

## Computerized Treatment Planning in Radiation Therapy of Intact Breast: Influence of Number of CT-Cuts

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### ABSTRACT

**Purpose:** To compare the accuracy of 2D algorithm with an established 3D algorithm, and to define the number of CT-slices needed for treatment planning of intact breast irradiation.

**Material and Methods:** Twenty patients with breast cancer treated with conservative surgery were included in this study, ten of them had right breast cancer and the other 10 patients had cancer of the left breast. For each patient, 3-D calculations (HeLax-TMS) were performed using one CT-slice (central), 3 CT-slices (central, caudal, and cephalic) and full set CT-slices in addition to 2D calculations (Multidata System) on the digitized central cut. All calculations were done using 6MV-photon.

**Results:** When using 2D planning with lung correction, a large hot area of 105% was found at the medial and lateral subcutaneous (SC) regions. Comparison of 2D-treatment planning using Multidata System (2D-physics) and 2D-planning using HeLax System (3D-physics) showed that the 2D planning using Multidata System gave a large hot area of 105% compared with HeLax-2D at the subcutaneous region. The central axis dose distributions obtained from 2D and 3D calculations using HeLax system were compared. No differences were found in the two planes (central cut plane) and this was because the two planes were based on the same algorithm. The only difference was that the hot area (110%) was found at the superior or the inferior border of the field. Also, a comparison using the 3D-system for the central slice and the multiple slices showed a difference in calculating the maximum dose to the target of 2.19%, which was statistically significant ( $p=0.001$ ). For all left sided patients, the maximum dose to the heart was significantly different from one to full CT-cuts. It was  $12.0\pm 6.0\%$  when using one CT-cut versus  $6.6\pm 1.3\%$  when using full CT-cuts ( $p<0.03$ ). We compared isodose distributions using three and full CT-cuts for both small and large breasts. For the "large" breast patients, larger differences in isodose distributions were observed in the cephalic and the caudal planes than for "small" breast patients.

**Conclusion:** Dose distributions based on a single CT cut through the central axis using 2D or even 3D treatment planning system will lead, quite often, to hot volumes in

excess of 105%. For patients whose breast contours vary slowly within the tangential fields, a three-slice CT scan appears to be adequate for clinical decision. However, for patients with large variation of contours within the tangential fields, a full CT scan gives more accurate dose distributions than the three-slice model.

**Key Words:** *Treatment planning — Breast — Computed tomography — Three-dimensional.*

### INTRODUCTION

Historically, treatment planning of the intact breast was generally performed using two-dimensional (2D) techniques. In 2D treatment planning, all dose distributions are calculated on the central-axis plane (CAX) without lung inhomogeneity correction. Although 2D treatment-planning systems predict reasonable isodose distributions in this plane, they generally do not provide information in off-axis planes. Treatment plans optimized using 2D systems can lead to hot volumes as large as 25 percent inadvertently being administered to the patient, even though the hot volumes appear to be minimized [1]. The use of the 2D-option in 3D-planning system with 3D mathematics resulted in a more accurate picture of the dose distributions in the CAX plane than using 2D-system (using 2D physics) [2].

3-D treatment planning with inhomogeneity corrections allows a better appreciation of the volume and magnitude of the hot spots within the treatment volume particularly in normal tissues adjacent to the target volume (ribs, muscle, soft tissue and lung). Although the results of intact breast treatment using conventional 3-D treatment planning show excellent local control with good cosmetic results [3-4], there still occurs a small but significant rate of

complications such as pneumonitis (1-9%), rib fractures (1-5%) and myositis (1-5%) [4-5]. The major factors contributing to these hot spots are lung inhomogeneity and changes in breast contour and size [1,6,7].

To carry out 3-D dose calculations, a dedicated computed tomography (CT) and a 3-D treatment planning system are required. While all previous studies have demonstrated the need for 3-D planning, the requirement of the number of CT slices in a 3-D procedure has not been discussed widely in literature [8,9]. In a busy radiotherapy department, a full scale CT planning on every breast patient can be time consuming to the personnel involved and would increase the cost of patient care. As a compromise between the conventional 2-D approach and the labour intensive full scale CT planning, some institutions are now using a three-slice CT scan, which includes CAX and two slices representing the superior and the inferior planes.

The use of a full CT study in tangential breast irradiation provides a detailed picture of the dose distributions through the breast volume. However, using a full CT study in the treatment planning process cannot reduce dose inhomogeneities within the breast volume. This goal can only be accomplished by using 3-D compensators [1]. Thus a simple breast model, which can be used by the physician to evaluate dose distributions throughout the breast volume, would be a welcome alternative to a full-scale CT study.

*The Objective of this Study were Two-Points:* (a) to compare the accuracy of 2D algorithm with an established 3D algorithm, and (b) to define the number of CT-slices needed for 3D treatment planning of intact breast irradiation.

## MATERIAL AND METHODS

*Patient Selection:* A total of 20 patients with breast cancer treated with conservative surgery were included in this study. Ten of them had right breast cancer and the other 10 patients had left breast cancer.

*Patient CT Data:* All patients were scanned using Siemens Somatom plus CT system. The patients were positioned supine on an angled board placed on the top of CT table with the ipsilateral arm positioned above the head to

allow the patient to fit through the gantry for scanning.

Prior to CT scanning, the treatment volume was marked and lead wires were placed at the superior, inferior, medial and lateral borders. The scans were taken with slices spaced at 1cm interval. The scanned region extended at least 2cm cephalic to the superior border of the breast and at least 2cm caudal to the inferior border of the breast. After CT scanning, the CT technologist electronically transferred the scans and patient information data set to the 3-D treatment planning system (HeLax-TMS) [10]. For 2-D planning we used the Multidata System [11]. The central CT cut was only digitized and transferred to the planning system.

*Patient Outlining and Treatment Planning:* For each patient, 3-D calculations (HeLax-TMS) were performed using one CT-slice (central), 3 CT-slices (central, caudal, and cephalic) and full set CT-slices in addition to 2D calculations (Multidata System) on the digitized central cut. All calculations were done using 6MV-photon. The dose per fraction was 200cGy and the dose prescribed to the isocenter.

*Treatment Planning Using 3D-Planning System (HeLax-TMS):* The gross target volume (GTV) was considered to be the entire breast volume and was equal to the clinical target volume (CTV). The planning target volume (PTV) was defined as the CTV plus a 2-cm additional margin to account for respiration and movement of the patient. The ipsilateral lung, contra-lateral lung and heart were also outlined. Patients were grouped into "small" breast volume patients (breast volume <1000cc) and "large" breast volume patients (breast volume ≥1000cc). The full CT cuts were used to obtain a treatment plan taking into consideration the ICRU 50 recommendations [12]. We applied the same 3D planning parameters (entrance points, gantry angles, wedge angles, beam weighting, normalization points etc.) to the planning made on one and three CT slices. Each patient had 3-plans (one slice, three slices and serial slices) with a total of 60 plans. The dose volume histograms (DVH) for the clinical target volume; both lungs and the heart were plotted. There was also a printout of dose statistics for the target volume, including mean dose, maximum dose, and standard deviation.

*Treatment Planning Using 2D-Planning System (Multidata System):* The central cut was introduced to the planning system by the digitizer. The target and the critical structure were drawn. The same set up technique as the 3D planning was used by putting markers on the normalization point and the entrance points of the beams.

## RESULTS

### *Lung Correction for 6MV Photon Using 2D-Planning System:*

This was checked in the 2D-planning system by calculating the dose distribution for intact breast with and without lung correction. A large hot area of 105% was found at the medial and lateral subcutaneous (SC) regions when calculating with lung correction.

### *Comparison of 2D-Treatment Planning Using Multidata System (2D-Physics) and 2D-Planning Using HeLax System (3D-Physics):*

The central axis (CAX) dose distributions obtained with 2D calculations using Multidata and HeLax Systems were compared. The 2D planning using Multidata system showed a large hot area of 105% compared with HeLax-2D at the subcutaneous region. There was a difference of 2.96% in calculating the maximum dose to the target, which was statistically significant ( $p=0.006$ ) (Table 1). The mean dose difference was 0.54%, which was not statistically significant ( $p=0.21$ ).

### *Comparison of 2D and 3D-Planning Using HeLax System:*

The central axis dose distributions obtained from 2D and 3D calculations using HeLax system were compared. No differences were found in the two plans (central cut plan) and this was because the two plans were based on the same algorithm. The only difference was that the hot area (110%) was not in the central cut but it was found at the superior or the inferior border of the field. Also, a comparison using the 3D-system for the central slice and the multiple slices showed a difference in calculating the maximum dose to the target of 2.19%, which was statistically significant ( $p=0.001$ ). For the mean dose to the target, there was a good agreement between 2D and 3D planning using the HeLax system with only a difference of 0.63% ( $p=0.081$ ) (Table 2).

### *Minimum Number of Calculation Planes Sufficient for 3D Planning of Intact Breast:*

Estimation of the dose volume distributions of the target, heart and lung using CT planning were done. For 20 patients, the maximum and mean dose  $\pm$  standard deviation were calculated using one, three and full CT-slices (Fig. 1). The effects of the number of CT-cuts on dose distributions are shown in table (3). As regards the heart of the 10 left sided breast patients, there was a significant difference in the mean percentage dose, where it was  $12.0\pm 6.0\%$  when using one CT-cut versus  $6.6\pm 1.3\%$  when using full CT-cuts.

The percentage target volume fulfilling the ICRU 50 recommendations for dose criteria was evaluated from the DVH of the target. The mean dose to the target volume meeting the criteria in the 1 cut was  $85.53\pm 9.09\%$ ,  $83.4\pm 8.2\%$  in the 3 cuts and  $78.65\pm 11.67\%$  in the full CT study. The difference was not statistically significant ( $p<0.3$ ).

The mean percentage volume of the ipsilateral lung that received a dose of 30Gy or more was  $19.1\pm 10.4\%$  in the 1 cut study,  $15.04\pm 6.80\%$  in the 3 cut study and  $13.1\pm 6.4\%$  in the full CT study ( $p<0.03$ ). The mean volume of ipsilateral lung tissue that received a dose of 45Gy or more was  $13.1\pm 6.2\%$  in the 1 cut study,  $7.8\pm 4.8\%$  in the 3 cut study and  $6.1\pm 4.9\%$  in the full CT study ( $p<0.01$ ).

The mean percentage volume of the heart that received a dose of 24Gy or more was  $9.7\pm 7.0\%$  in the 1 cut study,  $8.0\pm 6.0\%$  in the 3 cut study and  $7.0\pm 5.6\%$  in the full CT study ( $p<0.7$ ). The mean percentage volume of the heart that received a dose of 45Gy or more was  $5.0\pm 5.0\%$  in the 1 cut study,  $4.0\pm 3.0\%$  in the 3 cut study and  $1.7\pm 2.4\%$  in the full CT ( $p<0.01$ ).

We compared isodose distributions using three and full CT-cuts for both small and large breasts (Table 4). For small breasts, there was no significant difference between 3 and full CT-cuts as regards mean target dose ( $p<0.2$ ) and maximum dose ( $p<0.1$ ). On the other hand, large breast isodose distributions showed that the maximum dose was significantly underestimated when using 3 CT-cuts compared to full CT-cuts ( $p<0.006$ ), while the mean dose was not statistically different ( $p<0.06$ ). Fig. (2)

shows the dose distribution for “small” breast patients determined from the three-slice and the full CT techniques. For the “large” breast patients, because of more dramatic variation of the breast contours in the tangential fields (in terms of separation changes), larger differences in isodose distributions were observed in the cephalic and the caudal plans than for “small” breast patients (Fig. 3). The largest difference

was noticed in the caudal plane, where the three-slice model showed a large high-dose region at that level while the full CT model predicted a substantially smaller region. In the cephalic plane, the three-slice model showed a somewhat larger under-dose region (90-99%) in the center of the breast compared to the full CT breast model as the size of the breast contour increases toward the cephalic margin.

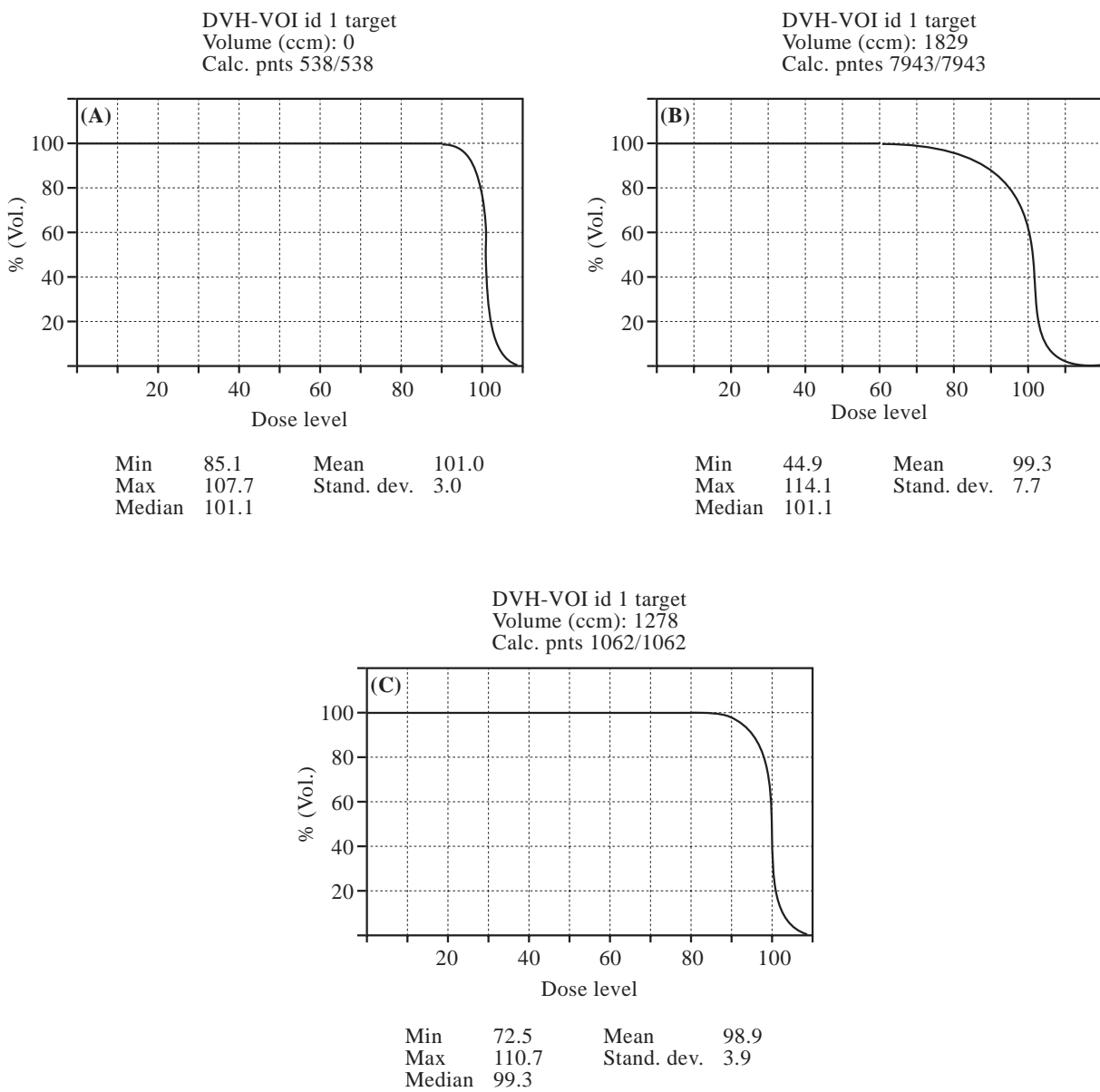


Fig. (1): Dose-volume histogram (DVH) of the target for (a) 1-cut, (b) 3-cuts and (c) full-cuts.

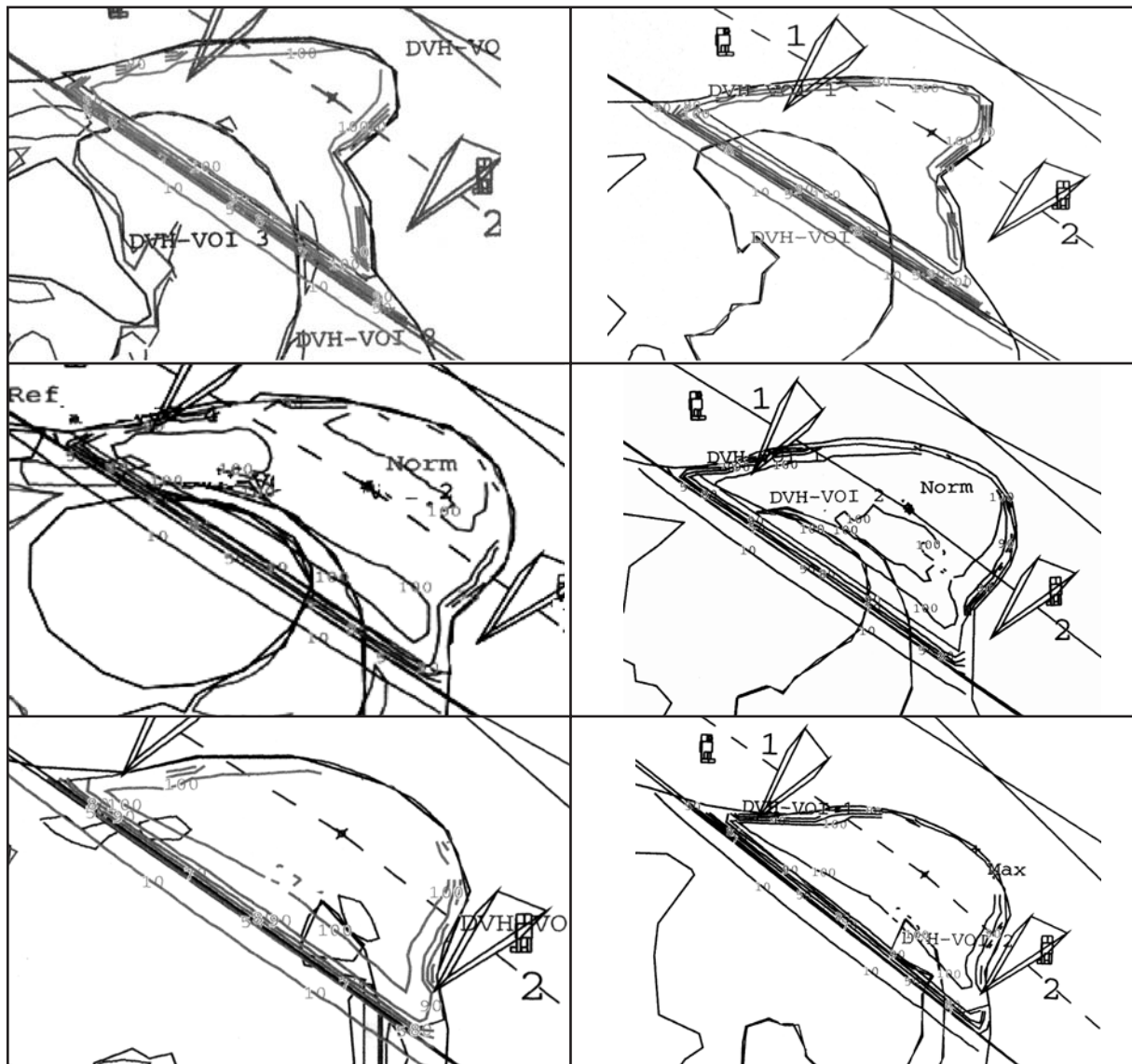


Fig. (2): Comparison of isodose distributions for a patient with small breast between the three slice model (Rt.) and the full CT model (Lt.) The two panels are the distributions in the cephalic plane. The middle panels are the distributions in central axis plane. The bottom panels are the distributions in the caudal plane.

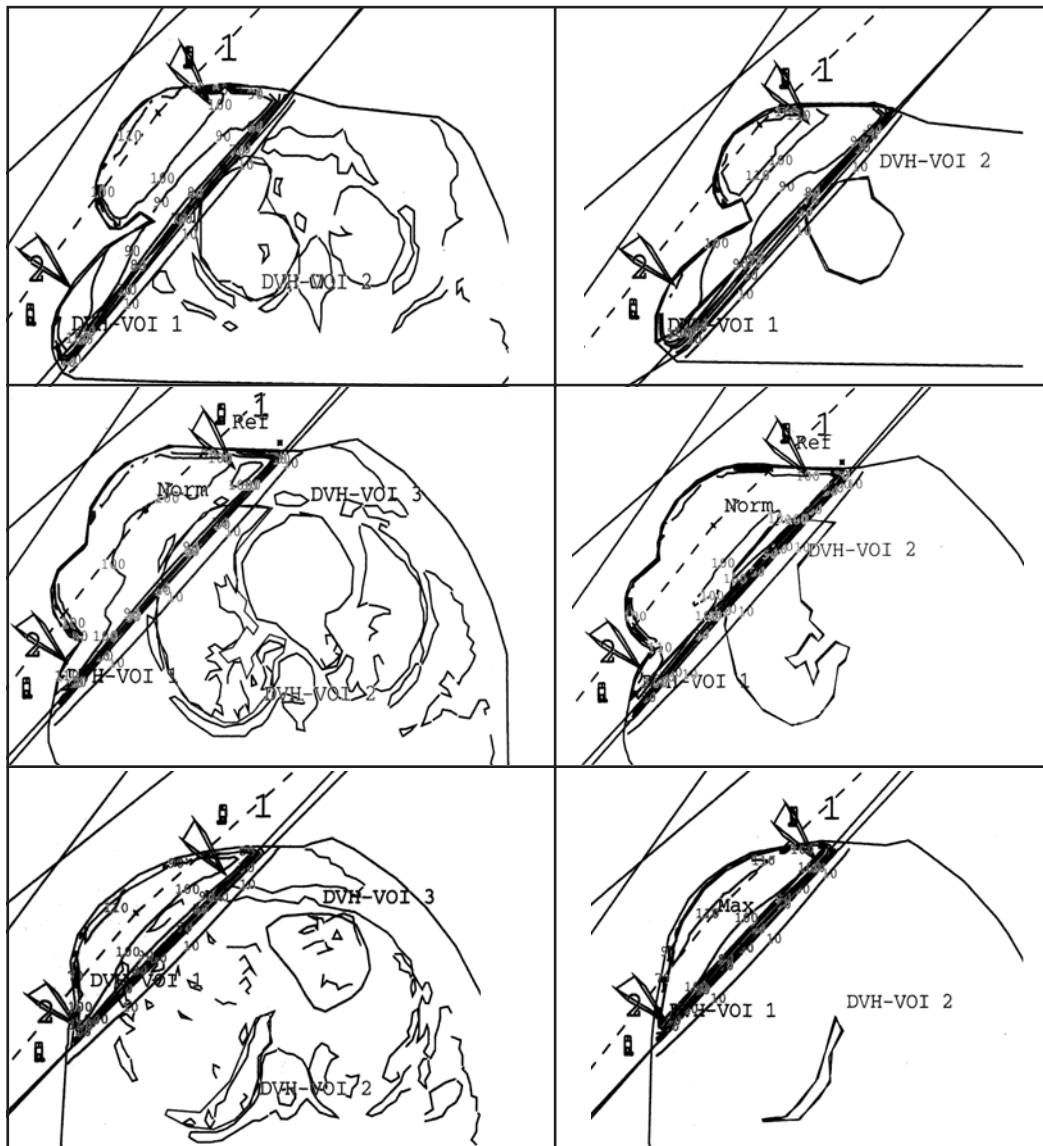


Fig. (3): Comparison of isodose distributions for a patient with large breast between the three slice model (Rt.) and the full CT model (Lt.) the top two panels are the distributions in the cephalic plane. The middle panel is the central axis distributions. The button panels are the distributions in the caudal plane.

Table (1): Percentage target dose from 2D-Multidata and 2D-HeLax systems.

% Target dose	2D-Multidata	2D-HeLax	p-value
	Mean±SD	Mean±SD	
Maximum	112.4±3.32	109.2±1.99	0.006
Mean	99.87±0.33	100.4±1.36	0.209

Table (2): Percentage target dose for breast cancer patients using HeLax planning system (2&3D)-for 6MV.

% Target dose	2D-HeLax	2D-Multidata	p-value
	Mean±SD	Mean±SD	
Maximum	109.2±1.99	114.6±3.38	0.001
Mean	100.4±1.36	99.78±0.95	0.081

Table (3): Dose distributions to target volume, heart and lung calculated from DVH.

	Percentage dose distributions		
	Mean±SD	Max.±SD	
<i>Target (20 patients):</i>			
One CT-slice	100.7±5.3		
Three CT-slice	99.4±7.9	$p<0.9$	$p<0.03$
Full CT-slice	99.4±8.1		
<i>Heart (10 patients):</i>			
One CT-slice	12.0±6.0		
Three CT-slice	11.7±6.0	$p<0.03$	$p<0.3$
Full CT-slice	6.6±1.3		
<i>Ipsilateral Rt lung (10 patients):</i>			
One CT-slice	18.9±5.3		
Three CT-slice	19.9±6.1	$p<0.9$	$p<0.9$
Full CT-slice	17.2±6.0		
<i>Ipsilateral Lt lung (10 patients):</i>			
One CT-slice	21.2±9.9		
Three CT-slice	16.3±3.6	$p<0.04$	$p<0.9$
Full CT-slice	17.9±6.5		

Table (4): Relationship between % target dose, size of breast and number of CT-cuts.

% Target dose	Maximum dose		Mean dose	
	Mean±SD		Mean±SD	
<i>Small breast (10 patients):</i>				
Three cuts	106.9±2.2		100.3±3.3	
Full cuts	109.2±2.4	$p<0.1$	101.9±3.1	$p<0.2$
<i>Large breast (10 patients):</i>				
Three cuts	104.6±2.04		97.2±2.7	
Full cuts	109.8±2.7	$p<0.006$	101.2±3.1	$p<0.06$

## DISCUSSION

The breast is a difficult structure to irradiate in a homogeneous manner as it has a complex three dimensional (3D) shape and is located at the body-air interface, with rapid changes in contour and tissue separation, together with much inter-patient variation in breast size and shape. This can present a problem in terms of beam obliquity and increased radiation build-up in the subcutaneous tissues. Secondly, the dose-limiting organs at risk (OAR's), i.e. lung and heart in case of left-sided tumors, are in close proximity to the undersurface of the breast and chest wall. Finally, there is also the issue of inhomogeneity produced by the lungs, which have a lower electron density than the muscle and fat. This leads to less attenuation of the primary beam and less scattered radiation contribution to the adjacent breast [13].

Most centers determine the breast dose distribution by superimposing the radiation beam parameters on a solitary 2D contour of the patient taken along the central plane of the breast. This makes it impossible to take account of variations in contour for the vast bulk of the breast lying on either side of the central plane. Also, such 2D contours do not include the underlying lung as they are usually obtained by transferring the external contour by hand rather than by radiological imaging of the thorax. However, some centers take account of the underlying lung by acquiring a single computerized tomography (CT) image through the central plane, but again this represents only a single 0.5-2cm wide strip of lung and ignores the changes in contour and density along its length. The only way to truly appreciate the dose inhomogeneity within the clinical target volume is to devise a 3D plan, perform a 3D

dose calculation, and display the result in the form of a dose volume histogram (DVH). However, such technology may be difficult to implement on a large scale due to logistic and economic considerations [8,13].

One of the objectives of 3-D treatment planning of the breast is reducing the size and magnitude of the hot spots within the normal tissues particularly in the soft tissues lateral to the breast and in the costochondral junctions medially, where patients often complain of significant pain and tenderness following treatment. Furthermore, cosmesis is a major advantage and a significant motivating factor in choosing conservative treatment of breast cancer.

In this study, we compared CAX distributions based on 2-D calculations without lung correction and 3-D calculations with an established 3-D dose algorithm. Our results indicate that the 2-D distribution generally shows a more uniform distribution and smaller subcutaneous hot spots compared to the 3-D calculations. These results confirm the limitation of 2-D treatment planning in breast irradiation as reported previously [1,3,6,7,14].

The comparison of 2D-option in 3D-planning system (with 3D mathematics) using only a single CT cut with the full 3D calculation using serial cuts resulted in an accurate dose distribution in the central cut but could not give an accurate calculation of the maximum or the mean dose to the target, also they do not give an accurate picture of the magnitude and location of the hot volumes. In the 2D-option of the 3D planning system, the point of maximum dose was obviously located in the central-axis plane, while in the 3D calculations it was either in the superior or inferior aspects of the breast.

In our study, it was clear that a single CT-cut at level of CAX plane was associated with overestimation of isodose distributions compared to three-slice and full-slice plans as regards target and normal tissues (heart and lung). In a study conducted by Vincent et al. [8], they concluded that a single-slice plan is unsatisfactory in providing sufficient information about the dose variation across the treatment volume and that ideally a 3D plan with DVHs should be produced. If the required data is unavailable then a minimum of three slices should be used as an approximation. However, 21% of patients

would have had a more homogeneous distribution of absorbed dose from a 3D optimized plan (over a three-slice plan) and therefore if the resources are available it is worthwhile to plan with a full CT set and calculate throughout the entire volume.

The different techniques used in the planning of tangential fields are largely dependent on the equipment available and the workload capabilities of a department. The planning can vary from using one central axis (CAX) slice (or manual contour) to using many CT slices. Obviously, performing a CT scan and voluming a full data set on all patients undergoing tangential radiotherapy is time consuming, costly and may be unnecessary. Conversely, performing a single slice calculation may not be accurately predicting the dose variation that may be occurring outside the CAX slice. As a compromise between these two options some departments plan using 3-slices (the CAX slices plus two other slices which are representative of the superior and inferior transverse planes) [13]. In the present study, there was no difference in the isodose distributions between 3-cuts and full CT plans of the small breast patients. A large difference in the dose distributions was more observed in the cephalic and the caudal plans between the 3-slice and full CT plans for the "large" breast patients in comparison with the small breast patients. This is attributed to the rapid change of breast contour near the margins of the breast than the central portion of the breast. Cheng et al. [9] reported similar findings where they conducted a study on three representative patients with different breast sizes based on the chest wall separation. They concluded that no significant difference existed between the 3 and 5 CT plans and the full CT plans in small and medium sized breasts. However, there was a significant difference between 3 and 5 CT plans and the full CT plan in large sized breast patients in the cephalic and caudal planes.

#### *Conclusion:*

Basing the treatment geometry on a single CT cut through the central axis using a 2D treatment planning system, or even a 3D treatment planning system with a 3D calculation algorithm, will lead, quite often, to hot volumes in excess of 105%. Our study indicates that three-slice CT scan is sufficient for patients

whose contours change slowly within the tangential fields whereas a full CT scan gives more accurate dose distributions for those whose contours change more rapidly.

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