Measurement of ipsilateral lung and heart dose in radiotherapy of left sided mastectomy patients in common different clinical techniques: A phantom study

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► ***Technical note***

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ABSTRACT

Background*:** The aim of this study was to compare the radiation dose to ipsilateral lung and heart for different radiotherapy (RT) techniques including; two tangential photon beams, electron therapy and combined photon-electron. ***Materials and Methods*:** Treatment planning of the mentioned techniques on the CT images of a chest phantom was done using treatment planning system (TiGRT, Lina Tech, China). According to the plans, the phantom was irradiated with 6 MV photon and 10 MeV electron beams of Siemens Primus linac. Radiation dose was also measured using LiF Thermo Luminescence Dosimeter (TLD) which was placed inside 3 mm depth holes of ipsilateral lung and heart on the phantom. ***Results: The mean (± SD) radiation dose to the ipsilateral lung of the combined photon-electron was 66.12 ± 5.16% of prescribed dose. Whereas for the heart, it was 64.05 ± 2.62%. Mean (± SD) dose of ipsilateral lung and heart for electron irradiation was 54.51 ± 3.88 % and 34.21 ± 3.41%, respectively. The mean (± SD) radiation dose to ipsilateral lung and heart of the tangential was 50.73 ± 3.01 % and 31.36 ± 3.13%, respectively. The mean (± SD) radiation dose to the chest wall-lung interface for electron therapy (72.44 ± 2.01 %) was significantly different in comparison with tangential (65.23± 4.20%; p = 0.045) and combined photon-electron (68.14± 3.53 %; p = 0.032). ***Conclusion:*** Tangential beams is more suitable for treating mastectomy patients compared to the other techniques such as electron therapy and combined photon-electron, due to lower radiation dose to patient's ipsilateral lung and heart.

Keywords: *Electron beam radiation therapy, combined photon-electron beams, radiation imposed lung and heart dose, mastectomy patients, breast cancer, tangential beams.*

INTRODUCTION

For breast cancer patients, mastectomy and postoperative RT of the chest wall, is considered as the most common treatment [1,2]. In the U.S, about 120,000 breast cancer females are treated yearly by the RT [3,4]. Meanwhile, number of these patients has significantly been increased during the past two decades [5,6].

There are some different RT techniques such as electron therapy, two tangential photon beams and combined photon-electron, which have been used to treat mastectomy patients. However, exact advantages and disadvantages of each method, with regard to the radiation dose and adverse effects on the critical organs such as lung and heart, are still under consideration. Several studies have shown that, chest wall RT may increase the risk of ipsilateral lung cancer, and also heart morbidity and mortality [7-11]. Zablotska and Neugut found that, following 10 years of postmastectomy RT, a moderate increase in risk for ipsilateral lung carcinoma may provided, mainly depending on the radiation dose [7]. Rubino *et al.* have reported that, high radiation doses due to RT slightly increase the risk of second malignancies [8]. Fisher et al. have investigated the results of 20 years follow-up for patients underwent RT after mastectomy [9]. They found that, high dose RT was associated with a significant decrease in death due to cancer. Whereas, this decrease was partially offset by an increase in deaths from other causes, due to the RT dose [9].

This study aimed to compare the imposed radiation dose for ipsilateral lung and heart, in different RT techniques, including; two tangential photon beams, electron therapy and combined photon-electron.

MATERIALS AND METHODS

A chest phantom (designed and produced at the Medical Physics Department, School of Medicine ,Isfahan University of Medical Sciences, Iran) was used. The phantom was made of 30 transversal slabs of tissue equivalent plexiglas. As the purpose of this study was dose measurement of ipsilateral lung and heart, cork and Teflon were used instead of lungs and ribs. The chest wall thickness of the phantom was 2 cm.

Planning CT of the phantom was done with 1 mm slice thickness. The CT images of the phantom were imported to the treatment planning system (TiGRT, Lina Tech, China). The organs at risks including; ipsilateral lung and heart were contoured by an expert radiation oncology physician in the TiGRT planning software. The CTV of the plans were included the surface of the chest wall, three levels of axilla, supraclavicular and internal mammary lymph nodes. The PTV was defined with 1 cm margin around the CTV. TiGRT TPS has been commissioned based on Siemens Primus linac measured data. A Siemens Primus linac system with 6 MV photon and 10 MeV electron beam were used in this study. Treatment planning of the techniques including; one direct electron, two isocentric tangential photon beams and combined direct photon-electron were performed according to the clinical standard at our department. The schematic image of the techniques is illustrated in figure 1.

According to Figure 1, in the first technique the whole chest wall was irradiated by 10 MeV electrons. To expose the chest wall with tangential beams, a 15° wedge was used. Field sizes were 25 cm and 15 cm. The prescribed dose to PTV was 2 Gy per fraction with a total dose of 50 Gy. The dose measurements were done using LiF Thermo Luminescence dosimeters LiF (TLD-100), placed inside the ipsilateral lung and heart of the phantom. The points for TLD placement were chosen in order to measure the dose to the center of the ipsilateral lung and heart and some points around to cover the whole organs.

TLDs were readout with a SOLARO-2A TLD reader (NEC Technology). Calibration of each of the TLDs were done using 6 MV photon beam of a Siemens Primus linac and according with the manufacture procedure. The dosimeters were divided to different groups for batch calibration. Dose measurements were repeated for 3 independent experiments showed a dose error between 2.3% and 2.8%. The TLD placement holes were closed with a pad which was made of a tissue equivalent material. Then, the phantom was irradiated according to previously dose defined.

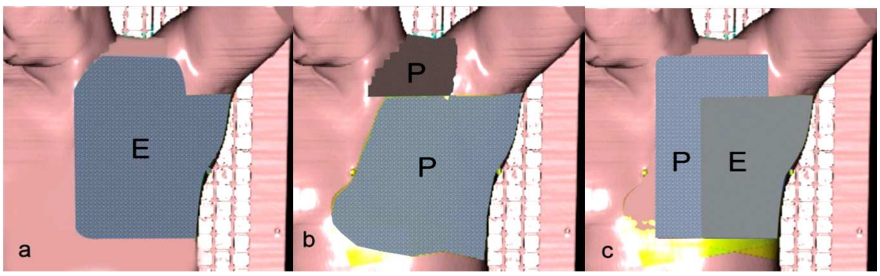

Figure 1. Images of different techniques with electron (**E**) and photon (**P**) beams, including; Electron therapy (**a**), tangential photon and supraclavicular fields (**b**), and combined photon-electron (**c**).

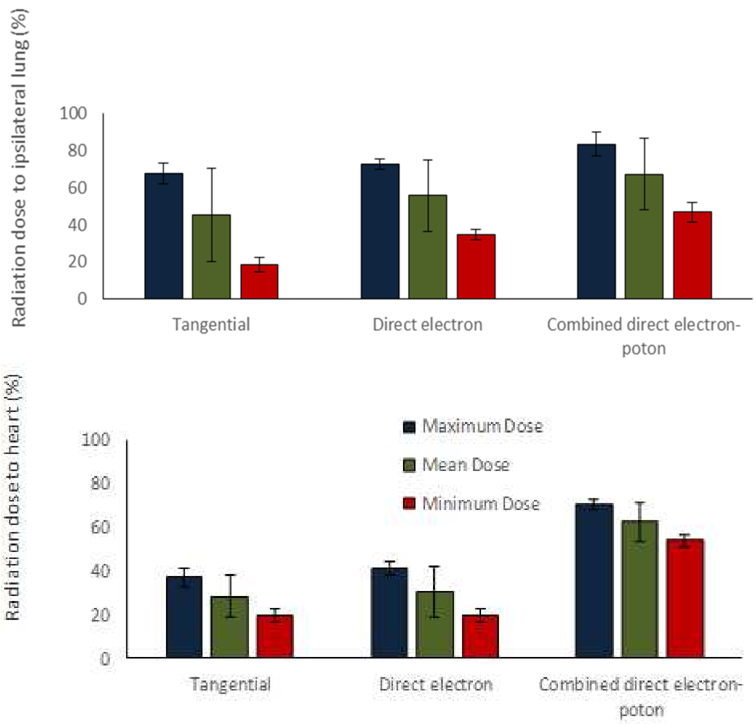

Figure 2. The ipsilateral lung (**a**) dose (in percentage) among three techniques. The heart (**b**) dose (in percentage) among three techniques.

Statistical analysis

Mean values and standard deviations of the dose were calculated and statistical significance of the differences between the studied methods was evaluated. A computer program (SPSS version 16.0, Chicago, IL, USA) was used for statistical analysis. Data were analyzed by Wilcoxon test (Nonparametric version of paired samples *t- test*). All hypotheses tested using a criterion level of P = 0.05.

RESULTS

Table 1 indicates the measured radiation dose to ipsilateral lung and heart for electron therapy, tangential beams and combined photon -electron as a percentage of prescribed dose. Figures 2-a and 2-b compare the maximum, mean and minimum imposed dose to mentioned organs for the techniques. Results showed that the mean (± SD) radiation dose to ipsilateral lung of the combined photon-electron was 66.12 ± 5.16 %. Table 1, also illustrates the maximum and minimum radiation dose for ipsilateral lung for combined photon-electron was 84.12 ± 6.35% and 49.23 ± 19.26%, respectively. For the mentioned organs, the mean (± SD) dose of ipsilateral lung for electron irradiation was 54.51 ± 3.88%. The maximum and minimum dose for ipsilateral lung of electron therapy was 72.34 ± 2.84% and 35.25 ± 18.01%, respectively (table 1).

The mean (± SD) radiation dose to ipsilateral lung for tangential was 50.73 ± 3.01% (table 1). According to table 1, the maximum and minimum dose for ipsilateral lung of tangential was 67.42 ± 5.64% and 20.45 ± 23.02%, respectively.

Whereas, for the heart, the mean (± SD) radiation dose for the combined photon-electron was 64.05 ± 2.62 %. According to Table 1, the maximum and minimum heart dose for combined photon-electron was 74.12 ± 2.33% and 55.22 ± 8.84%, respectively. The mean (± SD) dose of the heart for electron therapy was 34.21 ± 3.41 % (table 1). The table shows that the maximum and minimum dose for heart for electron therapy was 43.35 ± 2.94% and 20.87 ±

11.51%, respectively.

The mean (± SD) radiation dose to heart for the tangential was 22.57 ± 9.89 %. In addition, the maximum and minimum heart dose for tangential was 35.13 ± 4.27% and 20.12 ± 9.56%, respectively (table 1). In table 2, the mean (± SD) radiation dose to the chest wall-lung interface is illustrated for the mentioned techniques as a percentage of prescribed dose.

Table 1. Measured radiation dose to ipsilateral lung and heart as a percentage of 2 Gy prescribed dose.

	Electron therapy	Tangential	Combined photon-electron	Electron therapy vs tangential (adjusted p value)	Electron therapy vs combined photon-electron (adjusted p value)	Tangential vs combined photon-electron (adjusted p value)
Ipsilateral lung						
Maximum Dose (%)	2.84 ± 72.34	5.64 ± 67.42	6.35 ± 84.12	0.067	0.001	0.001
Minimum Dose (%)	18.01 ± 35.25	23.02 ± 20.45	19.26 ± 49.23	0.059	0.048	0.002
Mean Dose (%)	3.88 ± 54.51	3.01 ± 50.73	5.16 ± 66.12	0.025	0.018	0.011
Heart						
Maximum Dose (%)	2.94 ± 43.35	4.27 ± 35.13	2.33 ± 74.12	0.032	0.039>	0.041
Minimum Dose (%)	11.51 ± 20.87	9.56 ± 20.12	8.84 ± 55.22	0.973	0.014	0.020
Mean Dose (%)	3.41 ± 34.21	3.13 ± 31.36	2.62 ± 64.05	0.734	0.029	0.033

Table 1. Measured radiation dose to ipsilateral lung and heart as a percentage of 2 Gy prescribed dose.

	Mean radiation dose to chest wall-lung interface	Electron therapy vs tangential (adjusted p value)	Electron therapy vs combined photon-electron (adjusted p value)	Tangential vs combined photon-electron (adjusted p value)
Electron only (%)	2.01 ± 72.44	0.045	0.032	0.048
Tangential (%)	4.20 ± 65.23			
Combined photon-electron (%)	3.53 ± 68.14			

DISCUSSION

A number of studies have discussed about the imposed radiation dose to ipsilateral lung and heart for different RT techniques which were used to treat mastectomy patients. However, there is a limited data on comparison of these methods. Therefore, this study was performed to compare the imposed ipsilateral lung and heart radiation dose for different RT techniques namely; tangential beams, electron therapy and combined photon-electron.

Our data showed that, as expected, there was a significant differences of the imposed radiation dose to ipsilateral lung and heart among different studied methods (table 1). Table 1 and figures 2-a and 2-b, give the comparison of radiation dose to ipsilateral lung and heart between the mentioned techniques. It is mainly due to lateral scattering of electrons that may create high dose regions under the photon fields (12). Furthermore, there was not a gap between photon and electron fields in combined photon-electron, in which, the divergence of the electron and photon beams can overlap the isodose curves on each other and may lead to high dose regions in the depth of ipsilateral lung and heart (12).

The maximum radiation dose to the heart for electron irradiation was considerably higher than tangential (up to 23%; p = 0.032). While, the mean and minimum imposed dose to heart for electron therapy and tangential were not significantly different (p = 0.734, and p = 0.973, respectively). This was seen as a result of the dose fall of the electron beam beyond the build-up region and it is sharper compared to photon (13,14). Moreover, electron beam was affected because of in-homogeneities, including; lung and ribs (12,14). Also, electron beam has x-ray contamination at the end of its path [12]. Furthermore, lateral scattering of electrons is higher than photons.

These results are in an agreement with Inskip *et al*. who stated that the lung dose is mainly depended on the radiation technique and some techniques such as tangential beams results in less extensive exposure of the lungs [15]. Recently Dogan *et al*. have reported that, the mean hurt dose of the electron treatment is significantly higher than the combined photon-electron one [16], which is in line with our finding.

Similar results have been reported in other studies. Vaiduriam *et al*. have compared tangential photon beams to electron treatment [17]. In their study, they found the lung dose was not significantly different for tangential photons and enface electrons. Whereas, heart dose for electrons was significantly lower than tangential [17]. Prasad et al, have reported similar results for the radiation dose to lung for electron irradiation [14]. As opposed to these results, Zimmerman et al. concluded that using low energy electron beam and bolus for treating post mastectomy patients can protect their lung without sacrificing tumor control probability [18]. The different result may be due to using bolus, in which, the chest wall thickness was increased. Jansson *et al*, have compared using two tangential photon beams with combination of one direct electron and three photon fields by a multileaf collimator in left sided breast cancer patients [19]. In contrast, the results showed that the combination of photon-electron imposed significantly lower dose to heart compared to tangential beams.

The geometric differences of the lung, heart, and chest wall surface and also tumor volume of the used phantom, compared to real patients may affect the measured imposed radiation dose to these organs [20].

CONCLUSION

In this paper, imposed radiation dose to ipsilateral lung and heart were compared for tangential photon beams, electron and combined photon-electron irradiation techniques.

RT of mastectomy patients is suggested to be performed by tangential, due to lower radiation dose to ipsilateral lung and heart. Other techniques such as direct electron and combined direct photon-electron may impose a significant higher dose to ipsilateral lung and heart compared to tangential.

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Conflicts of interest*: *Declared none.

REFERENCES

1. Overgaard M, Hansen P, Overgaard J, Rose C, AnderssonM, Bach F, Kjaer M, Gadeberg CC, Mouridsen HT, Jensen MB (1997) Postoperative radiotherapy in high-risk premenopausal women with breast cancer who receive adjuvant chemotherapy. *New England Journal of Medicine*, ***337****: 949-955*.
2. Clarke M, Collins R, Darby S, Davies C, Elphinstone P, Evans E, Godwin J, Gray R, Hicks C, James S (2005) Early breast cancer trialists' collaborative G (2005) Effects of radiotherapy and of differences in the extent of surgery for early breast cancer on local recurrence and 15-year survival: an overview of the randomised trials. *Lancet*, ***366****: 2087-2106*.
3. Smith BD, Haffty BG, Wilson LD, Smith GL, Patel AN, Buchholz TA (2010) The future of radiation oncology in the United States from 2010 to 2020: will supply keep pace with demand? *Journal of Cinical Oncology*, ***28****: 5160-5165*.
4. Dessena M, Dessi M, Demontis B, Grosso L, Porru S, Meleddu G, Lay G, Murenu G, Amichetti M, Di Martino) (2011Exclusive intra-operative radiation therapy (IORT) for early stage breast cancer: pilot study of feasibility]. *Il Giornale di chirurgia*, ***32****: 104-109*.
5. Jereczek-Fossa B, Santoro L, Colangione S, Morselli L, Fodor C, Vischioni B, Rozza D, Leppa A, Cambria R, Leonardi M (2012) Electronic portal imaging registration in breast cancer radiotherapy verification: analysis of inter-observer agreement among different categories of health practitioners. *Neoplasma*, ***60****: 302-308*.
6. Alford SL, Prassas GN, Vogelesang CR, Leggett HJ, Hamilton CS (2013) Adjuvant breast radiotherapy using a

simultaneous integrated boost: clinical and dosimetric perspectives. *Journal of Medical Imaging and Radiation Oncology*, ***57***: *222-229*.

7. Zablotska LB and Neugut AI (2003) Lung carcinoma after radiation therapy in women treated with lumpectomy or mastectomy for primary breast carcinoma. *Cancer*, ***97***: *1404-1411*.
8. Rubino C, De Vathaire F, Shamsaldin A, Labbe M, Le M (2003) Radiation dose, chemotherapy, hormonal treatment and risk of second cancer after breast cancer treatment. *British Journal of Cancer*, ***89***: *840-846*.
9. Fisher B, Anderson S, Bryant J, Margolese RG, Deutsch M, Fisher ER, Jeong JH, Wolmark N (2002) Twenty-year follow-up of a randomized trial comparing total mastectomy, lumpectomy, and lumpectomy plus irradiation for the treatment of invasive breast cancer. *New England Journal of Medicine*, **347**: *1233-1241*.
10. Darby SC, McGale P, Taylor CW, Peto R (2005) Long-term mortality from heart disease and lung cancer after radiotherapy for early breast cancer: prospective cohort study of about 300 000 women in US SEER cancer registries. *The lancet Oncology*, ***6***: *557-565*.
11. Darby S, McGale P, Peto R, Granath F, Hall P, Ekbom A (2003) Mortality from cardiovascular disease more than 10 years after radiotherapy for breast cancer: nationwide cohort study of 90 000 Swedish women. *BMJ*, ***326***: *256-257*.
12. Khan FM and Gibbons JP (2014) *Khan's the physics of radiation therapy*. Lippincott Williams & Wilkins.
13. Salem A, Mohamad I, Dayyat A, Kanaa'n H, Sarhan N, Roujob I, Salem AF, Afifi S, Jaradat I, Mubiden R (2015) Combined photon-electron beams in the treatment of the supraclavicular lymph nodes in breast cancer: A novel technique that achieves adequate coverage while reducing lung dose. *Medical Dosimetry*, ***40***: *210-217*.
14. Prasad S, Bedwinek J, Gerber R (1983) Lung dose in electron beam therapy of chest wall. *Acta Radiologica: Oncology*, ***22***: *91-95*.
15. Inskip PD, Stovall M, Flannery JT (1994) Lung cancer risk and radiation dose among women treated for breast cancer. *Journal of the National Cancer Institute*, ***86***: *983-988*.
16. Dogan MH, Zincircioglu SB, Aydinol M (2013) Research on different techniques in breast cancer radiotherapy. *Contemporary Oncology*, ***17(3)***: *291–297*.
17. Vaiduriam M, Parameswaran S, Arjunan A, Jayaprakash P, Ratheesan K, Saju B, Shaiju V, Kumar PR (2013) Dosimetric comparison between electrons and tangential photons in postmastectomy chest wall irradiation. *Int J Radiat Oncol Biol Phys*, ***87***: *S206-S207*.
18. Amin-Zimmerman F, Paris K, Minor G, Spanos W (2005) Postmastectomy chest wall radiation with electron-beam therapy: Outcomes and Complications at the University of Louisville. *The Cancer Journal*, ***11***: *204-208*.
19. Jansson T, Lindman H, Nygård K, Dahlgren CV, Montelius A, Öberg-Kreuger C, Asplund S, Bergh J (1998) Radiotherapy of breast cancer after breast-conserving surgery: an improved technique using mixed electron–photon beams with a multileaf collimator. *Radiotherapy and Oncology*, ***46***: *83-89*.
20. Rudat V, Alaradi AA, Mohamed A, Khaled AY, Altuwaijri S (2011) Tangential beam IMRT versus tangential beam 3D-CRT of the chest wall in postmastectomy breast cancer patients: a dosimetric comparison. *Radiation Oncology*, ***6***: *1*.