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COMPARISON OF VARIOUS PLANNING TECHNIQUES IN IRRADIATION OF WHOLE BREAST

Medical Science

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ABSTRACT

AIM OF STUDY : To compare the various planning techniques in irradiation of whole breast. **MATERIALS AND METHODS:** Twenty patients with early breast cancers treated with conservative breast surgery were included in the study and various planning techniques were applied i.e conventional standard tangential plan, 3D conformal therapy, Intensity modulated radiotherapy(IMRT) using 5 beams and 11 beams were analysed for each patient and the various aspects in planning like dose homogeneity, planning target volume coverage, dose volume histograms for organs at risk were studied in detail. **CONCLUSION:** IMRT significantly improved the conformity and homogeneity for the breast when compared to other techniques. Heart and lung volume receiving high doses were decreased, but more healthy tissues received low doses. However it remains to be seen whether the dosimetric improvements achievable with IMRT will lead to significant clinical outcome.

ORIGIN OF STUDY:

It is widely accepted that early stage breast cancer can be managed with conservative surgery and radiation therapy as an alternative to mastectomy. Several studies have demonstrated dose inhomogeneities as large as 20% due to rapid changes in the patient contour in the superior and inferior regions of the breast with standard wedged tangential beams. Other potential complications of breast irradiation include radiation induced myocardial damage and radiation induced pneumonitis.

All of these concerns highlight the fact that improvements in the technical delivery of breast irradiation are still needed. Conventional radiotherapy is being gradually replaced by image-based conformal radiotherapy techniques. Hence, it was decided to carry out a study to compare the techniques of whole breast radiation using conventional and conformal techniques.

AIM AND OBJECTIVES:

1. To improve the efficacy of whole breast RT delivery by optimizing dose homogeneity.
2. To compare the techniques of whole breast radiation using tangential(CONVEN),

3D conformal(3DCRT) and Intensity modulated radiotherapy(IMRT) in terms of dose uniformity in the planning target volume, volume of radiation received by organs at risk and dose to the contralateral breast.

MATERIALS AND METHODS:

Patient population:

Twenty consecutive patients with early stage breast cancer who were taken up for breast conservation surgery and for whom whole breast irradiation was planned were included in this study. All of them had histologically proven infiltrating ductal carcinoma.

Procedure:

A planning CT scan in treatment position using breast boards and aquaplast mould was taken for each patient, as detailed below:

- Patients were placed in the treatment position - supine position with arms raised and hands placed above the head.
- Radio-opaque markers were placed to represent conventional field borders.
- Using helical CT scanner, CT axial images with 5 mm thickness were obtained extending from the clavicles to the upper abdomen including the entire breasts and lungs bilaterally.
- The CT series was then transferred through DICOM network to a 3D treatment planning work station for treatment planning.

Conventional treatment plans:

- Markers representing the conventional field borders were used to construct two opposing tangential beams by means of virtual simulation similar to conventional procedure by direct simulation.
- Dose to the breast was considered to be 50 Gy delivered at conventional fractionation of 180-200 cGy per day delivered at five fractions per week + Electron boost 20 Gy. As the boost is delivered with electron beam, the boost volume was not considered in this study.

CT guided definition of target volumes and critical structures:

- Target volumes were defined following the recommendations of ICRU 62.
- The clinical target volume(CTV) included the breast as defined by the markers. Posteriorly the CTV was the junction of the breast tissue and chest wall or pectoralis major muscle, anteriorly the CTV was 5 mm inside the skin.
- The CTV was extended posteriorly by 7 mm to form the planning target volume(PTV) to account for the effects of setup error and intra-fraction motion because of respiration as recommended by ICRU 62.
- The following structures were also defined for each patient – ipsilateral and contralateral lungs, contralateral breast, and heart.

Standard plans:

- Using beams eye view(BEV), the optimal standard tangential opposing beams were inserted with SSD 100 cm.
- The central axis of the tangent beams were placed on the medial and lateral markers placed at the time of CT scanning and suitable asymmetric field size is used to cover the PTV in BEV.
- Beam weights and wedge angles were optimized based on the dose distribution for the central axis plane calculated without inhomogeneity corrections. (1)

3D conformal therapy (3D CRT):

- Three dimensional information for the target volume and for each of the normal tissues was obtained by combining the individual CT slices.

- Gantry angles were determined to achieve maximum avoidance of heart, ipsilateral lung and contralateral breast.

- Multileaf collimator(MLC) shielding was applied in such a way that 95% isodose closely encompassed the PTV in three dimensions and a uniform dose distribution was obtained. (5, 7)

Intensity Modulated Radiation Therapy (IMRT):

- The same PTV was used.

- All patients had an inverse planned IMRT dose distribution with 6 MV photons using 5 beams and 11 beams.

- The optimization was done to deliver the prescribed dose to PTV and minimum dose to surrounding normal tissues as much as possible by keeping the tolerance of organs at risk as constraints. (3, 4, 6)

Constraints:

- TD 50 Gy to 95% of the breast volume.
- 20 Gy to less than 25% of ipsilateral lung.
- 25 Gy to less than 9% of the heart.
- Contralateral breast max dose 10 Gy.
- Contralateral lung max dose 5 Gy. (3)

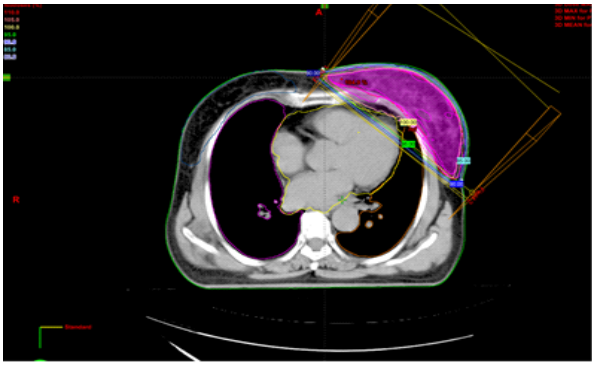
Evaluation tools:

Quantitative evaluation of plans was performed by means of standard dose volume histograms. The target homogeneity was expressed by D5% - D95% (difference between the dose covering 5% and 95% of the PTV). The degree of conformality of the plans was measured with a conformity index, CI95%, which is defined as the ratio between the patient volume receiving at least 95% of the prescribed dose and the volume of the PTV.

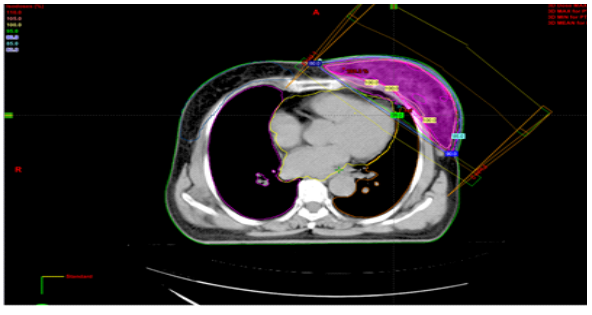
The average cumulative dose volume histogram (DVH) for PTV and organs at risks (OAR) were built from the individual DVHs obtained by averaging the corresponding volumes at each dose bin (0.01Gy). To appraise the difference between the techniques, the paired two tailed student's t-test was applied. Data were considered statistically significant for $p < 0.05$.

ISODOSE DISTRIBUTIONS:

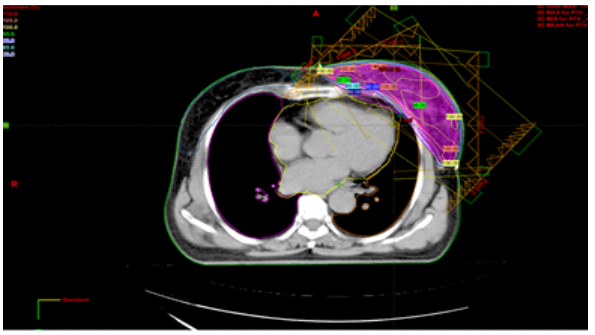
CONVENTIONAL TECHNIQUE



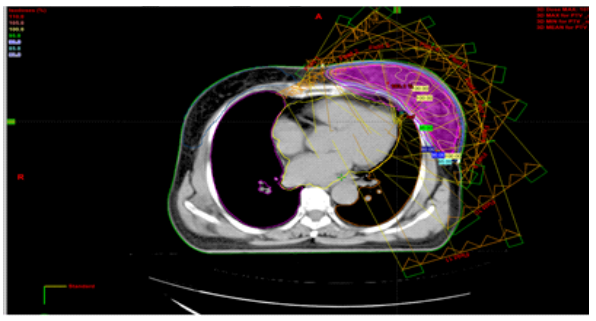
3-D CONFORMAL TECHNIQUE



IMRT WITH 5 FIELDS



IMRT WITH 11 FIELDS



RESULTS:

Table showing percentage of the volume of the ipsilateral lung receiving different doses (40 Gy, 30 Gy, 20 Gy, 10 Gy and 5 Gy) with different techniques

	% of ipsilateral lung volume	P value				
	IMRT (11F)	IMRT (5F)	3D CRT	CONVEN	IMRT x 3DCRT	IMRT x CONVEN
V_{40Gy}	0	0.01-0.07	6.4-7.3	3.5-5.6	<0.0001	<0.0001
V_{30Gy}	2.3-2.8	4.4-7.8	7.3-10.0	5.6-10.2	<0.0001	<0.0001
V_{20Gy}	14.5-16.0	14.8-17.6	10.5-19.6	11.7-15.7	NS	<0.0001
V_{10Gy}	58.1-78.2	38.3-65.8	12.6-22.8	13.7-18.4	<0.0001	<0.0001
V_{5Gy}	81.5-99.2	61.9-85.6	15.8-33.6	15.2-22.4	<0.0001	<0.0001

Ipsilateral lung:

The IMRT plans significantly reduced the volume of the ipsilateral lung receiving 40 Gy and 30 Gy in comparison with the other two techniques. When compared to the 3D CRT technique, the volume of ipsilateral lung receiving 20 Gy was not significantly reduced, but when compared to the standard plan the reduction was significant. V10Gy and V5Gy were significantly higher in IMRT as a result of larger volumes receiving lower doses from multiple beams.

Table showing percentage of the volume of the contralateral lung receiving different doses 5 Gy with different techniques

	% of contralateral lung volume	P value				
	IMRT (11F)	IMRT (5F)	3D CRT	CONVEN	IMRT (11F) x 3DCRT x CONVEN	IMRT (5F) x 3DCRT x CONVEN
V_{5Gy}	48.3-79.5	0.40-7.46	0	0	<0.0001	0.0002

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Contralateral lung:
As expected significant volume of the contralateral lung received 5 Gy with IMRT techniques, particularly with 11-field IMRT, whereas the volume of the contralateral lung receiving 5 Gy of dose was nil with the other two techniques.

Table showing percentage of the volume of the heart receiving different doses (30 Gy, 20 Gy, 10 Gy and 5 Gy) with different techniques when left breast tumour was treated

	% of heart	P value				
	IMRT (11F)	IMRT (5F)	3D CRT	CONV EN	IMRT x 3DCRT	IMRT x CONVEN
V_{30Gy}	0	0	2.8-4.1	1.2-5.0	<0.0001	<0.0001
V_{20Gy}	2.1-2.2	3.4-4.6	4.7-5.9	2.1-6.7	<0.0001	0.003
V_{10Gy}	47.7-53.5	56.7-57.9	6.4-8.3	8.6-15.8	<0.0001	<0.0001
V_{5Gy}	88.5-99.0	59.6-79.1	8.7-12.4	4.4-17.9	<0.0001	<0.0001

Heart:
Patients with left breast tumour:
The volume of the heart receiving 30 Gy was nil with IMRT whereas it was 2.8-4.1%, 1.2-5% in the 3D CRT and standard plans, respectively. The V20Gy was also significantly decreased in IMRT when compared to other two techniques but V10Gy and V5Gy were much higher.

Table showing percentage of the volume of the heart receiving different doses (10 Gy and 5 Gy) with different techniques when right breast tumour was treated

	% of heart volume	P value				
	IMRT (11F)	IMRT (5F)	3D CRT	CONV EN	IMRT x 3DCRT	IMRT x CONVEN
V_{10Gy}	60.5-62.4	31.8-34.6	0	0	<0.0001	0.0006
V_{5Gy}	99.2-99.8	43.5-58.6	0	0	<0.0001	<0.0001

Heart:
Patients with right breast tumour:
V_{30Gy} and V_{20Gy} were nil with all the three techniques, but lower doses were received in larger volumes in IMRT when compared to other techniques, similar to the patients with left breast tumours.

Table showing percentage of the volume of the contralateral breast receiving 5 Gy with different techniques

	% of contralateral breast	P value				
	IMRT (11F)	IMRT (5F)	3D CRT	CONV EN	IMRT x 3DCRT	IMRT x CONVEN
V_{5Gy}	1.4-6.6	---	1.5-11.7	2.8-6.2	NS	0.02
	---	19.1-27.3	1.5-11.7	2.8-6.2	<0.0001	<0.0001

Contralateral breast:
When IMRT was planned with 5 fields, the dose received by the medial aspect of the contralateral breast exceeded the given constraints. V_{5Gy} was very much less with conformal and standard plans as compared to that of 5-field IMRT.

Table showing Conformity Index and Homogeneity Index with different techniques:

Index	IMRT (11 F)	IMRT (5 F)	3D CRT	CONVEN
Conformity	0.98-1.03	0.97-1.04	0.81-1.8	1.02-1.27
Homogeneity	257.3-330.0	317.8-399.7	434.7-647.6	654.9-918.8

Table showing P Value when different techniques are compared with reference to Conformity Index and Homogeneity Index:

Index	IMRT (11F) x CRT	IMRT (11F) x CONVEN	IMRT (5F) x CRT	IMRT (5F) x CONVEN
Conformity	0.002	0.0001	0.0051	0.0003
Homogeneity	<0.0001	<0.0001	<0.0001	<0.0001

Conformity Index / Homogeneity Index:
IMRT significantly improved conformity index and dose uniformity in the PTV.

DISCUSSION:
This study demonstrated that IMRT technique with 11 beams can improve homogeneity and conformity indices and reduce the volume of critical normal tissues such as the heart and ipsilateral lung receiving high doses. The IMRT plans contributed a lower dose to larger volumes of adjacent healthy tissues, especially the contralateral lung and contralateral breast, when compared to the conventional technique. The main concern with healthy tissue dose increase is an increased risk of late second malignancies. This is likely to be of greatest concern in young women and in patients with a low risk for systemic relapse, who are likely to live for many decades after the diagnosis of breast cancer. The baseline risk of contralateral breast cancer without RT is 3-5% at 10 years. There have been reports that adjuvant RT for breast cancer increase the risk of lung cancer and angiosarcoma. The increased planning effort necessary to implement IMRT could be a hindrance to its routine use. It is not yet known whether the gains in normal structure doses and target dose homogeneity are sufficient to justify huge increase in planning effort for routine clinical diseases. (8,9,10) The necessity for IMRT, when only the breast is treated, can be questioned because standard tangential beams have resulted in excellent local control rates, low rates of cardiac and pulmonary complications. However, it is important to remember that despite these excellent results, standard tangential fields have numerous limitations. First dose homogeneity throughout the entire breast is difficult to produce because the breast is invariably a non-uniform structure. Typically dose inhomogeneities are observed with tangents at the entrance and exit points of the beams, in the nipple, and in the superior and inferior portions of the breast, though the use of wedges and lung inhomogeneity corrections can reduce the dose inhomogeneities. These areas of overdosage can and will produce unnecessary acute and chronic toxicities in many patients..

A second concern with standard tangential fields is that a small amount of ipsilateral lung is invariably irradiated to a significant dose, and in left sided patients, a portion of the heart can sometimes be irradiated to significant doses as well. Reducing unnecessary normal tissue radiation exposure is difficult to achieve with standard tangential fields.

IMRT allows the possibility to reduce unnecessary heart and lung doses. With IMRT, it is possible to reduce the volume of the lung irradiated to full doses by tangential fields, and in left sided cases, the heart can also be partially spared. This view has been shared by many other authors also. (12,13,14,15)

CONCLUSION:
IMRT significantly improved the conformity and homogeneity for the breast CTV when compared to other techniques. Heart and lung volume receiving high doses were decreased, but more healthy tissues received low doses. However it remains to be seen whether the dosimetric improvements achievable with IMRT will lead to significant clinical outcome.

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