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Case report

Volumetric modulated arc therapy for synchronous bilateral whole breast irradiation – A case study

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ABSTRACT

Purpose: The treatment planning of bilateral breast irradiation (BBI) is a challenging task. The overlapping of tangential fields is usually unavoidable without compromising the target coverage. The purpose of this study was to investigate the technical feasibility and benefits of a single isocentre volumetric modulated arc therapy (VMAT) in BBI.

Methods and materials: Two women with bilateral breast cancer were included in this case study. The first patient (Pat#1) underwent a bilateral breast-conserving surgery and sentinel lymph node biopsy. The second patient (Pat#2) underwent a bilateral ablation and axillary lymph node dissection. Planning target volumes (PTV) and organs at risk were delineated on CT images. VMAT plans were created with four (two for both sides, Pat#1) or two (one for each breast, Pat#2) separate VMAT fields. Subsequently, traditional tangential field plans were generated for each patient and the dosimetric parameters were compared.

Results: The treatment times of the patients with VMAT were less than 15 min with daily CBCT imaging. When compared to the standard tangential field technique, the VMAT plans improved the PTV dose coverage and dose homogeneity with improved sparing of lungs and heart. With traditional field arrangement, the overlapping of the tangential fields was inevitable without significantly compromising the target coverage, whereas with VMAT the hotspots were avoided. The patients were treated with the VMAT technique and no acute skin toxicity was observed with either of the patients.

Conclusions: A single isocentre VMAT technique has been implemented clinically for BBI. With the VMAT techniques, the dose delivery was quick and the hotspots in the field overlapping areas were avoided. The PTV dose coverage was superior in VMAT plans when compared with conventional tangential technique plans.

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1. Introduction

Breast cancer is the leading cancer site in women worldwide with an estimated 1.4 million new cases diagnosed every year.[1] Synchronous bilateral breast cancer (BBC) is very uncommon, the latest estimate for the incidence being only 2.1%.[2] Although the number of cases of BBC is rare in one treatment centre the overall BBC patient population grows approximately to 30,000 new cases a year worldwide. Compared to unilateral breast cancer radiotherapy, the treatment planning and dose delivery of BBC is very complex and time consuming. One of the standard treatment techniques for BBC is to use a tangential field configuration.[3,4] With the traditional tangential field-arrangement either a significant amount of beam overlap is needed or, alternatively, under-dosage of some parts of the PTV has to be accepted with some patient groups. The drawbacks of the conventional tangential technique often also include inhomogeneous dose distribution with hotspots or inadequate coverage of the target structure, especially with obese patients, or the inability to reduce the high dose volumes of the heart and ipsilateral lung. The dose inhomogeneities have been correlated with radiation-induced dermatitis, acute desquamation and late soft-tissue fibrosis and the quality of life of the treated patients has been reported to decline by these physical symptoms.[5–8]

The use of a volumetric modulated arc therapy (VMAT) has steadily increased in external beam radiotherapy. In VMAT the radiation dose is delivered by continuously varying gantry speed, field shape and dose rate. In the literature, there are only a few reports that have studied the modulated treatment techniques for BBC. These studies are mainly treatment planning and dosimetric studies with an intensity modulated radiotherapy (IMRT)[9] or a VMAT technique[10] and the actual radiotherapy treatments have been carried out with a conventional technique. Intensity modulated proton[11] and electron arc[12] treatment planning studies have also been investigated for BBI. In our knowledge, the only reported case about BBC patients treated with a modulated technique is a study of Cendales et al.[13] where they used Helical Tomotherapy for complex treatment volumes. Unfortunately, however, in that particular study it was not specified how the treatment plans were accomplished and more specific information about the treatment planning for the bilateral breast cases were not given. In our knowledge, this is the first report to use a VMAT technique for bilateral breast irradiation (BBI) to enhance dose distributions within the irradiated volume. In the present study, we report two cases of BBC patients treated with a single isocentric VMAT technique.

2. Case reports

2.1. Patient histories and diagnoses

Two different patient cases are reported. The first case (Pat#1), was a 67-year-old female with bilateral ductal breast carcinoma. She underwent bilateral breast-conserving surgery and sentinel lymph node biopsy (right breast: T2N1M0 stage IIA, left breast: T1aN0M0 stage I). The second patient (Pat#2) was a 71-year-old female with bilateral multifocal lobular breast carcinoma. She underwent bilateral ablation and axillary lymph node dissection (right breast: T2N2M0 stage IIIA, left breast: T2N2M0 stage IIIA). With both patients, chemotherapy consisted of three cycles of docetaxel plus three cycles of cyclophosphamide, epirubicin and fluorouracil (CEF).

2.2. Imaging and treatment planning

Both patients were imaged supine with a CT scanner (Toshiba Aquilion LB, Toshiba Medical Systems Co., Tochigi, Japan) in treatment position with a slice thickness of 2 mm. Planning target volumes (PTV) of the left and right breast were delineated on the CT data according to the department guidelines. With Pat#1 the PTV included the glandular breast tissue and the lower part of the fossa axillae. With Pat#2 the chest wall and the regional lymph node areas were included into the PTV. Atlas-based auto-segmentation software (ABAS, Elekta AB, Stockholm, Sweden) was used to delineate the critical structures which were verified by the user and manually corrected if necessary. The critical structures delineated were both lungs, heart, left anterior descending (LAD) coronary artery, thyroid gland, shoulder joints and oesophagus.

The VMAT plans were generated on Monaco® treatment planning system (TPS) (version 3.30.01, Elekta AB) for Elekta Infinity linear accelerator with Agility MLC. The VMAT plans were created with four (two for both breast, Pat#1) or two (one for each breast, Pat#2) separate VMAT fields with an energy of 6 MV. The field arrangements are shown in Fig. 1. The plans were optimised simultaneously for all arcs with a single isocentre located below sternum (Fig. 1). Treatment plans were optimised with a maximum number of control points of 140, a minimum segment width of 1.0 cm and with high fluence smoothing. An autoflash margin of 1.5 cm and surface margin of 0.5 cm were used in the optimisation (e.g. the inner margin from the skin surface that was excluded from the optimisation). A standard deviation of 1% was used in Monte Carlo (MC) dose calculation with a dose grid of 3.0 mm. The prescription dose (50 Gy/25 fr) was normalised to the mean dose of the PTV (excluding a 5 mm margin from the skin surface).

For comparative reasons, a traditional field-in-field (FinF) tangential technique, which has become a standard technique in breast cancer radiotherapy,[14] was used to create a treatment plan with the identical CT data and structure sets. In FinF, planning subfields are created by manually moving the MLC positions to enhance the dose homogeneity.[15] The FinF plans were generated in Oncentra® TPS (version 4.3.0.410, Elekta AB) with an identical single isocentre. Dose distributions were calculated with collapsed cone convolution (CCC) algorithm with a dose grid of 3.0 mm.

2.3. Treatment verification

The calculated dose distributions of the VMAT plans were verified by delivering the treatment plans to a MatriXX ionisation chamber array with a MultiCube phantom (IBA, Schwarzenbruck, Germany). The gantry angle corrections were performed and the measured coronal planes were compared against the calculated dose distributions (Fig. 2). OmniProI'mRT (v1.7.0021, IBA) software was used to analyse

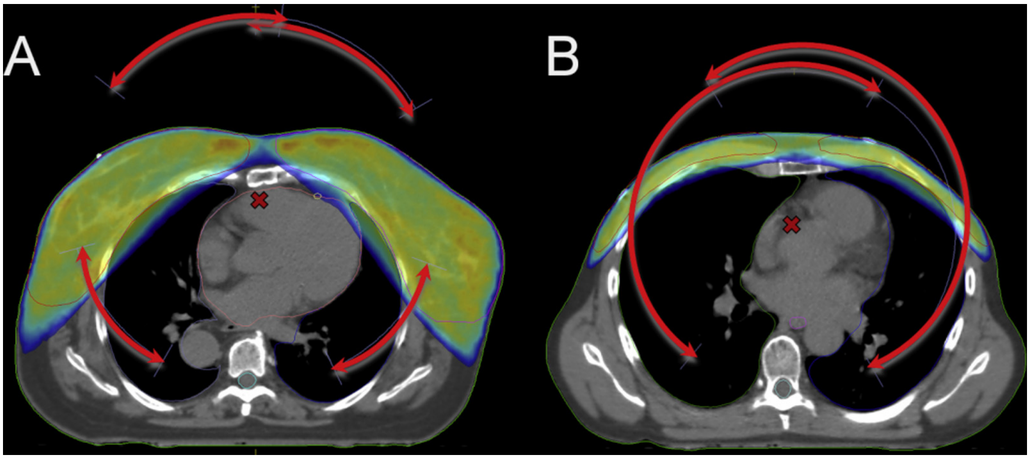

Fig. 1 – The VMAT field arrangements (the red arcs) and the axial dose distributions for the patients studied (A: Pat#1 and B: Pat#2) with a dose colour wash ranging from 35 Gy to 60 Gy. The single plan isocentre is marked with a red cross.

the results by using a gamma plot for 3% and 3 mm. With both treatment plans the gamma agreements were greater than 99.5%, which is shown in Fig. 2 for Pat#1.

2.4. Treatment delivery with image-guidance

With the reported patient cases a single daily cone-beam CT (CBCT) imaging was performed to setup the patient (Fig. 3). Low dose (tube current 20 mA, exposure time 32 ms) 200° rotation CBCT was performed on the Elekta XVI (Elekta, Crawley, UK) with an aluminium bowtie filter to reduce panel saturation effects[16] and small field of view (FOV, reconstruction diameter of 27 cm). Image reconstruction and automatic image registration was performed in XVI software (version 4.5.) by using bone algorithm. The shifts to cranio-caudal, left–right and anterior–posterior directions from the daily CBCT images ranged between −0.7 and 0.7 cm (average 0.3 cm), 0.1–0.8 cm (average 0.4 cm) and −0.7 to 0.8 (average −0.2 cm), respectively.

3. Results and discussion

The PTV dose coverage was increased by using the VMAT technique when compared to FinF technique, as the PTV volume encompassed by the 95% isodose line (V95%; 47.5 Gy) was increased on average from 84% to 98% (Fig. 4). When compared to a standard tangential FinF technique, the VMAT plans improved the dose homogeneity as the average V107% (V53.5Gy) was decreased from 12.4% to 0.2%. The VMAT technique also improved the sparing of the surrounding critical structures. The mean dose to both lungs was decreased on average from 11.6 Gy to 10.1 Gy. The volume of the heart receiving doses greater than 25 Gy (V25Gy), which has been related to radiation-associated cardiac diseases,[17] was decreased from 6.5% to 4.2% when VMAT was compared against the FinF technique. However, the mean dose to the heart was slightly increased by using VMAT, from 5.7 Gy to 6.6 Gy, when compared to the FinF technique. With traditional field arrangement, the overlapping of the tangential fields was inevitable as the maximum dose to a volume of 5 cm^3 (D5cc) was on average 67.0 Gy. With the VMAT technique, the hotspots in the overlapping areas were avoided (the average D5cc = 52.7 Gy).

Overall, the VMAT treatment plans decreased the doses to the lungs and heart and increased the dose homogeneity in the treatment volume. The main drawback considering the VMAT planning was a slight increase in the low dose volume. However, the volume of the lungs covered by the dose of 5 Gy

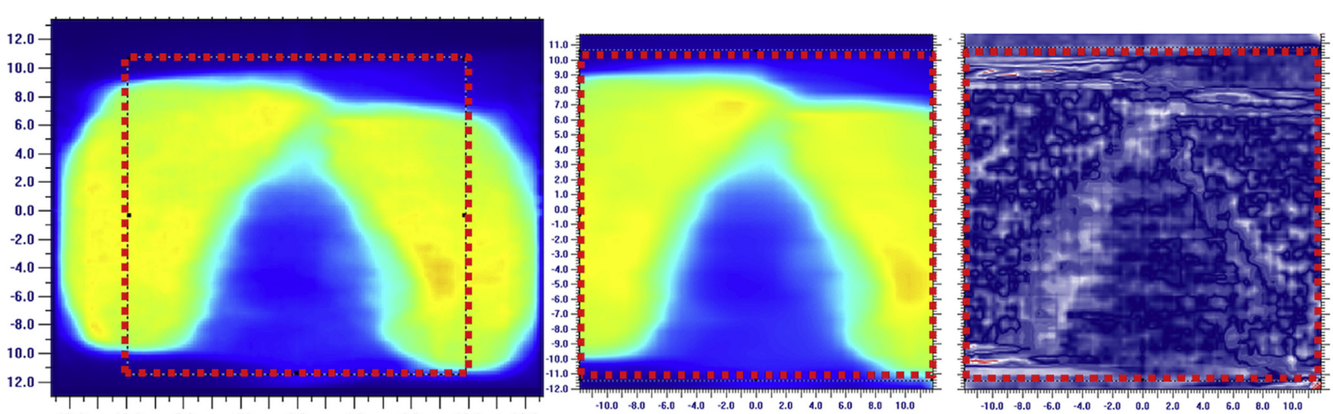

Fig. 2 – Calculated (A), measured (B) and the corresponding gamma evaluation of the two 2D-dose distributions (C) for Pat#1. The gamma agreement (±3%/±3 mm) between the measured and the calculated dose was 99.9%.

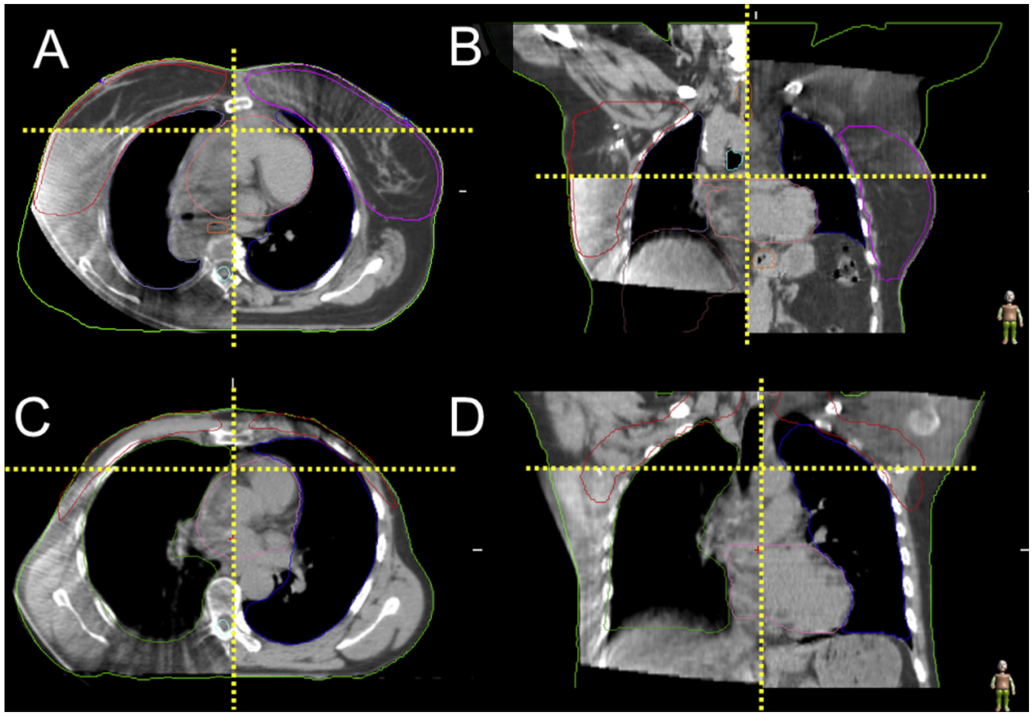

Fig. 3 – Patients were imaged with a daily CBCT. An example of the quartered 3D-matching (dose planning CT and CBCT) is given for Pat#1 and Pat#2 for axial (A, C) and coronal (B, D) directions, respectively.

(V5Gy) was on average only 43%, while with the reported Helical Tomotherapy treatment deliveries the respective volume was 78%.[13] Although the risk of second cancer among patients treated with radiotherapy is small,[18] it cannot be neglected. The low dose volume has to be considered when selecting the patients to be treated with a VMAT bearing in mind the increased possibility of second cancers, especially for patients with younger age. It should also be recognised that with the introduced VMAT dose delivery technique the treatment planning complexity is increased thus escalating the potential for error and thus increasing the importance of the quality assurance processes.[19]

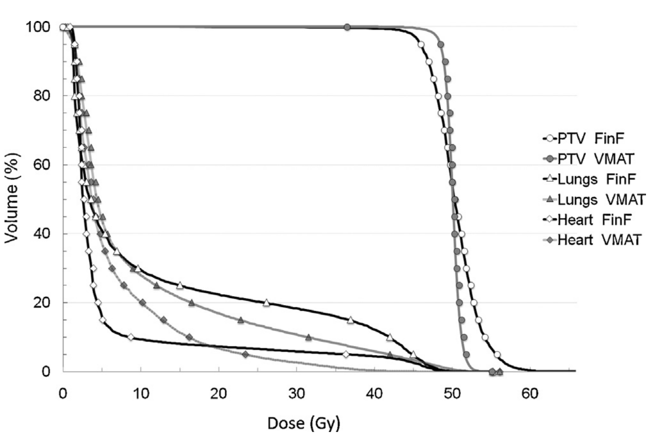

Fig. 4 – Average cumulative dose volume histograms (DVHs) of the two patients for the two different techniques studied (FinF and VMAT).

Patients were treated in 25 fractions to the total dose of 50 Gy with the VMAT technique. Total number of monitor units (MU) with the VMAT technique was 1184 and 1585 MU with Pat#1 and Pat#2, respectively, while with the tangential technique the respective MUs were 455 and 913 MU. The overall treatment time with daily CBCT matching was less than 15 min with both patients with an average beam-on time of 280 s. The cosmetic outcome was good and no breast oedema, erythema or fibrosis were reported during routine follow-up.

Treatment planning for BBC is difficult and in most cases the field overlapping cannot be avoided with traditional tangential field arrangements. As a consequence, some patients have been reported to develop fibrosis at the area of the overlapping fields.[3] Thus, to minimise damage to the skin, the overlapping areas with large hotspots should be avoided. On the other hand, the PTV area should receive the prescription dose without cold spots to minimise the risk of tumour recurrence. This paper describes the process of planning synchronous BBC radiotherapy with a single isocentre VMAT technique. The introduced technique decreases the hotspots, increases the dose coverage and is easy to deliver. The most important aspect with this technique is that the major field overlapping problems existing with the tangential field arrangements are avoided. As no treatment guidelines exist for the BBC, our study highlights the possibility of a single isocentre VMAT technique to enhance the dose distributions in the treated area. The use of a single isocentre also simplifies the treatment process decreasing the time spent on the treatment machine.

Furthermore, to avoid long-term cardiac mortality, extensive blocking of the heart is usually needed with the traditional field arrangements. This will, as a consequence, require the acceptance of incomplete dose coverage of the PTV. With the VMAT technique, the high dose areas in the heart can be avoided without compromising the PTV dose coverage.

4. Conclusions

This case study represents feasibility of VMAT technique in the treatment of bilateral breast cancer. The introduced single isocentric VMAT technique is fast to deliver, it increases the dose homogeneity of the target volume and avoids the field overlapping problems. The delivered VMAT treatments were well tolerated without treatment related toxicities after the treatment courses.

Conflict of interest

None declared.

Financial disclosure

None declared.

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