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Evaluation of a new hybrid VMAT simultaneous integrated boost technique for breast radiotherapy

Abstract: In this survey we propose a new hybrid simultaneous integrated boost (SIB) delivery method for breast radiotherapy that was implemented in our department of Radiation Oncology. This technique encompasses non-modulated tangential fields as well as VMAT-arcs and combines the robustness and the dose confinement properties of tangential opposed fields with the benefits of a complex VMAT-technique. The results of the dosimetric evaluation indicate that the proposed technique enables a balanced mix between dose coverage, homogeneity and conformity versus the exposure of the organs-at-risks. More precisely, the proposed technique is on par with other recently published SIB techniques for breast radiotherapy.

Keywords: Breast Cancer, Simultaneous integrated Boost (SIB), Volumetric Modulated Arc Therapy (VMAT)

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1 Background

Breast Cancer is the most common malignant neoplasm in women worldwide [1]. The standard treatment procedure for patients with early stage breast cancer is wide tumour excision while conserving the remaining breast. In order to improve local control adjuvant irradiation of the whole breast as well as an additional dose escalation of the tumour-bed (boost) is accomplished. However, a sequential boost prolongs the treatment duration and increases the risk of moderate to severe breast fibrosis [2].

The simultaneous integrated boost (SIB) escalates the dose to the tumour-bed by delivering the boost volume with a higher dose per fraction. Beside shorter treatment duration, the SIB is dosimetrically advantageous with respect to the dose conformity of the boost volume [3, 4].

Recent publications propose several delivery methods that use modern intensity-modulated treatment techniques (IMRT, VMAT, RapidArc) or a combination of them as well [5–8]. However, multiple-field IMRT or full-arc VMAT plans seem to increase the dose in the contralateral breast and in the lungs compared to the standard tangential-field plan and thus, they are associated with a higher second cancer risk [8].

Consequently, we propose a new hybrid treatment technique that encompasses non-modulated tangential fields as well as VMAT-arcs. A dosimetric evaluation was done with regard to target coverage as well as organ-at-risks (OAR) doses.

2 Material and methods

2.1 Patient selection and delineation of target volumes and organs at risk

Forty female breast cancer patients (20 left-sided and 20 right-sided), who were currently treated at our department of Radiation Oncology in Greifswald, were randomly selected for dosimetric evaluation. The patients underwent computed tomography (CT) in supine treatment position with arms

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raised above the head. A standard imaging protocol with a slice thickness of 3 mm was used.

Target volumes and organs at risk were delineated by a clinical oncologist. The whole breast is referred to as PTV_{Breast} whereas the tumour-bed is referred to as PTV_{Boost}. The organs at risk encompass the lungs (ipsilateral lung and contralateral lung), the contralateral breast and the heart. Additionally, the volume PTV_{5040} was created by means of reducing PTV_{Breast} by PTV_{Boost}. In order to perform a reasonable dosimetric evaluation, PTV_{5040} was further reduced by the skin.

2.2 Treatment planning

Treatment planning was performed on the Philips Pinnacle treatment planning system version 9.10 using a grid size of 2.5x2.5x2.5 mm³. Hybrid plans were generated treating the whole breast to 5040 cGy and the tumour-bed to 6300 cGy in 28 fractions following the guidelines as proposed for example in [9].

In the first planning step, two opposing tangential fields at one isocenter were added conforming the PTV_{Breast}. A margin of 3cm anteriorly was added. This ensures entire breast coverage in spite of breathing. Further, the gantry angle of both fields was optimized for a minimum lung area. Dose calculation was done to a prescribed dose of 4580 to 5040 cGy as the maximum dose in PTV_{Breast}. This enables robust dose coverage of the breast and spares the contralateral side dosimetrically as well.

As the second step, two VMAT-arcs were added at the same isocenter. Dose deposition was applied in clockwise and counter clockwise direction. The gantry angles of the VMAT-arcs were adapted from the tangential fields. More precisely, the angle in medial direction had exactly the same value. In contrast, the angle of the lateral side was enlarged by 15 – 20 ° depending on the anatomy of the patient.

An inverse optimization of the two VMAT-arcs was performed considering the dose deposition of the tangential fields. The used dose objectives for target volumes and organs at risk are listed in table 1. These criteria represent the minimum requirements. Consequently, substantial effort was made to go below these limits in order to achieve the best plan for each individual patient.

During optimization, a flab surrounding the whole breast of 5 mm thickness with 1 g/cm³ mass density was added. This prevented the optimizer from adding dose to the surface in order to compensate the build-up effect.

Table 1: Minimum planning aims.

Target Volume	Dose Objectives
PTV_{5040}	$V_{4536\ cGy} > 98\ \%$ $V_{5544\ cGy} < 5\ \%$
PTV_{Boost}	$V_{5670\ cGy} > 99\ \%$ $D_{max} < 6930$ cGy
Organs at risk	**Dose Objectives**
ipsilateral lung	$D_{mean} < 1000$ cGy $V_{2000\ cGy} < 30\ \%$
contralateral lung	$D_{mean} < 300$ cGy $V_{500\ cGy} < 10\ \%$
heart	$D_{mean} < 500$ cGy $V_{2500\ cGy} < 10\ \%$
contralateral breast	$D_{mean} < 400$ cGy

3 Results

The results of the dosimetric evaluation are shown in table 2 for the target volumes and in table 3 for the organs at risk. Note that the dose to the heart was separated into two groups depending on which breast was affected. Hence, for that evaluation only 20 patients were considered for each side.

Our method could achieve good PTV coverage as well as acceptable exposure of the organs at risk. More precisely, we were able to go below the limits of the planning aims as stated in table 1.

Table 2: The results of the target volume coverage considering the data of all 40 patients.

Target Volume	DVH-parameter	Results of the analysis
PTV_{5040}	$V_{4788\ cGy}$	(96.3 ± 2.4) %
	$V_{5544\ cGy}$	(4.7 ± 2.1) %
PTV_{Boost}	$V_{5985\ cGy}$	(98.0 ± 2.3) %
	D_{max}	(6649.7 ± 91.1) cGy ≙ (105.6 ± 1.4) %

Table 3: The results of the dosimetric evaluation of the organs at risk. Note that the analysis of the dose to the heart is separated into left and right in order to take into account which breast was affected.

Organs at risk	DVH-parameter	Results of the analysis
ipsilateral lung	D_{mean}	(947.8 ± 123.0) cGy
	$V_{2000\ cGy}$	(16.1 ± 4.1) %
contralateral lung	D_{mean}	(114.3 ± 29.5) cGy
	$V_{500\ cGy}$	(0.2 ± 0.4) %

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heart (the affected side was right)	D_{mean}	(201.3 ± 55.6) cGy
heart (the affected side was left)	D_{mean} $V_{2500\ cGy}$	(524.9 ± 113.8) cGy (4.6 ± 2.6) %
contralateral breast	D_{mean}	(115.9 ± 33.7) cGy

4 Discussion

In this survey we propose a new hybrid simultaneous integrated boost delivery method for breast radiotherapy and did a dosimetric evaluation. The results show that with our technique we could achieve comparable dose deposition to the target volumes and exposure of the organs at risk as published in other papers dealing with SIB treatment techniques [5 – 8].

Our primary goals during optimization were a good PTV coverage. Thus, reducing this importance may also reduce the exposure to the organs at risk.

The total MU's of the tangential fields (114.3 ± 4.5 MU) compared to the total MU's of the VMAT-arcs (104.2 ± 15.8 MU) was almost in a ratio of 1:1. This means that most of the dose was deposited by the tangential fields and the VMAT-arcs are only used to homogenize the PTV. Thus, dose deposition in the contralateral side of the patient could be decreased. The investigation of the benefit of the dose reduction is projected as future work. We further plan an extensive planning comparison between our method and other delivery techniques.

5 Conclusion

In conclusion, the proposed technique enables a robust treatment while obtaining a balanced mix between dose coverage, homogeneity and conformity versus the exposure of the organs at risks. Further, the results indicate that our technique is comparable to recently published SIB techniques for breast radiotherapy.

Author's Statement

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