-30% of individuals who undergo curative neck RT. Notably, about half of these cases emerge within the initial 5-year period following treatment [13]. In breast cancer RT, it is important to minimize the dose to the OARs since long-term adverse outcomes such as secondary cancers can occur [14]. The thyroid gland is difficult to completely avoid during RT due to its midline location. Some studies have shown that nearly 6-21% of patients develop hypothyroidism 2-7 years after breast RT. Those studies recommended protection of the thyroid gland during RT and routine monitoring of thyroid function after RT [15]. Some reports have shown a correlation between the gantry angle of the supraclavicular field and the dose to the organs at risk (thyroid and spinal cord). Therefore we decided to evaluate this topic.

A previous study by Vlachopoulou and colleagues revealed that thyroid radiation exposure varied significantly depending on the treatment approach. When supraclavicular field irradiation was included, the thyroid absorbed 8.0±2.0% of the prescribed dose, compared to only 2.0±0.8% without this field [16] .The average thyroid dose with different gantry angle (0, 5, and 10) in our institution was 873 cGy, 662 cGy, and 556 cGy (17%, 13.2%, and 11% of the prescribed dose, respectively), which is higher than the values reported before. In another study, Momeni *et al.* demonstrated that the thyroid dose in breast RT was 3.02% of the prescribed dose [11]. Farhood *et al.* and Ansari *et al.* (2020) have also reported higher proportions of 7% and 13%, respectively [17]. In another study conducted by Akyurek *et al.*, thyroid dysfunction following supraclavicular radiation was assessed. The mean thyroid dose was reported to be 31 Gy, and the mean thyroid volume was 32 cc. They found that the mean thyroid doses >36 Gy had a significant effect on the occurrence of hypothyroidism [18]. Ansari *et al.* evaluated the absorbed dose of the thyroid with Gafchoromic film and reported that the mean thyroid dose was 26 cGy [19]. Another study by Tunio and colleagues demonstrated that for breast cancer patients receiving supraclavicular RT, the likelihood of developing hypothyroidism is influenced by the volume of the thyroid gland and a V30 higher than 50% [20]. These discrepancies are due to differences in RT techniques, dose measurement systems, volume of the thyroid, and the distance of the thyroid from the radiation field [11].

In our study, changes in spinal cord dose were also investigated using a gantry angle. The results demonstrated that a smaller gantry angle was associated with a higher spinal cord dose (0^0, 5^0, and 10^0, 5.41 Gy, 17.01 Gy, and 33.49 Gy, respectively). This result was consistent with the result of another study [21]. Tahani *et al.* (No reference number) (Not in reference list) showed that the mean dose received by the spinal cord had lower values at larger angles (the values for 15, 10 and 0 angles were 9.5 Gy, 17.3 Gy, and 33.6 Gy, respectively). Based on their study, they found that the mean percentage volumes of thyroid absorption were V15= 26% and V50= 2.8% and concluded that a smaller field angle was linked to a lower mean percentage of volume absorption doses.

[DOI: 10.61186/ijrr.23.3.40]

Their results contradicted our results. We found that a smaller field angle was associated with higher V15 and V45 values (V15 at 0^{0}, 5^{0}, and 10^{0} were 15.88, 11.62, 9.11, and V45 at 0^{0}, 5^{0}, and 10^{0} were 6.65, 4.03, and 2.81, respectively). Accordingly, we found that the corresponding volumes were V15= 12.2% and V45= 4.5%.

CONCLUSION

The results show that using a larger gantry angle significantly reduces the dose received by the spinal cord and thyroid. Therefore, it is suggested that the thyroid be marked as an OAR and that a larger gantry angle be used, paying attention to the dose distribution of the SC field and to the supraclavicular nodes to ensure an adequate dose.

ACKNOWLEDGMENTS

None.

Ethics approval: All research protocols have been conducted under the approval of the Ethics Committee of Kerman University of Medical Sciences (Registration number; IR KMU.AHREc 1400/106). Data were collected retrospectively using the clinical and imaging records; therefore, the ethics committee waived the need for informed consent. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication: Not applicable.

Competing interests: The authors declare that no competing and financial interests exist.

Funding: The authors received no financial support for the current study.

Authors' contributions: All authors have conceived and designed the concept and road map of the study. S.Y contributed to the data collection. M.B critically reviewed the manuscript for its content, originality, usage of English language, and accuracy of interpreted data. All authors have made substantive contributions and attest to approving the final manuscript.

REFERENCES

1. Bahador M, Larizadeh MH, Samareh Fekri M, Naghibzadeh-Tahami A, Mohseni M, Arabnejad F (2022) Investigation of pulmonary complications induced by radiotherapy and chemotherapy in patients with breast cancer through spirometry, CT scan imaging patterns, and clinical criteria in a six-month follow-up. *Middle East Journal of Cancer, **13**(4): 692-700.*
2. Smith RA, Andrews KS, Brooks D, Fedewa SA, Manassaram-Baptiste D, Saslow D, *et al.* (2018) Cancer screening in the United States, 2018: a review of current American Cancer Society guidelines and current issues in cancer screening. *CA: A Cancer Journal for Clinicians, **68**(4): 297-316.*
3. Lee B, Lee S, Sung J, Yoon M (2014) Radiotherapy-induced secondary cancer risk for breast cancer: 3D conformal therapy versus IMRT versus VMAT. *J Radiol Prot, **34**(2): 325-31.*
4. Smith GL, Smith BD, Giordano SH, Shih YC, Woodward WA, Strom EA, *et al.* (2008) Risk of hypothyroidism in older breast cancer patients treated with radiation. *Cancer, **112**(6): 1371-9.*
5. Wu AK, Damico NJ, Healy E, Kharouta MZ, Khandel G, Deshane A, *et al.* (2021) Thyroid-optimized and thyroid-sparing radiotherapy in oral cavity and oropharyngeal carcinoma: A dosimetric study. *Tech Innov Patient Support Radiat Oncol, **20**: 28-34.*
6. Kikawa Y, Kosaka Y, Hashimoto K, Hohokabe E, Takebe S, Narukami R, *et al.* (2017) Prevalence of hypothyroidism among patients with breast cancer treated with radiation to the supraclavicular field: a single-centre survey. *ESMO Open, **2**(1): e000161.*
7. Reinertsen KV, Cvancarova M, Wist E, Bjøro T, Dahl AA, Danielsen T, *et al.* (2009) Thyroid function in women after multimodal treatment for breast cancer stage II/III: comparison with controls from a population sample. *Int J Radiat Oncol Biol Phys, **75**(3): 764-70.*
8. NSABP B-39, RTOG 0413 (2006): A Randomized Phase III Study of conventional whole breast irradiation versus partial breast irradiation for women with stage 0, I, or II breast cancer. *Clin Adv Hematol Oncol, **4**(10):719-21.*
9. Farhood B, Bahreyni Toossi MT, Vosoughi H, Khademi S, Knaup C (2016) Measurement of thyroid dose by TLD arising from radiotherapy of breast cancer patients from supraclavicular field. *J Biomed Phys Eng, **6**(3):147-56*.
10. Vlachopoulou V, Malatara G, Delis H, Kardamakis D, Panayiotakis G (2013) Estimation of the risk of secondary cancer in the thyroid gland and the breast outside the treated volume in patients undergoing brain, mediastinum and breast radiotherapy. *Radiat Prot Dosimetry, **154**(1): 121-6*.
11. Momeni Z, Tavakoli MB, Atarod M (2018) Estimation of the thyroid secondary cancer risk on the patient of standard breast external beam radiotherapy. *J Med Signals Sens, **8**(4): 238-43*.
12. Ron E and Brenner A (2010) Non-malignant thyroid diseases after a wide range of radiation exposures. *Radiat Res, **174**(6): 877-88.*
13. Gul A, Faaruq S, Abbasi NZ, Siddique T, Ali A, Shehzadi NN, *et al.* (2013) Estimation of absorbed dose to thyroid in patients treated with radiotherapy for various cancers. *Radiat Prot Dosimetry, **156** (1): 37-41.*
14. Nejad SS, Bahador M, Yazdani S, Kiani M (2023) Comparative evaluation of wedge and field-in-field methods in minimizing brachial plexus radiation dose in breast cancer patients undergoing radiotherapy. *Frontiers in Biomedical Technologies, **12**(2): 446-450.*
15. Wolny-Rokicka E, Tukiendorf A, Wydmański J, Roszkowska D, Staniul B, Zembroń-Łacny A (2016) Thyroid function after postoperative radiation therapy in patients with breast cancer. Asian Pacific journal of cancer prevention: *APJCP, **17**(10): 4577.*
16. Vlachopoulou V, Malatara G, Delis H, Kardamakis D, Panayiotakis G (2013) Estimation of the risk of secondary cancer in the thyroid gland and the breast outside the treated volume in patients undergoing brain, mediastinum and breast radiotherapy. *Radiation Protection Dosimetry, **154**(1): 121-6.*
17. Singh S, Verma A, Aryal G, Thapa S, Khakurel S, Shrestha K (2016) Thyroid hormone profile in patients with chronic kidney disease: a single centre study. *J Nepal Health Res Counc, **14**(34): 197-201*.
18. Daoud J, Siala W, Guermazi F, Besbes M, Frikha M, Ghorbel M, *et al.* (2005) Hypothyroidism following cervical irradiation in the management of carcinoma of the nasopharynx and of the breast: a prospective study on eighty-four cases. *Cancer Radiother, **9**(3): 140-7.*
19. Ansari L, Nasiri N, Aminolroayaei F, Sani KG, Dorri-Giv M, Abedi-Firouzjah R, *et al.* (2020) The measurement of thyroid absorbed dose by Gafchromic™ EBT2 film and changes in thyroid hormone levels following radiotherapy in patients with breast cancer. *J Med Signals Sens, **10**(1): 42-7.*
20. Tunio MA, Al Asiri M, Bayoumi Y, Stanciu LG, Al Johani N, Al Saeed EF (2015) Is thyroid gland an organ at risk in breast cancer patients treated with locoregional radiotherapy? Results of a pilot study. *J Cancer Res Ther, **11**(4): 684-9.*
21. Nageeti T, Mahfouz M, Al Gaod M, Zatar R (2018) Absorbed radiation dose in the thyroid gland following regional nodal irradiation for breast cancer. *Int J Oncol Res, **1**(2).*

[DOI: 10.61186/ijrr.23.3.40]