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Original research article

Treatment planning study of Volumetric Modulated Arc Therapy and three dimensional field-in-field techniques for left chest-wall cancers with regional lymph nodes

Heping Xu[a,b,*], *Gillian Hatcher*[a]

[a] *Cape Breton Cancer Centre, Nova Scotia Health Authority, 1482 George St., Sydney, NS, Canada B1P 1P3*
[b] *Department of Radiation Oncology, Dalhousie University, Halifax, NS, Canada*

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ABSTRACT

Aim: This study aims to investigate whether there are dosimetric advantages to using VMAT (Volumetric Modulated Arc Therapy) for left-sided chest-wall patients over the three-dimensional conformal field-in-field (FinF) technique.
Background: There is a lack of dosimetric studies dedicated for chest-wall patients. Potential dosimetric advantage could be obtained using VMAT due to complex geometry of PTVs (Planning Target Volumes) and OARs (Organs at Risk) in chest-wall and lymph nodes.
Materials and methods: VMAT and FinF plans were generated and evaluated based on DVHs (Dose Volume Histograms) for both PTVs and OARs for 22 left-sided chest-wall patients with involved regional nodes. PTV HIs (Homogeneity Indices) and CIs (Conformity Indices), and EUDs (Equivalent Uniform Doses) for PTVs and OARs were also evaluated for comparisons between VMAT and FinF.
Results: FinF planning met PTV criteria adequately in all cases except two. In these two cases, VMAT was able to meet PTV criteria adequately. VMAT demonstrated significant reduction in left lung $V_{20\,Gy}$ in chest-wall patients compared to FinF plans. The volumes of the right lung and right breast receiving 5 Gy were much higher in VMAT than those in FinF for all patients.
Conclusions: Compared to the FinF technique, there is a generally limited benefit using VMAT for left-sided chest-wall patients due to large low-dose-bath to OARs with insignificant improvement in PTV coverage. In case where FinF planning cannot meet dose constrains, VMAT provides a viable option. The use of VMAT planning over the FinF technique in chest-wall cancers should be carefully analyzed on an individual basis.

* *Corresponding author at*: Cape Breton Cancer Centre, 1482 George St., Sydney, NS, Canada B1P 1P3.
E-mail address: heping.xu@nshealth.ca (H. Xu).

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1. Background

The tangential beam arrangement has been commonly accepted as the standard external beam radiation technique for breast and chest-wall cancers. In this beam setup, using simple wedges to modulate the beam fluence, significant dose inhomogeneity may be present, especially for large breasted patients.[1,2] Better dose distribution can be achieved through more sophisticated beam fluence modulation. The field-in-field technique (also known as forward intensity modulated radiation therapy) divides a beam into segments that can result in improved dose homogeneity and conformity to the Planning Target Volumes (PTVs) by applying a systematic way of blocking hot spots.[3,4] Further improvement can be achieved using intensity modulated radiation therapy (IMRT). The fixed-gantry IMRT (fIMRT) has been under much investigation either in tangential setup[5] or in multi-beam setup.[6,7] Its dosimetric improvement over conventional planning methods has been demonstrated. For left-sided breast/chest-wall cancers, greater efforts have been expended aimed at reducing lung and cardiac dose, while still providing adequate PTV coverage and homogeneity.

VMAT (Volumetric Modulated Arc Therapy) has been increasingly gaining popularity in clinical application since its introduction in 2008.[8] VMAT is an arc-based technique that leads to highly conformal dose distributions through employing beam fluence modulation, variable dose rate, and gantry speed. While VMAT is shown to achieve similar or better PTV coverage and sparing of OARs to that of fIMRT, the major advantages of VMAT are less delivered monitor units (MUs), and reduced total treatment time in the treatment unit.[9–12]

Recently, there has been growing interest in applying VMAT to treating breast and chest-wall cancers. For the treatment of patients post breast conservative surgery (intact breast), some studies comparing VMAT to fIMRT and the field-in-field (FinF) technique have indicated that VMAT provides an improvement in PTV coverage and dose homogeneity.[13,14] However, VMAT is not recommended as the dosimetric quality of plans has not been shown to be superior to FinF or fIMRT.[15,16]

For post-mastectomy patients with regional node involvement, a traditional delivery method is an isocentric technique consisting of tangential beams to treat the primary site and a parallel-opposed pair (POP) to treat supraclavicular/axillary nodes. Due to the thin wall of the chest-wall, PTV heterogeneity can be quite pronounced, and adequate dose coverage for the PTV is difficult to achieve without increased dose to the adjacent organs such as the ipsilateral lung and heart. The need for dose feathering at the junction between the chest-wall tangents and nodal POP presents an additional challenge to achieve dose homogeneity. Scarcity of literature on the comparison of VMAT with FinF precludes clinicians from drawing a definitive conclusion on the best practice. One study stated that VMAT may benefit chest-wall patients, however, only one chest-wall patient was examined.[13] Another feasibility study showed that both VMAT and tomotherapy provided acceptable treatment plans for chest-wall patients.[15,16] More study is needed to directly compare VMAT with FinF, as FinF is the most routinely used 3D conformal technique in chest-wall cancer treatment. VMAT also has the potential to reduce lung and heart dose in left-sided chest-wall treatment. Further reduction in dose to normal tissues is possible when VMAT is applied to the POP treatment of nodal volumes.

1.1. Aim

In this article, we focused on the treatment of the left-sided chest-walls with positive supraclavicular nodes. We presented a comparison of dosimetric analysis of PTVs and OARs, using the following two methods: 3D conformal field-in-field technique and VMAT. We aim to investigate whether there are dosimetric advantages to using VMAT for chest-wall sites compared to using the field-in-field technique.

2. Materials and methods

2.1. Patient selections, dose prescription and objectives

Twenty-two left-sided chest-wall patients of median age 64 (range: 31–88) with positive supraclavicular/axillary nodes were randomly selected for VMAT chest-wall study. Dose prescriptions were 50 Gy in 25 fractions for chest-wall target volumes (PTV50) and 45 Gy in 25 fractions for supraclavicular nodes (PTV45). The average chest-wall separation was 19.7 ± 2.8 cm. The average volume of PTV50, PTV45 was $255.6 \pm 97.8\ cm^3$ and $233.7 \pm 71.6\ cm^3$, respectively. The average volume of the lung was: $1171.3 \pm 261.5\ cm^3$ (left) and $1361.7 \pm 229.1\ cm^3$ (right); the average volume of the heart was $489.5 \pm 172.9\ cm^3$. All patients underwent free-breathing CT simulation in the supine position with both arms abducted superiorly using a breast board system (MedTec®) The scan slice thickness was 0.25 cm. The scan volume was defined by the superior border at the level of the mastoid/ear lobe junction and inferior border at 7.0 cm beyond the most inferior extent of the breast/chest-wall wire.

The dosimetric objectives for the coverage of chest-wall and nodal PTVs (PTV50, PTV45, respectively) were as follows: 95% of the volume to be covered by 95% of the prescribed dose. This constraint could be relaxed to 93% volume coverage if 95% could not be achieved. OARs were to receive dose as low as possible. Various levels of importance of dose objectives were assigned to PTVs and OARs. Hot spots (volume was no greater than $2.0\ cm^3$) were not to receive more than 107% of the prescribed dose. Details of dose objectives can be found in Table 1.

2.2. Field-in-field planning technique

In the conventional four field technique treating chest-wall with positive regional nodes, a lateral beam at gantry angle of around 130° and a medial beam at the gantry angle of around 315° were used to cover the chest-wall PTV50. The nodal PTV45s were covered by an anterior/posterior oblique POP pair. The field matching of the POP pair and tangential beams were obtained through a half beam block. Bolus of thickness 0.5 cm was placed on the chest-wall every second fraction of the entire treatment course. Chest-wall planning was performed using the three dimensional conformal field-in-field (FinF) technique applied iteratively to reduce hot spots