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3-Field versus 2-field photon boost technique in breast conserving radiotherapy; more conformality, lower lung dose and a higher heart dose

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Background: Our standard photon boost technique consists of two wedged oblique photon-beams, with an angle of some 90–110 degrees between them. However, due to this technique the breast volume receiving at least 95% of the prescribed dose (V95) is high and this might, therefore, result in worse cosmetic outcome. A reduction of the irradiated boost volume (V95) is feasible using a 3 field technique. This third field (with a low weight) is directed almost perpendicular to the other 2 fields.

Material and Methods: In 17 breast cancer patients we compared 2- and 3-field photon boost treatment plans. All patients were irradiated as part of their breast conserving therapy and received 25×2 Gy whole breast irradiation followed by a boost of 8×2 Gy. CT guided target volume delineation both for CTV breast and CTV boost were done. The heart and both lungs were also delineated. We compared the two boost techniques specifically with respect to: i) V95/PTV, ii) the mean lung dose (MLD) and iii) in the 10 left sided breast cancer patients the mean heart dose (MHD).

Results: The 3-field compared to the 2-field technique resulted in a relative reduction of volume of breast tissue outside the PTV boost receiving at least 95% of the prescribed dose (V95/PTV) from 1.96 to 1.50. The addition of a third field resulted in a reduction of the MLD from 0.96% to 0.68%. The MHD in the 3-field plan is 2.25 times higher compared with that of the 2-field plan (4.43% vs 1.9%).

Conclusions: Adding a third field to our standard 2 field photon boost technique resulted in a reduction of the mean breast dose and the mean lung dose. However, in left sided cases, a higher mean heart dose was noted. A possible next step in the optimalization of the photon boost technique could be the simultaneous integrated boost technique.

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Adjuvant locoregional breast radiotherapy using intensity modulated radiation therapy with helical tomotherapy for breast cancer – A comparative treatment planning study and a launch of a prospective clinical study

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Background: We have evaluated Intensity Modulated Radiation Therapy using Helical Tomotherapy (IMRT-HT), in the planning of adjuvant locoregional left breast cancer radiation therapy, to obtain dosimetric data before implementing a prospective study to clinically assess its benefits and risks.

Methods: Ten consecutively left breast cancer women stage III had a Planning Target Volume (PTV) defined as breast/chest-wall and nodal regions including the internal mammary chain (IMC). A dose of 50 Gy in 25 fractions was prescribed using our standard four-field technique: partial wide tangent beams to treat the breast and IMC and 2 anterior posterior beams to treat the axilla and supraclavicular regions. The IMRT-HT plans were developed using target and normal tissue dose constraints. Different metrics were extracted from dose-volume histograms of the standard and IMRT-HT plans and were compared.

Results: Volume of PTV irradiated by the isodose 95% was not significantly different between the standard and the IMRT-HT plans (98.8%±1.4 vs 99.0%±0.4, p = 0.66) but the volume receiving a dose of 107% or more was significantly greater with the standard technique (60%±21 vs. 17%±12, $p < 10^{-3}$). The mean heart dose was similar between both techniques but with IMRT-HT the heart volume receiving at least 30 Gy was reduced (1.5%±1.9 vs. 3.2%±2.2, p = 0.05) and the dose receiving 45 Gy was nil. The mean total lung dose was lower with the IMRT-HT (8 Gy±2 vs 10 Gy±1.5, $p < 10^{-3}$), as well the volume receiving at least 20 Gy (5.8%±1.9 vs. 14.9%±3.3, $p < 10^{-3}$). Contralateral breast volume receiving a low dose of 5 Gy was significantly greater with HT (31%±20 vs. 4.4%±9.9; p = 0.0002). Following these results and since January 2007, we have started a prospective phase II clinical study to evaluate IMRT-HT for locoregional breast radiation with daily acquisition of MV-CT images for positioning and with follow-up of cardiac and lung functions. Ten women have completed the full course of radiation without any particular side effects outside of a skin erythema CTC grade 2, at the maximum.

Conclusions: Compared to a standard technique, IMRT-HT provides a better PTV dose homogeneity and can spare heart and lung exposure to high dose of radiation, while keeping or decreasing the mean dose. As we any multiple beam technique, a larger normal tissue volume is receiving low dose of radiation. The clinical experience of IMRT-HT will be presented.

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Improving dose homogeneity in large breasts by IMRT – efficacy and dosimetric accuracy of different techniques

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Background: While simple tangents with a beam energy of 6 MV are satisfactory for most clinical situations, inherent drawbacks exist for the treatment of large breast volumes. Among these are the unavoidable hot regions created within the PTV. We evaluated 4 treatment techniques regarding: dose homogeneity, target coverage, feasibility, and dosimetric reliability in patients with large breasts treated postoperatively for breast cancer.

Materials and Methods: CT datasets of 10 patients treated for breast cancer with relatively large breast volumes were selected. For each patient four treatment plans were created; Low-Energy-Conventional (C-LE) [6MV], High-Energy-Conventional (C-HE) [6MV+15MV], 3-field (MFT), and a 2-field aperture-based IMRT technique (IMRT). The conventional plans used the standard 2-tangential beams. The MFT used the same standard with a third ventral beam with 2−3 apertures. IMRT used the same 2-beam setup with 4−10 apertures each. Apertures for the IMRT and MFT were created with the aid of a 3D-dose-display which provides in the beam-eye-view a dot matrix of varying colors, representing different dose ranges in different volume depths. Dosimetric accuracy of each technique was evaluated in an anthropomorphic thoracic/breast phantom, using pencil-beam & collapsed-cone (CC) calculation algorithms, and radiochromic-films. [1]

Results: The mean of PTV volumes receiving <95% or >105% of the prescribed total dose was reduced from 16.0% to 13.9% to 10.4% to 8.9% in the C-LE, C-HE, MFT, and IMRT plans respectively. Phantom dose measurements agreed well with the calculated dose within the breast tissue, with the CC-algorithm being clearly superior in predicting the dose in the area exposed in the lung.

Conclusion: Aperture based IMRT using two tangential incident beam directions, as well as a 3-field technique with inverse optimization, provide a better alternative to the standard wedged tangential beams for patients with large breasts treated on low energy linacs while maintaining the efficiency of the treatment planning and delivery process.

Table 1. DVH Statistics. Mean ±SD for the PTV

PTV	C-LE	C-HE	MFT	IMRT
D% to V95%	94.5±1.1	94.7±0.8	95.2±0.9	95.5±0.7
D% to V1%	109.4±1.4	108.2±.5	107.7±1.4	107.2±1.3
Max D%	114.3±2.9	112.7±2.7	112.3±2.6	110.6±2.1
V% receiving D <95% or >105%	16.0±4.4	13.9±3.8	10.4±4.2	8.9±3.9
V% receiving D <95% or >107%	10.8±3.8	8.3±3.5	6.5±2.7	5.5±2.4

*D=dose, V=Volume

References

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Long-term sequel of adjuvant internal mammary node irradiation after mastectomy – an Indian experience

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Background: There is no consensus regarding post-mastectomy adjuvant internal mammary node (IMN) irradiation in patients with medial or central quadrant breast cancer receiving anthracycline-based chemotherapy. The study aims to evaluate the benefit of inclusion of IMN during adjuvant radiotherapy as well as to analyze the cardiac effect amounting from radiation of this additional anatomical area. Study end points: locoregional recurrence, cardiac complications.

Material and Methods: After mastectomy with level II axilla dissection, IMN radiation was considered only in medial or central quadrant disease with axilla involvement.

Between June 2000 and November 2002, 203 patients receiving post surgery chest wall radiation (50 Gy/25 fractions/5 wks), were randomized (after informed consent) to: Arm I – receiving additional IMN radiation (n = 94; left breast: 43) and Arm II – no IMN radiation (n = 109; left breast: 55). All patients received 6 cycles of FAC chemotherapy.

CT-based planning was done for each patient to optimize IMN coverage. Volume of heart irradiated and the volume of heart receiving 5 Gy **(V5)** were estimated individually from integral DVH. Maximum heart distance **(MHD)** was measured for majority.

All patients were monitored with ECG, Chest X-ray, Echocardiogram at the start of radiation, on completion and then 6 monthly. TMT and 24 hr. Holter monitoring were performed in selected cases.

Results: After a median follow up of 72 months, 4 had chest wall recurrence – 2 of who received IMN radiation. IMN recurrence was observed in none, whether they received IMN radiation or not.

Regarding cardiac effects, 2 patients of Arm I developed constrictive pericarditis. 3 had LV dysfunction (estimated by EF < 50%) and 3 developed congestive failure – all belonged to Arm I with left sided disease. No toxicity was noted in 55 left breast cases of Arm II ($p < 0.001$). So significant late cardiac effect was observed in 8/43 left breast IMN-treated and in 0/55 left breast IMN-not treated cases ($p < 0.001$). It was absent in right breast patients, even if IMN treated. DVH analysis revealed 50% of heart volume was exposed to 22−25 Gy in Arm I vs. 8−10 Gy in Arm II with left sided disease. MHD ranged between 1.87 and 2.9 cm.

Conclusion: In centers without IMRT or 3DCRT facility, addition of IMN portal is not justifiable at least in left breast cancer, even with axilla positive medial quadrant disease, as it may invite fatal late cardiac toxicity without any additional gain in loco-regional control.

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Prone position breast irradiation for women with larger or pendulous breasts: an intensity modulated radiotherapy (IMRT) planning study

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Background: Supine position breast radiotherapy is most commonly used for whole breast radiotherapy in patients treated with breast-conserving therapy for early breast cancer. In women with larger and/or pendulous breasts, this technique can cause increased dose inhomogeneity and hot spots to skin fold areas, with, as a result, increased skin toxicity and impaired cosmetic outcome. In prone position, with the breast hanging free from the thoracic wall, skin folds can be eliminated and field separation could be reduced. We aimed to evaluate prone position breast radiotherapy by means of a CT planning study.

Materials and Methods: A pilot study was performed including 15 women with large or pendulous breasts. All women had a CT scan in supine and in prone position. The patients were treated conventionally, in supine position. Opposed tangential beam arrangements were set up in both positions. For each position, both a conventional 3D plan and an IMRT plan was developed. Breast coverage, dose homogeneity, and dose to the lung and heart were compared.

Results: In prone position, skin folds can be adequately eliminated. The mean field separation in supine position was 24.7 cm (range 21.5−28.2 cm); this was reduced to 20.8 cm (range 16.2−24.6 cm) in prone position. In prone position, the breast tissue could be adequately covered, but the conformal radiotherapy plan caused underdosage in the medial part of the breast, whereas with IMRT, a homogeneous dose could be obtained. The percentage of the breast receiving >95% of the dose was 93%, 95%, 89% and 96%, for supine conventional, supine IMRT, prone conventional and prone IMRT plans, respectively.

In prone position, the dose to the ipsilateral lung was reduced compared with the supine position (average dose 6.02 Gy, 6.47 Gy, 1.20 Gy, 1.53 Gy for supine conventional, supine IMRT, prone conventional and prone IMRT plans, respectively). The dose given to the heart in prone was similar to that in supine position.

Conclusions: Prone position breast radiotherapy is a feasible technique for women with pendulous breasts, if IMRT is used. With this technique a homogeneous dose to a larger breast can be given, and skin folds are eliminated thereby reducing the risk of epidermolysis. Also, the irradiated lung volume is reduced compared with supine breast irradiation. The dose delivered to the heart is similar in both positions due to the heart moving anteriorly in prone position.

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Treatment position verification in tangential breast irradiation

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Purpose: As part of a joint study to improve heart sparing during whole breast irradiation the Leiden University Medical Centre and Medical Centre Haaglanden have prospectively investigated inter- and intra-fraction variability during tangential breast irradiation.

An important part of this study consists of a precise registration of the 3-D variability of the treatment position verification. By correction of the patient variation we hope to determine an optimal CTV (Clinical Target Volume) – PTV (Planning Target Volume) margin.

Methods and Materials: A combination of anatomical structures and 5 skin markers have prospectively been used to quantify changes in all directions. During the whole treatment period electronic portal movies of 26 patients were taken (± 4 frames) two days a week. This enabled us to quantify the degree of both intra- and interfraction variability. We also investigated changes in patients having lifted either one arm or both arms during irradiation.

Results: The mean value of the intrafraction variability (n = 91), for marker as well as for anatomical match, is less than 2 mm (SD 1 mm).

The interfraction variability for patients with one arm (n = 84) and two arms (n = 105) lifted is shown in the table.

	Skin markers								Anatomical structures							
	Horizontal				Vertical				First EPI as ref. image				DRR as ref. image			
	Cran	Caud	Med	Lat	Cran	Caud	Med	Lat	CLD	CCD	MHD	BD	CLD	CCD	MHD	BD
1 arm																
μ:	−1.0	−0.8	−2.5	−1.9	0.7	1.7	−1.4	1.7	0.0	0.1	−0.6	−0.6	2.7	−2.3	2.1	2.6
Σ:	2.7	3.1	3.1	5.2	3.9	4.0	5.1	5.6	2.5	2.4	2.7	2.7	3.0	3.9	2.3	4.9
σ:	2.2	2.6	3.3	2.9	2.8	3.0	2.9	3.0	2.0	2.5	3.2	3.2	2.0	2.6	3.1	2.1
2 arms																
μ:	0.4	0.0	0.4	−0.4	0.3	0.8	0.6	−0.1	−1.4	−0.2	−1.4	0.2	0.2	−1.0	−0.7	1.5
Σ:	2.2	2.0	3.0	3.5	4.0	3.0	3.3	6.1	2.2	2.5	2.8	1.9	3.5	2.7	2.0	4.3
σ:	2.1	3.2	2.5	3.7	2.9	2.0	2.1	3.4	2.2	2.1	2.2	1.8	2.2	2.2	2.2	1.8

μ = mean of means; Σ = SD of means; σ = mean of SD; CLD = Central Lung Distance; CCD = Cranial Caudal Distance; MHD = Max. Heart Distance; BD = Breast Depth.

Conclusion: Our results point out that the intrafraction variability is limited: <2 mm. For the interfraction variability a difference appears in the patient outline between the DRR and EPI, and that μ doesn't correspond.

A potential pitfall for clinical use of the marker data is the recurring diversity in marker placement from day to day. There is no correlation between the movement of the skin markers and the anatomical structures, both visualised on the EPI.

The data enabled us to analyse the patient variability and develop a position verification protocol. Thus we were able to determine the optimal CTV-PTV margin for breast irradiation in our institute.

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Prone versus supine breast irradiation in early stage breast cancer patients

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Introduction: External beam radiotherapy for breast cancer patients is necessary after breast conserving therapy. Volume of breast tissue which needs to be irradiated is close to critical structures such as lung, heart; therefore an alternative prone position could be used to improve dose homogeneity during radiotherapy. The purpose of this study was to compare dose distribution within target and normal tissue volumes between two radiotherapy plans in prone and supine position in women with large and small breasts.

Material and Methods: 35 early breast cancer patients in clinical stage T1−2N0 were treated with breast conserving therapy and were dedicated for further radiotherapy. Planning CT was performed in a prone and supine position and two treatment plans for each patient were developed using conventional tangents technique. Dose volume histograms were produced and plans were compared with regard to dose volumes parameters.

Results: The mean doses to the target volume were (50.9±0.59 Gy for supine position and 50.3±0.81 Gy for prone position), minimum dose (39.2±4.1 Gy vs. 40±5.4 Gy) and maximum dose (54.9±0.76 Gy vs. 54.3±1.0 Gy), the dose in 95% of PTV was significantly higher in supine compare to prone position (48.4±1.05 vs. 47.1±1.34). The percentage of ipsilateral lung receiving >5, 10 and 20 Gy were significantly higher in