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RESEARCH ARTICLE

ESTIMATING CARDIAC, LUNGS AND RIGHT BREAST DOSES FROM CONVENTIONAL LEFTBREAST CANCER RADIOTHERAPY

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ABSTRACT

Background: Adjuvant radiotherapy has been given to many women with breast cancer for more than 50 years and it is currently recommended for a substantial proportion of such women. Long-term follow-up of these women has, however, revealed that some past radiotherapy techniques led to cardiac and pulmonary toxicity, because of unwanted irradiation of the cardiac structures and lungs by using traditional 2D techniques. Most of the breast cancer patients in our center traditionally treated with 2D technique and cobalt 60 machine up to 3 years ago. Therefore we present a study on cardiac and pulmonary dose-volume data of conventional 2D tangential breast irradiation achieved by three-dimensional conformal tangential irradiation. The result of this study may be beneficial to guide the radiation oncologists to improve treatment outcome by decreasing radiation toxicities in normal tissues.
Material and Methods: Twenty consecutive patients with left-sided breast cancer who were irradiated with 2D- conventional tangential beams, entered to this study. For each patient (CT)-based three-dimensional treatment planning has been used to reconstruct conventional RT regimens. Then images were transferred to treatment planning system, then Contralateral breast, both lungs and heart were contoured after reconstruction of tangential fields by considering radio opaque markers located on field borders. Dose-volume histograms (DVH) for the heart, right breast and both lungs were calculated.
Results: For individual women in the study, there was a wide range of cardiac doses of between 4.52 and 19.17Gy and between 9.86 and 24.75Gy mean left lung dose.
Conclusion: We strongly advise 3D treatment planning or utilizing shielding system and techniques such as breath holding to reduce the dose irradiated to vital organs in 2D left breast cancer radiotherapy.

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INTRODUCTION

Adjuvant radiotherapy has been given to many women with breast cancer for more than 50 years and it is currently recommended for a substantial proportion of such women. Overviews of the trials of radiotherapy for breast cancer have shown that radiotherapy reduces the risk of local recurrence and improves mortality from breast cancer in most categories of women. (Patt *et al*., 2005) The most recent overview from the Early Breast Cancer Trialists' Collaborative Group (EBCTCG)included individual patient data from 45,000 women in 86 randomized trials. Provisional results from this overview show that radiotherapy after breast conserving surgery reduced the 5 year local recurrence by 15.7% and the15 year breast cancer mortality by 4.2% and that post mastectomy radiotherapy fornode-positive disease reduced the 5 year local recurrence by 19.3% and the 20 year breast cancer mortality by 6.3%. Some previous breast cancer radio therapy regimens, especially by using 2D techniques, involved some unwanted normal tissues by irradiation, including the heart and lungs. The EBCTCG overview has shown that the beneficial effect of the radiotherapy was reduced by an increase in mortality from non-breast cancer causes. Long-term follow-up of these women has, however, revealed that some past radiotherapy techniques led to an increased risk of death from heart disease, particularly10 years after RT, presumably because of some unwanted irradiation of the cardiac structures by using traditional 2D techniques. (Early Breast Cancer Trialists, 2005) However, regimens used to treat left-sided cancers usually deliver a higher cardiac radiation dose than those used to treat right-sided cancers. The risk of cardiac mortality after breast cancer radiotherapy was investigated in around 21,000 women

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diagnosed with breast cancer between 1971 and 1988 and registered on the Thames Cancer Registry database. The median follow-up was 18.5 years and around half of the women received radiotherapy. When irradiated women with left-sided breast cancer were compared with irradiated women with right-sided breast cancer, the left- versus right- hazard ratios at 15years were 1.25 (95% CI 1.05, 1.49) for cardiovascular mortality and 1.23 (95% CI0.95, 1.60) for ischemic heart disease mortality. (Roychoudhuri *et al.,* 2007) Both animal and human studies suggest that irradiation of the heart can lead to later death and disability from heart disease through both micro vascular damage to the myocardial capillaries and macro vascular damage to the large coronary arteries. Therefore the cardiac structures that may be responsible for the excess of heart disease seen after radiotherapy are the whole myocardium and the three main coronary arteries (Gaya and Ashford, 2005). Most of the breast cancer patients in our center traditionally treated with 2D technique and cobalt 60 machine up to 3 years ago. It is the fact that treatment of breast cancer using 2 D techniques is continuous in some centers in Iran and other developing countries. Therefore we present a study on cardiac and pulmonary dose-volume data of conventional 2D tangential breast irradiation achieved by three-dimensional conformal tangential irradiation. The result of this study may be beneficial to guide the radiation oncologists to improve treatment outcome by decreasing radiation toxicities in normal tissues.

MATERIALS AND METHODS

Twenty consecutive patients with left-sided breast cancer treated at radiotherapy center of cancer institute, the most important referral center in Iran, during the year 2011 were selected. Modified radical mastectomy was done for ten patients and the remaining had breast conservative surgery. All patients were positioned on a breast board with the sternum horizontal to the treatment couch and left arm above the head. The tangential field borders were determined clinically by the attending clinician and marked using radio-opaquewires. The medial border was 1 cm ipsilateral to the midline, the superior border was the sternal notch, the inferior border was 1 cm below the infra-mammary fold and the lateral border was 1 cm outside the lateral palpable border of the breast (orthe mid-axillary line for MRM patients).

All patients were irradiated with Co-60 machine with conventional tangential beams to the breast or chest wall. For each patient (CT)-based three-dimensional treatment planning has been used to reconstruct conventional RT regimens used for treating the breast, chest wall, and/or locoregional lymph nodes. Patients were scanned using a wide-bore virtual simulator, with 8 mm slices. Then images were transferred to treatment planning system (RT Dose Plan system). Contralateral breast, both lungs and heart were contoured by radiation oncologist after reconstruction of tangential fields by considering radio opaque markers located on field borders. The cranial limit of the heart included the right atrium and excluded the pulmonary trunk, ascending aorta and superior vena cava. The lowest contour of the heart was the caudal myocardial border. The heart contour included heart muscle and circulating blood volume. Dose-volume histograms (DVH) for the heart, right breast and both lungs were calculated. By these DVHs mean dose radiated to the right breast, heart and both lungs were calculated.

RESULTS

From the 20 patients who entered this study, the mean age at diagnosis was 50.15 years (38- 67 years). 10 patients were operated with modified radical mastectomy (MRM) and 10 had history of breast conservative surgery (BCS). The mean age in MRM group was 50.1 (41- 64) years and the mean age in BCS group was 50.2 (38-67) years. There was no significant difference between those two groups.

Heart dose from chest wall or breast irradiation

For breast or chest wall RT the heart dose varied between 4.52 and 19.17Gy. (Min – Max.). For wide tangential RT, the medial border was 1 cm contra lateral to the midline. Hence, relatively large heart volumes were irradiated>10 Gy was received by 40% in MRM group and 100% for breast conservative group respectively .Mean heart dose was 8.29Gy and 15.84Gy for MRM and post BCS irradiation. For left breast or chest wall irradiation, the part of the heart receiving the greatest doses was the anterior surface of the left ventricle. The maximum heart dose was between 12.35 and 19.17Gy for MRM and BCS patients. ($p < 0.05$)

Right breast dose from chest wall or breast irradiation

For breast or chest wall RT the right breast dose varied between 2.27 and 8.56Gy. (min – max.). Mean right breast dose was 4.26Gy and 5.00Gy for MRM and post BCS irradiation, respectively. The maximum right breast dose was between 7.28 and 8.56Gy for MRM and BCS patients. ($p > 0.05$, NS)

Right lungdose from chest wall or breast irradiation

The right lung dose varied between 2.41 and 3.07Gy. (min – max.). Mean right lung dose was 2.64Gy and 2.54Gy for MRM and post BCS irradiation. The maximum right lung dose was between 3.07 and 2.73Gy for MRM and BCS patients. ($p > 0.05$, NS)

Table 1. Doses received by heart, right breast and lungs

	Heart dose (Gy)	Right Lung (Gy)	Left Lung (Gy)	Right Breast (Gy)
ALL	12.07 ± 0.74	2.59 ±015	15.92±0.74	4.63± 2.42
MRM (Modified radical Mastectomy)	8.29± 2.97	2.64 ±0.18	16.34±2.97	4.26 ±2.53
Breast conservative	15.84 ±2.30	2.54± 0.96	1549±2.30	5.00 ±2.38
P value	<.05	NS	NS	NS

Left lung dose from chest wall or breast irradiation

The left lung dose varied between 9.86 and 24.75Gy. (min – max.). Mean leftlung dose was 16.34Gy and 15.49Gy for MRM and post BCS irradiation. ($p > 0.05$, NS). The maximum left lung dose was between 24.75 and 18.97Gy for MRM and BCS patients. (p> 0.05, NS). There was significant correlation between MTD (Maximum Tolerable Dose) of lung and the left lung received dose. (p< 0.05)

DISCUSSION

Over the past few decades, indications for breast cancer radiotherapy, treatment techniques and available beam energies have changed throughout the world. Surgical techniques have also improved, with the increasing use of breast conserving surgery since the 1980s. In many countries, these changes have resulted in reductions in dose to the heart. The risk of radiation-induced heart disease in breast cancer survivors is known to be related to radiation dose (Overgaard and Christensen, 2008; Fuller *et al*., 1992; Gagliardi *et al*., 1996). This risk is, therefore, likely to have reduced in recent years. In several studies, cardiac doses reduced substantially between 1977 and 2001, (Hojris *et al*., 1999). CT based treatment planning provides detailed information about coverage of the target(s), dose homogeneity and doses to organs at risk. It has been found to improve the dose distribution in the target(s) and to reduce mean heart dose from around 4.5 Gy with standard left-tangential irradiation to 3.0 Gy with CT-based conformal left-tangential irradiation (Thomsen *et al*., 2008) Carolynestimated doses in 681 Danish and 130 Swedish breast cancer patients. Mean heart dose for patients varied from 1.6 to 14.9 Gray in Denmark and from 1.2 to 22.1 Gray in Sweden. Mean heart dose averaged across women remained around 6 Gy for left-sided and 2–3 Gray for right-sided radiotherapy. By improving radio therapeutic techniques in Sweden during 1977–2001, mean heart dose decreased from 12.0 to 7.3 Gray for left-sided and from 3.6 to 3.2 Gray for right-sided radiotherapy. (Taylor *et al*., 2011) In another study by Carolyn ,40 consecutive CT planning scans from the database of a U.K. RT department, were reviewed. Breast or chest wall RT resulted in whole heart doses of 0.9–14 Gy for left-sided and of 0.4–6 Gy for right sided irradiation (Taylor *et al*., 2006) The current study has estimated cardiac doses for women irradiated in Tehran cancer institute in the year 2011. For individual women in the study, there was a wide range of cardiac doses of between 4.52 and 19.17Gy and between 9.86 and 24.75Gymean left lung dose. These dose variations occurred because women irradiated after breast conservative surgery usually received higher cardiac doses than those irradiated for MRM patients mostly due to wider lateral margin. Radiation carcinogenesis is an unlikely process that increase the risk of induced cancer increases by dose and there is no dose threshold (Hall and Giaccia, 2006). Gao *et al*. found a relative risk of 1.32 and 1.15, respectively, for second cancer induction in the contra lateral breast of patients whose ages were below 45 years and over 55 years at the time of diagnosis. (Gao *et al*., 2003). Obedian reported a 10%increase in contra lateral breast cancer rate in patients who had radical mastectomy under the age of 45 and received a total dose of 46–54 Gy to the involved breast in a 15-year follow-up. This increase was small compared to a 7% increase in breast cancer in the control un irradiated group. (Obedian *et al*., 2000; Boice *et al*., 1990) Since the risk of a contra lateral breast cancer increases with dose, the dose has to be kept as lowas possible without compromising the primary treatment. The contra lateral breast dose is composed primarily of scatter dose from conventional radiotherapy and is determined by wedges, gantry angles, treatment volume, the use of half beam blocks as well as consideration of the field borders (Janjan *et al*., 1989; Das *et al*., 1998). In this study, Mean right breast dose was 4.26Gy and 5.00Gy for MRM and breast conservative groups. Estimation of the cardiac risk requires measurement of their cardiac dose, as well as dose-response relationships. Cardiac, lungs and right breast doses from left breast cancer radiotherapy from the most important Iranian radiotherapy centre, are presented in this study. These doses are likely to be similar to contemporary doses received from breast cancer radiotherapy in other geographical areas.

Conclusion

In many radiotherapy centers in Iran, 3-dimensional dose assessment is not yet possible. The strengths and limitations of a 2-dimensional method for estimating cardiac and lungs doses for these patients will cause great concern. We strongly advise 3D treatment planning or utilizing shielding system and techniques such as breath holding to reduce the dose irradiated to vital organs in 2D left breast cancer radiotherapy.

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