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Original paper

# Comparison of different breast planning techniques and algorithms for radiation therapy treatment

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ABSTRACT

This work aims at investigating the impact of treating breast cancer using different radiation therapy (RT) techniques – forwardly-planned intensity-modulated, f-IMRT, inversely-planned IMRT and dynamic conformal arc (DCART) RT – and their effects on the whole-breast irradiation and in the undesirable irradiation of the surrounding healthy tissues. Two algorithms of iPlan BrainLAB treatment planning system were compared: Pencil Beam Convolution (PBC) and commercial Monte Carlo (iMC).

Seven left-sided breast patients submitted to breast-conserving surgery were enrolled in the study. For each patient, four RT techniques – f-IMRT, IMRT using 2-fields and 5-fields (IMRT2 and IMRT5, respectively) and DCART – were applied. The dose distributions in the planned target volume (PTV) and the dose to the organs at risk (OAR) were compared analyzing dose–volume histograms; further statistical analysis was performed using IBM SPSS v20 software.

For PBC, all techniques provided adequate coverage of the PTV. However, statistically significant dose differences were observed between the techniques, in the PTV, OAR and also in the pattern of dose distribution spreading into normal tissues. IMRT5 and DCART spread low doses into greater volumes of normal tissue, right breast, right lung and heart than tangential techniques. However, IMRT5 plans improved distributions for the PTV, exhibiting better conformity and homogeneity in target and reduced high dose percentages in ipsilateral OAR. DCART did not present advantages over any of the techniques investigated. Differences were also found comparing the calculation algorithms: PBC estimated higher doses for the PTV, ipsilateral lung and heart than the iMC algorithm predicted.



## Introduction

Breast radiotherapy (RT) is particularly challenging due to the concave anatomy of the chest wall and breast that make it a difficult localization to achieve homogeneous dose distributions. Its complex shape is located near the body–air interface. There are organs at risk (OAR) in the vicinities, such as the lungs, heart and contralateral breast (CLB) that must receive doses as low as possible to avoid long term complications. It is also important to achieve dose homogeneity in target and high doses outside the target volume should be avoided. Other concerns are the dose to the CLB which is related to induced second malignancies [1,2], the increased risk of fatal cardiac events, [3] and of pneumonitis [2] for women after undergoing RT. As long as the volume to treat has adequate dose coverage, the side effects should be minimized.

Breast conserving therapy has become a widely accepted treatment option in the management of early-stage breast cancer improving local control [4–8]. The conventional radiotherapeutic approach after lumpectomy generally consists of delivering 50 Gy to the entire breast, with conventional wedged tangential fields, optimized using a single central-axis isodose distribution and a 10–15 Gy boost to the tumor bed [9,10].

Treatment of whole breast using a photon tangential field technique is still standard within radiotherapy departments, using isocentric tangential treatment fields, geometrically nondivergent at their posterior and superior borders, using 6 MV or combined

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6 MV with 10 MV or 16 MV according to the energies available in each linac, based on the method of Casebow [11], which has been modified and adapted with the advent of 3D treatment planning systems (TPS) and the use of beam modifiers, other beam configurations, etc. (e.g. Refs. [12–14]).

ICRU [15] recommends the enclosure of the planning target volume (PTV) within 95% and 107% isodose lines. However, this may be difficult to achieve with only two standard tangential beams using wedges technique, typically called 3D-CRT (3D-conformal RT). More complex treatment planning strategies have been developed to improve dose homogeneity, namely intensity modulated RT (IMRT) techniques varying in complexity, ranging from manual division of beam fields into several segments – forward-IMRT, f-IMRT – [16–23] to more complex techniques using inverse planning algorithms to treat using several individual beamlets [24].

Woo et al. [25] and Bhatnagar et al. [26], in separate experimental studies concluded that tangential-wedged 3D-CRT increases scattered dose into the normal tissues.

Several studies claim that IMRT has the potential to improve dose homogeneity and conformity in breast radiotherapy improving cosmetic results [27–31], reducing pulmonary and cardiac complications and CLB doses [23,32,33].

f-IMRT, using open fields and segments, is claimed to be dosimetrically superior to 3D-CRT using wedges and reported to have similar PTV coverage, better dose homogeneity and lower doses in the OAR [23,25,34–37].

When comparing 3D-CRT with IMRT (inverse planning), the implications on the irradiation of the healthy tissues surrounding are not as conclusive: some studies reported lower doses using IMRT on the CLB [16,26,33,38], on the heart [39–41], and on the ipsilateral lung [33,38,41,42] whilst other studies verified lower doses on the CLB [43] and on the normal tissues [44] using 3D-CRT. Jagsi et al. [45], comparing different IMRT techniques concluded tangential beamlet IMRT technique reduced exposure to normal tissues and maintained reasonable tissue coverage.

It is well-established that 3D-CRT with wedges increases scattered doses [16,23,25,26,34,35]. Therefore in this study f-IMRT with multiple static fields was used and compared to other techniques without wedges.

Treatment plans are, in general, evaluated on the basis of dose calculations. Some comparisons between calculation algorithms may be found in the literature on breast irradiation, for Pencil Beam Convolution (PBC) [46] and Analytical Anisotropic Algorithm (AAA) [47–49]. The calculations using the PBC algorithm are known to be inaccurate in regions of electronic non-equilibrium, such as in air cavities or in build-up regions, and inhomogeneity corrections due to the lung media [50] or irregular body contour, which are major issues in breast RT [48,51]. Monte Carlo (MC) simulation methods and techniques are widely reported for their dose calculation accuracy. Applying MC techniques to dose calculations in RT has therefore the potential to decrease the uncertainties when compared to analytical/conventional treatment planning algorithms, regardless the beam geometry and target composition [52].

The main focus of the present study is to evaluate and compare the irradiation plans of four radiotherapy techniques (f-IMRT, IMRT using 2 and 5 fields – IMRT2 and IMRT5, respectively – and dynamic conformal arc RT – DCART), relevant for entire breast irradiation, considering only the 50 Gy plan as the boost plan is more patient-dependent due to tumor bed localization and prognostic factors for dose prescription. This study also aims at comparing two different algorithms, Pencil Beam Convolution, PBC, and commercial Monte Carlo, iMC, from iPlan (BrainLAB AG, Feldkirchen, Germany) treatment planning system (TPS) [53,54] for the techniques under investigation for breast cancer treatment.

## Patients, materials and methods

### *Patient selection and simulation*

7 Patients with left-sided stage I or II breast cancer that were referred to adjuvant RT after breast conserving surgery (BCS) were investigated. All the selected patients were randomly chosen among the 394 patients treated between 2010 and 2011 to left breast cancer using 3D-CRT. The breast volume of the elected patients varied from 350 cc to 1750 cc and was not a selection criterion in order to achieve general conclusions on the irradiation techniques despite the breast size.

### *CT scanning for treatment planning*

The patients were positioned in a standard breast immobilization device on the scanner table, in the treatment position with bilateral arm abduction above the head. Radiopaque wires were placed around the patients' breast and marked the superior–inferior (2 cm above and below the breast tissue) and the midline lateral borders. CT images of the thorax were acquired, with a Siemens®, Biograph 64R, CT scanner. The slice thickness was 3 mm, with coverage from above the mandible to several centimeters below the inframammary fold, to include the entire breasts, complete left and right lungs and heart. The CT data was then transferred to the iPlan® BrainLAB treatment planning system (TPS).

### *Delineation of target and OAR*

All contours were performed in the axial CT slices. For whole breast RT after BCS, the remaining mammary glandular tissue was considered clinical target volume (CTV). The heart, ipsilateral lung, contralateral lung and CLB were considered OAR. Auto contouring of the body and both lungs was used. For consistency, the delineation of the CTV, planning target volume (PTV), heart and CLB was performed by the same radiation oncologist. The PTV was defined by adding a 5 mm margin to the CTV. All structures were confined to 3 mm from the external surface of the patient. An additional structure specified as Body-PTV was also created to evaluate the doses on the body excluding the PTV.

### *Treatment planning*

The treatment plans were generated using iPlan® v. 4.1, the BrainLAB TPS. Four plans to deliver 50 Gy to the PTV in 25 fractions were developed for each patient: two plans used forward planned techniques (f-IMRT, and DCART); whereas for the other two plans (IMRT2 and IMRT5), inverse optimization was applied. The treatment sessions were planned for a Trilogy linear accelerator (Varian Medical Systems, Palo Alto, CA) equipped with the High Definition (HD) micromultileaf collimator (MLC) with 120 leaves. The plans were normalized to a point in the isocenter axial plane inside the PTV. For all plans, the isocenter was placed in the center of the PTV volume and the couch rotation was set to 0°; the collimator rotation was left free to minimize the opening of the main jaws, but normally was set to 0°.

For treating the PTV, specific objectives were established to treat 95% of the PTV with ideally 47.5 Gy but at least 45 Gy, and maximum hotspots should not exceed 110%. Other goals were to keep the dose to the OAR as low as possible by setting higher priority upon avoidance of the contralateral breast, lungs and heart, without compromising the PTV dose coverage considering