Original Article

Assessment of the Effect of Breast Size on Dose Distribution for 3D and Conventional Methods with TLD Dosimetry in Breast Phantoms

Mahdieh Afkhami Ardakani[1], Mahbood Esfahani[2], Yalda Nourollahi[3,*], Yaghub Ashuri Taziyani[4], and Mohamad Hagh Parast[1]

1- Department of Radiology, faculty of Para-Medicine, Hormozgan University of Medical Sciences, Bandare- Abbas, Iran.

2- Department of radiotherapy, Cancer Institute, Emam hospital, Tehran, Iran.

3- Department of Radiation and Oncology, Shahid Fayaz Bakhsh Hospital, Tehran, Iran.

4- Department of Radiation Oncology, Omid cancer institute, Hormozgan University of Medical Sciences, Bandare- Abbas, Iran.

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ABSTRACT

Purpose- The complex geometry of breast tissue, variable shape, size of breasts, their lack of homogeneity and other organs at risk like the heart and lungs make dose distribution difficult, especially for cases involving large breasts. Assessment of breast dosimetry includes homogeneity dose distribution with complete target coverage and the avoidance of organs at risk as much as possible. The aim of this study is to assess dose distribution and coverage of the target by TLD dosimeter in slab breast phantoms.

Methods- This study used a slab anatomical phantom with lung inhomogenity for two different breast sizes, large and small. Exposure was done with 6 MV, utilized PTW reader, oven LTM to annulling conventional methods were carried out with a hand generated contour, 3D treatment planning used RT Dose Plan software.

Results- There were areas with lower than 95 percent reference dose in 3D methods decreased in compare of conventional methods. This result for large breasts was remarkable. Received area of target for both size more than 105 percent reference dose reduce to some extent, therefore getting more homogeneity also better coverage for target volume for large breast.

Conclusion- This study has shown that conventional methods are not suitable to assessment of dose distribution and coverage in target volume, especially for large breast. Also there was not sufficient dose distribution for small breast a as result of the 3D method, and so can it be useful for crowded hospitals with restricted facility centers because they can use conventional methods with nearly the same results as the 3D method.

1. Introduction

Breast cancer is the most common malignancy in women 40-years old. In the past, the most common treatment was total mastectomy, but currently, the most standard procedure method is lumpectomy and as a follow-up, the patient is given RT to reduce the risk of local regional recurrence [1].

Radiation therapy to the breast is a complex task

**** Corresponding Author:***
Yalda Nourollahi, MSc
Department of Radiation and Oncology, Shahid Fayaz Bakhsh Haspital, Tehran, Iran.
Tel: (+98) 9123954633/ Fax:(+98) 2155228591
E-mail: Nourollahi.yalda61@gmail.com

and breast is usually irradiated with two laterally opposed tangential beams.

The tangential fields are used to treat the breast to make a homogenous dose, provide complete coverage, and reduce organs at risk like the lungs and heart. Irregular geometry and variable shape and size make it technically difficult to deliver a homogenous dose to treatment volume [2]. The conventional method is common in many centers with a single plan hand-generated contour in which just the central plan is considered and neglected other information related to total target volume, the variation in contour and chest wall separation in the other plan, which has significant impact on dose homogeneity, as well as lack of homogeneity lung [3-4]. The availability of CT-Scanners most of the centers are gradually shifting towards CT-based treatment planning, to consider recent research, the 3D method is used with a full cuts of CT Scan to obtain the whole coverage of breast and good homogeneity. In fact this type of treatment planning evaluate the dosimetry across the entire breast, also reduce irradiated organs at risk when using the 3D planning system [5], one of the basic factor emphasized in breast dose distribution is breast size, which can affect target volume dose distribution.

The aim of this study is to compare the 3D and 2D methods for two different breast sizes examining the aspects of homogeneity in dose distribution and target volume coverage.

2. Materials and Methods

A slab anthropomorphic phantom including lung heterogeneity and heart part was constructed from 61 transverse slices, each with 5 mm thick Figure 1. The phantom does not contain any bone inset to simulate ribs. Materials used in the phantom were chosen to conform with the requirement of ICRU report No.44 [6].

CT Scans of 14 patients had been used to get an average of the size of typical breasts and determine required dimensions such as chest wall separation and breast height [7]. From this estimation, CT scans of one patient (who had dimensions nearest to this typical size) were selected and contours of the body, heart, and lungs were drawn on these slices.

To average, we used some parameters like breast separation, breast height, and volume. The small breast measurements: breast separation was 17 cm height 5 cm, volume 600 cc. Large breast: breast separation 20 cm, height 10.5, volume 1520 cc.

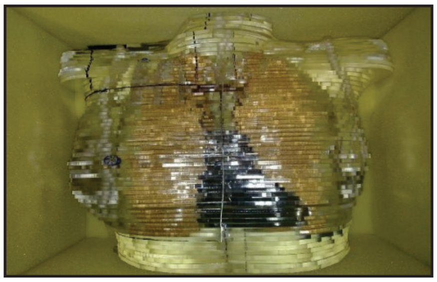


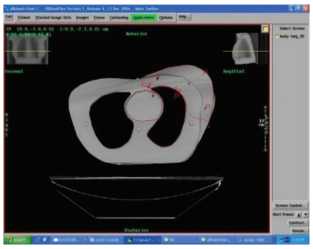
Figure 1. Slab breast phantom.

2.1. Dosimeter Placement and Preparing Phantom to Exposure

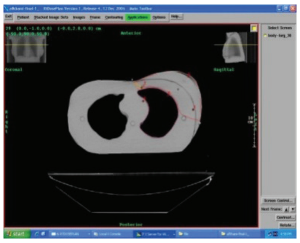
CT scan underwent with 5 mm slice and PTV related both two sizes were drawn by a physician. In this study supraclavicular and axillary field were neglected. Three slices were considered for insertion of dosimeter for each size. The first slice center of PTV, 2 other slices separated about 5 cm inferior and superior of center cut Figure 2.

In each slice, a 4-point measure while two points medial border area of target volume, so for each size 12 points were determined. Scholar with placement and numbers in Table 1.

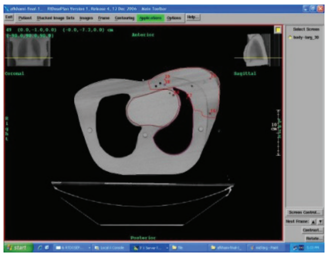
Before phantom positioning to treatment, insert dosimeters in specific points. Radiation was performed with 6 MV energy photon generated by Varian 2100 C/D and 200 cGy as a daily dose.



Central cut for large breast



Cranial cut for large breast



Caudal cut for large breast

Figure 2. Cuts related to large breast.

Table 1. TLD placement for large and small size.

Caudal cut	Central cut	Cranial cut
1-1- (Posterior of Medial) 1-2- (Anterior of Medial) 2- (Lateral) 3- (Anterior)	1-1- (Posterior of Medial) 1-2- (Anterior of Medial) 2- (Lateral) 3- (Anterior)	1- (Medial) 2- (Lateral) 3- (Anterior)

2.2. Dosimeter and Calibration

43 TLD kinds used: LIF: MG,p. Circle with 4.5 diameter, 0.8 mm wide with trademark GR207A [8]. A cubic plagsiglass hantom was also used for all TLD irradiations.

The phantom considered of a stack of 15 square 25×25 cm slabs, each about 1 cm in thickness, irradiation carried out in a 10×10 cm^2 field at a source to phantom surface of 100 cm in maximum depth for 6 MV photon.

For each TLD measurement, background subtraction was performed. Background was defined as the average reading from a TLD not exposed to radiation.

To delete remaining signals due to radiation in TLD crystal, after reading and before reusing apply TELDO oven constructed by PTW company. Annulling process for crystal increase temperature up to 240 ^{0} and stay this situation for 10 minutes and rapidly cooling, reading was done by LTM reader. Information was shown by numbers to get absorption dose of single and group calibration done. Single calibration was done due to difference result of each TLD and difference response with same dose. Group calibration was done to change readouts to dose, so variation plot into calibration curve.

2.3. Treatment Procedure

2.3.1. Conventional Methods

In this article, conventional methods were accomplished with hand-generated contouring with the SSD (source skin distance) technique. Length and width of tangential fields determined the extent that to cover cranial and caudal portion of tangential volume and breast anterior, respectively. Required parameters to set up phantom were applied exactly according to planning software.

2.3.2. 3D Method

3D planning was done by RT dose Plan software. Normalization point considers center of target volume, DVH related to PTV drawn with which determined percentage of target volume with dose less and more than prescribed dose of 90 percent and 95 percent, as well the percentage of target volume with more than 105 percent and 110 percent prescribed dose as a hot point, respectively. To calculate dose homogeneity index (DHI) in target volume used below formulation [2].

$$DHI^1 = 100 - (Vol < \%95 + Vol > \%105)$$

2.3.3. Statistical Analysis

To compare average and variance measured doses for both 2D and 3D methods applied pair T test and Levee's Test, respectively, by SPSS software. Significant level was in 5 percent.

3. Result

3.1. Calibration

Single correction coefficient achieved in range of %98, group calibration curve and correction factor in TLD shown in Figure 3. Ratio reading in variation angle to zero angle was almost 1 percent. So in phantom measurement neglect variable contact angle.

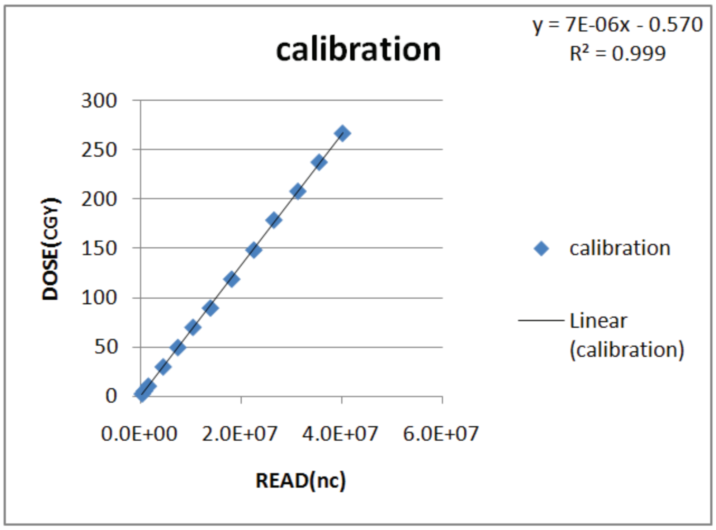


Figure 3. Calibration curve of TLD.

3.2. Target Volume Coverage

According to drawn target volume, some parts of target missed in medial and lateral target in large size and some area of medial for small size of breast, both of them occurred using the conventional method.

These results show the difference of target volume coverage 3D in comparison to the conventional method. Of course this data for large breast is remarkable. Mean measured dose for TLD for both conventional and 3D method also percentage of their amount error in phantom than treatment planning system Table 2, 3.

With regard to data, a total of 5 points in target volume received different dose of ICRU 50 report.

Table 2. Mean measured dose in small size for conventional method and percentage of error with planning system.

Cranial cut			Central cut			Caudal cut		
points	Dose (cGy)	Percentage of error	points	dose (cGy)	Percentage of error	points	dose (cGy) points	Percentage of error
*1	185.53 (-%4.5)		1-1 *2-1	192.57 (%2.1) 187.53 (-%3.9)		1-1 *2-1	197.91 (%1.7) 188.00 (-%2.6)	
2	205.23 (%1.3)		2	202.03 (%.5)		2	196.29 (%1.4)	
*3	214.37 (-%.4)		3	209.77 (-%.3)		*3	217.63 (%.4)	

Table 3. Mean measured dose in small size for 3D method and percentage of error with planning system.

Cranial cut Percentage of error - (cGy) dosepoint		Central cut Percentage of error - (cGy) dosepoint		Caudal cut Percentage of error - dose (cGy) points	
1	194.73 (-%2.7)	1-1 2-1	202.39 (-%1.1) 193.59 (-%2.17)	1-1 2-1	204.61 (-%1.8) 196.83 (-%1.7)
*2	212.94 (%1.3)	2	195.09 (-%4.4)	2	202.37 (%1.5)
*3	214.93 (-%.9)	3	209.18 (%1.13)	*3	215.8 (-%1)

Results show only 3 points received off-limits dose with ICRU 50 report.

Average measured dose by TLD for two conventional and 3D method and percentage of error from calculated planning system for large breast. Report Table 4, 5.

As results shown only 7 points were far from ICRU report.

According to result of 3D in large breast, a total of 5 points in target volume were different with ICRU report.

Table 4. Mean measured dose in large size for conventional method and percentage of error with planning system.

Cranial cut		Central cut		Caudal cut	
Percentage of error - dose (cGy) points		Percentage of error -(cGy) dosepoints		Percentage of error -(cGy) dosepoints	
*1	182.07 (-%4.4)	1-1 *2-1	194.63 (-%3.7) 187.13 (-%2.5)	1-1 *2-1	197.02 (-%3.7) 184.20 (-%4.7)
2	199.32 (%.9)	2	198.78 (%3.9)	*2	187.23 (-%4.9)
*3	223.44 (%.6)	*3	221.61 (-%.5)	*3	226.39 (%.6)

Table 5. Mean measured dose in large size for 3D method and percentage of error with planning system.

Cranial cut		Central cut		Caudal cut	
Percentage of error - dose (cGy) points		Percentage of error - dose (cGy) points		Percentage of error - (cGy) dosepoints	
*1	213.69 (%1.6)	1-1 2-1	207.68 (-%2.5) 200.82 (-%1.9)	1-1 2-1	209.86 (-%1.9) 202.37 (%2.3)
2	208.31 (-%.3)	2	209.33 (%2.4)	*2	213.83 (%1.5)
*3	217.02 (%.1)	*3	214.51 (-%1.4)	*3	219.76 (-%.01)

Table 6. Vol<90, vol<95, vol>105, vol>110, D_{max} in 3D planning and conventional methods for large size phantom.

Large breast phantom	Vol<% 90	Vol<% 95	Vol> %105	Vol> % 110	D-max
Conventional method	10.71	16.72	23.17	2.48	116
3D method	6.93	10.16	21.94	2.14	114

Table 7. Vol<90, vol<95, vol>105, vol>110, D_{max} in 3D planning and conventional methods for small size phantom.

Small breast phantom	Vol< % 90	Vol< %95	Vol>%105	Vol> %110	D-max
Conventional method	5.95	11. 43	12.51	0.24	113
3D method	4.01	8.52	11.45	0.21	112

In 3D method, target volume which received less than 95 percent of the prescribed dose reduced in comparison to the conventional method for large (6.56 %) and small (2.91 %) size breast also some area of target volume decreased greater than dose of 105 percent of the prescribed dose in large and small size breast.

Table 8. Homogeneity dose distribution in target volume for 3D and conventional method for both small and large size breast.

Small breast phantom	Conventional method	3D method
DHI (%)	76.06	80.03
Large breast phantom	Conventional method	3D method
DHI (%)	60.11	67.90

Homogeneity dose distribution getting better in 3D than conventional methods in small size (3.97 %)

And large (7.79%) to consider results in large breast, the average dose in 3D was bigger than conventional method significantly (P= 0.032), the average dose in small breast for 3D was bigger than conventional, but it wasn't very great (p= 0.072). The result of Levee's test shown amount of variance in conventional method in large size was bigger than 3D. In the small size, the difference was not significant between the two sizes in both variance (p= 0.188).

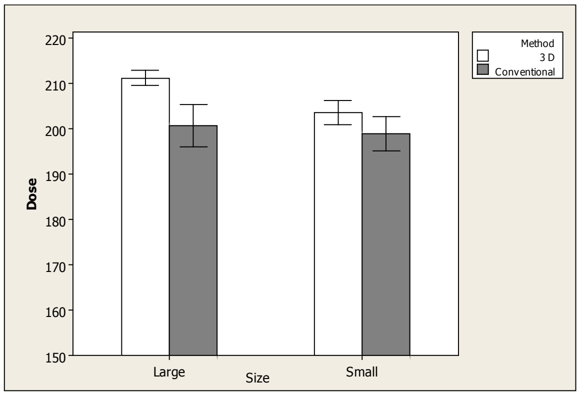


Figure 4. Bar error curve of dose distribution for separated size.

Considering the result of pair T test, the average of dose in 3D for medial in both size was bigger than in the conventional method (p<0.05).

However, in the larger size, the average dose for 3D was less than conventional method, (p= 0.001). In other placements there wasn't a difference for two method p>0.05.

Whereas, there wasn't any significant difference between the variance for two methods in other placement by considering leave test p>5 %.

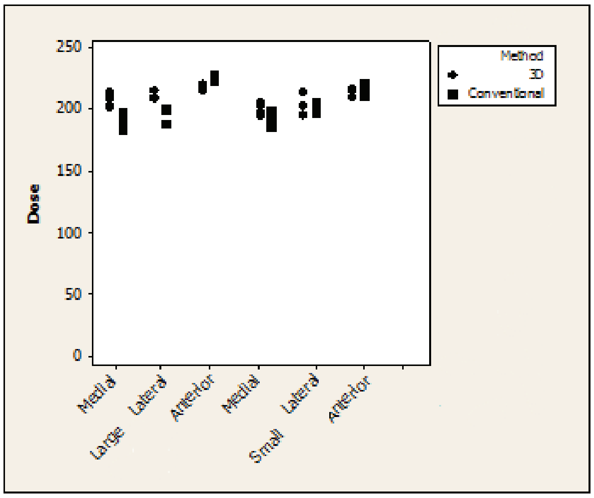


Figure 5. Shows the point size for both size and method separately.

4. Discussion

This study attempts to depict the amount of heterogeneity for different sizes and the suitable procedure of treatment to get good dose distribution with the aim of increasing further homogeneity to improve cosmetic results. In this study, measurements were carried three times to reduce statistical errors.

The correction according to adaptation unreferenced condition to reference condition and single and group correction for crystals reduce measurement error and get result assurance also acceptable error in dosimetry according to ICRU report.

Data shows the maximum dose (hot point) for both sizes in two methods happened in inferior point especially in caudal cut, this point in convention for large breast was remarkable.

This result caused decreased tissue thickness, increased angle collision, so increased the accumulated scatter dose under skin. In other study with 8 MV, hot point registered on anterior of caudal cut that emphasized our results [11].

Point dose less than 95% prescribed doses happened in medial and lateral of target volume. These results remarkable in large breast for conventional method that due to of unsuitable coverage of target volume. One reason is to consider that only one cut of PTV is in the conventional method and neglects the others, similar studies confirm our results [12].

Results of DVH for 3D treatment planning in large breasts shows that some parts of the target volume less than 95 percent of prescribed doses reduced remarkably in comparison to that of the conventional method.

Also, the target volume more than 105 percent prescribed doses reduced somehow. DVH related to 3D treatment volume in small sizes showed some area of target volume with less than 95 percent of the prescribed dose and some part with more than 105 percent of the prescribed dose reduced than when using conventional method. There are some results of heterogeneity, where parts of the target volume with doses of less than the prescribed dose due to reduction of control tumor and range of this effect depend of remained tumor and response dose tumor curve.

Past studies indicate decreasing the dose of 50 Gy to 45 Gy reduce the probability of controlling the tumor from 95 percent to 85 percent. Also hot points resulted in poor cosmetic appearance and injured normal tissue [13].

Measured points in different parts of phantom breast and DHI showed heterogeneity in 3D than conventional for both two sizes reduced, this subject in large breast was remarkable, in general there was more heterogeneity in the large size than small, even in 3D. Moody *et al*, have shown a significant relationship between heterogeneity and breast size, which due to abnormal cosmetic results especially in large breasts [14]. Neal *et al.* observed similar results, that large-breasted women are more likely to have more heterogeneous dose distributions, and stated that breast remnant volume of <600 cc and/or A or B bra cup size is associated with a low probability of a very heterogeneous dose distribution [15].

Also, other studies indicated the comparison of 2D and 3D method by Munshia *et al*, in this case there was a maximum dose difference for small SD (1.08) 1.93, for large breasts (2.4) 2.98 and medium size (2.69) 4.28, that highlighted the value of conventional methods for small size, Also with increasing breast volume, research indicates that 3D planning is mandatory for large breasts [16].

In conclusion radiotherapy centers with poor facilities, high workload, and the time-consuming nature of 3D can benefit from a conventional plan with a hand generated, single-cut method to approximate the dosimetric advantage of 3D planning. Results show that the 3D method gets more homogeneity and better coverage of target volume than conventional methods, which were never explicitly defined in single cut. This can also reduce recurrence and produce better cosmetic results. This note suggests the 3D method is not regarded as useful for small sizes in a poor facility; therefore, the first priority for large breasts is to use 3D treatment planning.

In general, it is difficult to achieve dose homogeneity as prescribed by the ICRU-50 report, even with 3D planning. Based on our dosimetric study, breast planning with hand-generated contour is an appropriate technique only for patients with small breasts. However, for large breasts, 3D planning has a definite role, and these results can be especially useful for treatments in busy oncology centers.

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