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A volumetric modulated arc therapy retrospective planning study of left sided chest wall treatments with and without bolus

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Abstract

Introduction

VMAT planning techniques have been used more to treat difficult-to-plan post-mastectomy cases. The primary advantage of VMAT is the better performance at intermediate-high dose sparing and mean heart dose, without sacrificing target coverage. The location of the chest wall leads to clinical target volumes (CTV) adjoined to the skin which would generate a planning target volume (PTV) located outside the body. To overcome these limitations a virtual bolus is used during optimization. The purpose of the study is to evaluate if a VMAT technique without a bolus, with 5 mm virtual bolus, or 1 cm virtual bolus provides better conformity and homogeneity while delivering adequate dose to the skin of the chest wall.

Methods

Three VMAT plans were created for ten female left sided breast cancer patients post-mastectomy treatments. A virtual bolus was created in various thickness of 5 mm and 1 cm for the optimization phase only. The plans were labeled NB- no bolus, 5 mm- 5 mm bolus and 1 cm- 1 cm bolus. In total thirty plans were created for the study.

Results

The main effect of bolus on CI and HI was not significant. CI: WL= .984, F (2, 8) = .066, p = .94; HI: WL = .567, F (2, 8) = 3.06, p = .10. The results showed that there was no significant effect of bolus on skin V5 or skin V85. Skin V5, WL = .668, F (2,8) = 1.99, p = .199; skin V85, F (1.06, 9.5) = .256, p = .638.

Conclusion

The results were not statistically significant in the metrics of conformity, homogeneity, and dose to the skin of the chest wall. The 1 cm bolus plans did have higher means in conformity, homogeneity, and skin V5.

Introduction

Breast cancer occurs when breast cells rapidly divide and grow abnormally in the milk producing ducts, glandular tissue or within the lobes and lobules, creating a lump or mass. Breast cancer is the most common cancer in US women, and on average a woman is diagnosed with breast cancer every 2 minutes (*American Cancer Society. Breast Cancer Facts & Figures 2019-2020.*, 2019). In 2020, more than 276, 480 new cases of invasive breast cancer will be diagnosed (*American Cancer Society. Breast Cancer Facts & Figures 2019-2020.,* 2019). There is a wide range of treatment options for breast cancer depending on type and how advanced the disease is to include: surgery, chemotherapy, hormone therapy, and radiation therapy.

The four major types of breast cancer are invasive breast cancer, ductal carcinoma, lobular carcinoma, and inflammatory breast cancer. Invasive breast cancer makes up 70% of all invasive breast cancer types and begins in the milk ducts. Also known as infiltrating breast cancer, this type of breast cancer spreads to tissue around the breast or other regions of the body. Ductal Carcinoma is the most common cancer type and originates from the milk ducts which carry breast milk to the nipple. Lobular carcinoma originates from the lobes or milk producing glands of the breast. It is typically a noninvasive form of breast cancer but elevates the risk of developing invasive breast cancer in the future. Inflammatory breast cancer results in the blockage of lymph vessels in the skin of the breast from infected soft tissue. It appears itchy, red, tender, warm and firm breast resulting from the accumulation of white blood cells and stimulated blood flow in the skin (*Understanding a Breast Cancer Diagnosis*, 2019).

Staging can be clinical or pathological. Clinical staging is based on the results of tests done before surgery, which may include physical examinations, mammogram, ultrasound, and MRI scans. Pathological staging is based on what is found during surgery to remove breast tissue and

lymph nodes. In general, pathological staging provides the most information to determine a patient's prognosis. There are 5 stages of breast cancer: stage 0 (zero), which is non-invasive ductal carcinoma in situ (DCIS), and stages I through IV (1 through 4), which are used for invasive breast cancer (*Breast Cancer: Stages*, n.d.). The stage provides a common way of describing the cancer, so doctors can work together to plan the best treatments. The most common tool that doctors use to describe the stage is the TNM system: Tumor (T)- "T" plus a letter or number (0 to 4) is used to describe the size and location of the tumor. Node (N)- "N" stands for lymph nodes. Lymph nodes near where the cancer started are called regional lymph nodes Lymph nodes in other parts of the body are called distant lymph nodes. Regional lymph nodes include axillary lymph nodes, internal mammary, Lymph nodes located above and below the collarbone. Metastasis (M)- "M" describes whether the cancer has spread to other parts of the body, called distant metastasis (*Breast Cancer: Stages*, n.d.).

Surgery is used to treat breast cancer and can be prophylactic or a breast conserving option. Lumpectomy is a breast conserving measure and removes a part of the breast to include the tumor and margins. A mastectomy is a surgical procedure where the entire breast is removed. The indications for mastectomy are two or more tumors in separate areas, large tumor, positive margins post lumpectomy, or if the patient is at elevated risk for getting a second breast cancer. There are several types of mastectomies such as: simple (or total) mastectomy, when the surgeon removes the entire breast, including the nipple, areola, and skin. Some underarm lymph nodes may be removed depending nodal involvement. In skin-sparing mastectomy the skin over the breast is left intact and only the breast tissue, nipple and areola are removed. The amount of breast tissue removed is the same as with a simple mastectomy and implants or tissue from other parts of the body can be used during the surgery to reconstruct the breast. Nipple-sparing mastectomy is a

variation of the skin-sparing mastectomy. The breast tissue is removed, but the breast skin and nipple are left in place. The surgeon often removes the breast tissue beneath the nipple (and areola) during the procedure to check for cancer cells. If cancer is found in this tissue, the nipple must be removed. Modified radical mastectomy offers the advantage of less scar tissue and a reconstructed breast that seems more natural. But it may not be suitable for larger tumors or those that are close to the surface of the skin. An option for women who have a small, early-stage cancer near the outer part of the breast, with no signs of cancer in the skin or near the nipple. Radical mastectomy is rarely done now but may still be done for large tumors that are growing into the pectoral muscles. The surgeon removes the entire breast, axillary (underarm) lymph nodes, and the pectoral (chest wall) muscles under the breast. This surgery was once common, but less extensive surgery (such as the modified radical mastectomy) has been found to be just as effective and with fewer side effects. Double mastectomy is when both breasts are removed. Double mastectomy is done as a prophylactic surgery for women at extremely high risk for getting breast cancer, such as those with a BRCA gene mutation (*Types of Mastectomies*, 2019).

Post mastectomy radiation therapy (PMRT) is given as an adjuvant treatment and indicated for women with four or more positive axillary nodes. Traditional treatment fields consist of two tangential fields of the affected side and a supraclavicular field and post axillary boost depending on nodal involvement. Radiation therapy treatment will usually start between three to six weeks after surgery or when the site has healed. The entire ipsilateral chest wall should be within the tangential fields to include the entire mastectomy scar and drain sites. The standard prescription for radiation therapy treatment of the chest wall post-mastectomy is 50 Gy / 25 fractions (fx) with a 0.5 – 1 cm bolus over the chest wall every other day or every day for 2 weeks. When nodes are involved a supra clavicular field (SCV) to 50 Gy / 25 fx and internal mammary chain (IMC): 50

Gy / 25 fx is used. A photon or electron boost dose of 10 Gy in 5 fractions to the mastectomy scar and tumor bed is used to reduce local recurrence (Trifiletti & Zaorsky, 2019). Bolus is a tissue equivalent material used to treat uneven areas and when dose to the surface or skin is desired. It is ideal for the post mastectomy chest wall to accommodate for the uneven surface caused by surgery. Bolus ranges from either 0.5 - 1 cm and is used daily or every other day depending on the physician's orders. Bolus placement by the therapist is important to ensure the correct area is getting the superficial dose and that no air gaps are between the bolus and patients' chest wall. An air gap of 4 mm will introduce a reduction of dose to the basal layer of approximately 0 – 4% depending on field size, angle of incidence and other patient specific parameters and a reduction of up to 10% could be seen at the basal cell layer for a 10 mm air gap (Lobo, D. & Srinivas,C., 2020). The goal of the bolus is to provide as much superficial dose to the skin causing radiation dermatitis without moist desquamation of the skin.

During the initial computed tomography (CT) scan called simulation, the patient is supine with both arms raised above their head approximately 90 - 120 degrees. The patient's chin will be turned away from the affected side to reduce any folds which could lead to radiation dermatitis and desquamation of the skin. An immobilization device called a Vac-Lok cushion forms a custom mold of the patient's body contours allowing for proper positioning and reproducibility between treatments. Accurate and repeatable patient setup is important in radiotherapy to limit the margin around the clinical target volume (CTV), planning target volume (PTV), and consequently minimize the irradiation of healthy tissues responsible for early and late side effects (Krengli et al., 2009). The radiation therapist will mark the mastectomy scar and drain sites with a wire since these are areas for recurrence. Clinical boundaries are all wired to plan for the tangential fields

borders. The superior wire is placed below the head of the clavicle, and medial wire located mid sternum. The inferior wire is marked 2 cm below the inframammary fold.

Target volumes are important in radiation therapy to ensure localized treatment to the tumor while sparing healthy tissue. Target volumes are drawn by the physician using multiple imaging modalities. The gross tumor volume (GTV) is the visible tumor, but only represents part of the tumor. The clinical target volume (CTV) includes the GTV and a margin around it to account for microscopic disease. It is entirely subjective and depends on the clinician's judgement. The planning target volume (PTV) accounts for variations in patient setup, physiologic motion of internal organs, patient breathing and positioning instability. The PTV is the ultimate target volume and primary focus of treatment planning and delivery (Sethi, 2018). The chest wall CTV should be contoured to the muscle-rib interface to include the pectoralis muscles and the entire scar plus margin. The cranial border extends to the caudal border of the clavicular head, and the caudal border is clinically determined based on markers placed at the time of simulation and using the contralateral breast as a guide. The lateral border typically extends to the mid-axillary line and medial border to the sternal-rib junction to avoid crossing midline. The chest wall planning target volume (PTV) is created by expanding the CTV from 0.5 to 1 cm. To ensure chest wall dose, the PTV can extend into the ribs about 2 mm (Trifiletti & Zaorsky, 2019).

Conventional forward planning mostly depends on geometric relationship between the tumor and nearby critical structures. Forward planning used in 3D conformal radiation therapy (CRT) depends on the planner to place beams into a planning system that can deliver sufficient radiation to the tumor while minimizing dose to critical structures. Varying angle directions, wedges, and MLC configurations are used to shape the radiation beam. The planning system then calculates the amount of monitor units to deliver the specified dose.

Inverse planning used in volumetric-modulated arc therapy (VMAT) is less dependent on the geometric parameters but more on specification of volumes of tumor targets and critical structures (Ping, 2004). The planner inputs dose requirements and constraints to critical organs and allows the optimization program to produce a treatment plan. VMAT delivers radiation using a cone beam that continuously rotates around the patient. During each rotation, the beam is shaped or modulated by the multi-leaf collimator (MLC). The dose rate and gantry speed are optimized to generate highly conformal dose distribution.

VMAT planning techniques have been used more frequently in the recent years for treating difficult-to-plan post-mastectomy and intact breast cases. The primary advantage of VMAT over 3D techniques is that it generally has a better performance at intermediate-high dose sparing and mean heart dose, which is related to ischemic heart disease without sacrificing target coverage (Yu et al., 2018). This advantage comes at the price of higher volumes of low dose to contralateral breast and lung and even higher low dose to ipsilateral organs at risk (Karpf et al., 2019).

Most treatment planning systems for breast cancer do not account for patient positioning, breathing, or anatomical changes when optimizing for volumetric modulated arc therapy. The location of the mammary gland leads to clinical target volumes (CTV) adjoined to the skin. This would generate a planning target volume (PTV) located partially outside the external body contour if isotropic margins were applied. In inverse planning optimization, this prevents from taking isotropic PTV margins (Tyran et al., 2018). To overcome these limitations a virtual bolus is generated in the treatment planning system and used during optimization.

The goal is to provide enough superficial dose to the skin to prevent recurrence without causing radiodermatitis or acute skin toxicity. Skin toxicity is the predominant acute side effect of radiotherapy to the breast, occurring during or after external beam radiation therapy (EBRT) in

more than 90% of all patients (Butson et al., 2000). The severity of skin reaction varies from mild erythema to moist desquamation and occasionally ulceration of the skin.

There have been different studies on VMAT planning techniques for left breast/ chest wall patients. A study by Yu examined a tangent based VMAT plan and found that it greatly decreased the radiation doses delivered to OARs while maintaining therapeutic efficacy (Yu et al., 2018). Another study evaluated the benefit of virtual bolus to compensate for interfraction motion due to setup errors. The results showed that virtual bolus significantly improved coverage of CTVs during treatment (Tyran et al., 2018). According to authors' Xu and Hatcher, there is a lack of dosimetric studies dedicated to chest-wall patients. Potential dosimetric advantages could be obtained using VMAT due to the complex geometry of planning target volumes and organs at risk (OAR) in chest-wall and lymph nodes (Xu & Hatcher, 2016). Monajemi and Oliver state that only a limited number of studies have investigated skin dose in VMAT treatment plans of the chest wall. There is an absence of a systemic study of different thickness bolus in VMAT treatment plans (Monajemi & Oliver, 2020). The purpose of the study is to evaluate if a VMAT technique without a bolus, with 5 mm virtual bolus, or 1 cm bolus provides better conformity and homogeneity to a large treatment area and deliver adequate dose to the superficial skin of the chest wall.

Null hypothesis (H_0): Breast treatment post mastectomy utilizing VMAT with virtual bolus does not show better conformity and homogeneity while providing adequate dose to superficial skin compared to VMAT without bolus.

Alternative hypothesis (Ha): Breast treatment post mastectomy utilizing VMAT with virtual bolus does show better dose conformity and homogeneity while providing adequate dose to superficial skin compared to VMAT without bolus.

Materials and Method

Patient Selection

The research is a retrospective planning study of ten female left sided breast cancer patients post-mastectomy. The subjects for the study were selected at random from the database of previously treated patients at a regional cancer center. The data obtained was of computed tomography images acquired during simulation for treatment planning purposes as well as previously delineated PTV and CTV. The inclusion criteria for subjects being females over the age of 18 years old, undergone a modified radical mastectomy (MRM), and had previous treatment for left sided breast cancer over the past three years from 2017-2020.

Ethical Considerations

All patient identifiers and personal health information was deleted and anonymized before use in accordance with personal health information (PHI) and to comply with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). The research proposal was submitted to the hospital Institutional Review Board (IRB) and was found to be a quality improvement initiative and exempt from IRB approval. The research proposal was then sent to Grand Valley State University (GVSU) Office of Research Compliance and Integrity for further review and approval. The board determined that the project did not require IRB approval but requested that a third party Honest Broker be used to de-identify all personally identifiable information from data being used for analysis.

Planning

Planning was completed using free breathing CT images utilizing Varian Eclipse planning software version 13.7.16 (Varian Medical Systems, Palo Alto, CA) and Anisotropic Analytical Algorithm (AAA) version 13.7.16. for volume dose calculation and the VMAT optimizer used was the Photon Optimizer version 13.7.6 (PO_ 13706) for planning optimization. Plans were

designed for use with a Truebeam equipped with HD 120 multileaf collimator (MLC) with 2.5 mm leaves and 5 mm outer leaves. The prescribed total dose of 50 Gy with 25 fractions with 2 Gy per fraction was used for each of the plans.

A virtual bolus was created in various thickness of 5 mm and 1 cm for the optimization phase only. Three plans were created for each patient and labeled NB- no bolus, 5 mm- 5 mm bolus and 1 cm- 1 cm bolus. In total thirty plans were created for the ten patients selected.

Targets

The plans utilized prior clinical treatment volumes (CTVs) and planning treatment volumes (PTVs) that were contoured by the physicians for previous treatment plans. Organs at risk (OAR) delineated were the heart, right lung, left lung, total lungs, right breast, esophagus, skin, and spinal cord in accordance with guidelines established by Radiation Therapy Oncology Group (RTOG). Previous PTV and CTV volumes for the chest wall and supraclavicular were used and later modified for the NB, 5 mm, and 1 cm plans. All artifacts and wires were contoured, and the density was overridden to zero Hounsfield units (HU).

Beam Parameters

Each plan was created using 6 MV photons with a single isocenter, collimator angles ± 10 degrees (10, 350) to minimize MLC travel and 4 full arcs. Arcs were then adjusted to adequately cover PTV volumes. All planning aspects such as collimator, gantry, and contours were based on recommendations by treatment planning website Dosepedia (*Dosepedia. 5 Minute Tutorials: VMAT Breast/CW with Flash Planning* 2021). Arc angles range from 150 – 196 degrees and average 170 degrees.

Virtual Bolus

No bolus plans

Each plan was created using 6 MV photons with a single isocenter, collimator angles ± 10 degrees (10, 350) to minimize MLC travel. The PTV for the no bolus plans were adjusted so that the PTV = CTV + 5 mm and then cropped 3 mm from inside the body contour. Using the arc geometry tool use the PTV total as the target and create two full arcs moving clockwise and two full arcs going counterclockwise. Arc length was then adjusted to cover the medial and lateral extent of the PTV. Arc angles in this study range from 150 – 196 degrees and average 170 degrees. All planning aspects such as collimator, gantry, and optimization objectives were based on recommendations by treatment planning website Dosepedia (*Dosepedia. 5 Minute Tutorials: VMAT Breast/CW with Flash Planning* 2021).

5 mm bolus plans

The 5 mm bolus plans will have two plans; one called 5 mm and the other 5 mm original. A virtual bolus, new body contour, and new PTV contour were created on the 5 mm plans only. The virtual bolus was created by using the margin for structure tool to create a 5 mm outer margin from the body contour. The VOI box was used to restrict the margin to the chest wall PTV only. The structure was then cropped from extending inside the body. This created a strip of contour along the anterior and lateral side of the PTV chest wall. The density of the virtual bolus was then overridden to zero Hounsfield units (HU). The new body contour was created by using the boolean tool to combine the body contour and virtual bolus. The body contour now contains the flash needed for optimization. The new PTV chest wall was created by using the boolean tool to combine the virtual bolus and PTV chest wall. The PTV was then cropped 2.5 mm from body contour. Optimization was run the same as the non-bolus plan optimization objectives. The calculation portion was aborted after optimization was completed. Each optimized arc was then

copied and pasted into the 5 mm original plan. Plans were calculated and normalized to reduce global max to below 110 %.

1 cm bolus plans

The 1 cm bolus plans were created the same as the 5 mm bolus plans with only minor differences. Two plans were created and named 1 cm and the other 1 cm original. The virtual bolus was created by using the margin for structure tool to create a 1 cm outer margin from the body contour. For the 1 cm bolus plan the new PTV was cropped 5 mm from the body contour. Optimization was run the same as the non-bolus plan objectives. Once the optimization phase is complete abort the calculation portion. Each optimized arc was then copied and pasted into the 1 cm original plan. The plan was then calculated and normalized to reduce global max to below 110 %.

Plan Evaluation

For planning evaluation and constraints, RTOG 1304 Arm 2B was used for organ at risk tolerance recommendations. See Table 1 for dose constraints. PTV Skin contour was used to evaluate dose to skin flash region. PTV skin contour was created by using the boolean operator to keep overlapping parts between the skin contour and PTV chest wall. The goal for PTV skin to reduce reoccurrence is: 5% of the volume receives 100% of prescription dose and 85-95% of volume receives 80% of prescription dose. Conformity Index was calculated as CI = V9 5% / V(PTV) where V95% represents the volume receiving the prescribed dose and V (PTV) is the planning target volume. Conformity index goal is to be as close to 1 as possible. Homogeneity index was calculated as HI = D 2% - D98 % / D. Where D2 % = minimum dose in 2 % of the PTV

(maximum dose), D98 % = minimum dose in 98 % of the PTV (minimum dose) and D = the prescription dose.

Optimization Technique

Initial optimization objectives were the same for all plans and then adjusted as needed to meet dose constraints. A ring around the PTV was created using extract wall 1 cm outside margin and -.1 mm inside margin to control dose. A PTV total and CTV total were used in the optimization process. Plans that had the virtual bolus were run with them in place during optimization phase only and removed before calculation. Dose parameters and priorities for planning optimization are outlined in Table.1.

For statistical analysis, an ANOVA repeated measures test was used for plan comparisons with a $p < 0.05$ to be significant. The software used for statistical analysis was IBM SPSS v24.

Results

The purpose of the study was to evaluate if a VMAT technique without a bolus, with a 5 mm virtual bolus, or a 1 cm virtual bolus provided better conformity, homogeneity to a large treatment area and deliver adequate dose to the superficial skin of the chest wall. Data of ten previously treated breast cancer patients post mastectomy was used for the study analysis. Using IBM SPSS v24 a one-way repeated measures ANOVA was used to compare the means of three or more groups.

Conformity Index

The conformity Index was calculated as CI = V95% / V(PTV) where V95% represents the volume receiving the prescribed dose and V (PTV) is the planning target volume. The calculated conformity index was compared to the Eclipse TPS for accuracy. The conformity index of all thirty plans was calculated with the goal being CI = 1.0.

Assumption of sphericity was met using Mauchly's test of Sphericity, X^2 (2) = .114, p = .944. The main effect of bolus was not significant, Wilks' Lambda = .984, F (2, 8) = .066, p = .94. The conformity index means for the no bolus, 5 mm plans and 1 cm bolus plans did not differ on conformity index (see Figure 1 for means).

Homogeneity Index

Homogeneity index was calculated as HI = D2% -D98% / D. Where D2% = minimum dose in 2% of the PTV (maximum dose), D98% = minimum dose in 98% of the PTV (minimum dose) and D = the prescription dose. The homogeneity index goal for all thirty plans was HI = 0.

The mean for homogeneity of the no bolus plan was (M = .14, SD = .039), 5 mm bolus plan (M = .15, SD = .044) and (M = .13, SD = .022) for the 1 cm bolus plans (Figure 2). Assumption of sphericity was met, X^2 (2) = 1.63, p = .443. The main effect of bolus was not significant, Wilk's Lambda = .567, F (2, 8) = 3.06, p = .10. Bolus and no bolus plans did not differ significantly in relation to homogeneity index.

Skin V5

A 5 mm margin contour was created where the PTV chest wall and 5mm skin contour overlap. The dose volume histogram (DVH) was used to calculate the dose that 5 % of the PTV skin volume was receiving. The goal for the PTV skin volume is to get 100% of the prescription dose to 5% of the volume to ensure adequate dose to the superficial skin of the chest wall and reduce any chances of recurrence.

Assumption of sphericity was met, X^2 (2) = 3.95, p =.138. The main effect of bolus was not significant, Wilk's Lambda = .668, F (2,8) = 1.99, p = .199. The skin V5 means for the no bolus, 5 mm plans and 1 cm bolus plans did not differ on skin V5 (see Figure 3 for means).

Skin V85

The PTV skin contour was evaluated on the dose volume histogram of each plan. The objective is to have 80% of the prescription dose covering 85% of the volume. The mean dose for the no bolus plan is (M = 56.6, SD = 8.03), 5 mm bolus (M = 55.6, SD = 5.08) and 1 cm bolus plan (M = 55.8, SD = 5.16). Mauchly's assumption of sphericity has been violated, X^2 (2) = 17.51, p = .000, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (E = .530). The results showed that there was no significant effect of bolus, and no bolus plans on skin V85, F (1.06, 9.5) = .256, p = .638. These results suggest that no plan was significantly better at obtaining 80% of the dose to 85% of the volume.

Discussion

The purpose of the study was to evaluate if a VMAT technique without a bolus, with a 5 mm virtual bolus, or a 1 cm virtual bolus provided better conformity and homogeneity to the treatment area while delivering adequate dose to the superficial skin of the chest wall.

Conformity Index

The conformity index is a tool used to evaluate ideal dose to ensure the irradiated volume covers the target volume. Conformity is important to ensure that the target volume is not underdosed or overdosed and treating healthy tissue. The study indicated that there was no significant effect between the plans. The means for the 1 cm plans were higher for conformity when compared to the other plans. Treating the PTV chest wall and supraclav separately would improve conformity and allow better coverage.

Homogeneity Index

The homogeneity index is a tool used to analyze the uniformity of dose distribution in a target volume. Homogeneity of the dose is important in chest wall radiation to avoid hot spots which could cause radiation dermatitis or moist desquamation. The means for the 1 cm plan were

higher when compared to the no bolus and 5 mm bolus plans. Larger arc length and different collimator angles for better modulation would improve dose homogeneity

Skin

Superficial skin dose is important to reduce any chance of recurrence within surgical scars. The results showed no significant effect on skin dose between the separate plans. By utilizing the 1 cm bolus it leaves room for flash in order to account for any interfraction movement, setup error, and breathing during treatment as seen in previous studies (Tyran et al., 2018)

Limitations

The main weakness of the study was the inexperience of the treatment planner. A seasoned dosimetrist who has experience with using VMAT to treat chest walls could have done a better job at meeting dose constraints and objectives. The treatment plan approach was limited by inexperience and by the suggestions of a planning tutorial. Treating separate PTVs, using alternate collimator, gantry angles would have improved homogeneity and conformity. The small population was the main factor that rendered the test results insignificant. Using G*Power 3.1.9.4 to find power analysis and it determined that a sample population of thirty-six patients is needed to get significant results.

Conclusion

The results did not show significant effect on conformity, homogeneity, or superficial skin dose between each of the plans. The 1 cm plan did show higher means in each of the categories. Using the 1 cm plan would create a desirable flash to account for breathing and interfraction movement while maintaining equivalent conformity and homogeneity. Future studies with a larger sample size could reinforce this study showing that the 1 cm bolus was a better choice overall.

Future studies utilizing a tangent based VMAT plan and 1 cm virtual bolus could show that it is a viable treatment option for left sided chest wall patients.

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Appendix

Table 1. Dose Constraints and Evaluation

Target	Criteria	Volume	Dose	ARM/2/Group 2B
Chest wall PTV	protocol	95%	95% of Rx dose	47.5 Gy
	variation	90%	90% of Rx dose	45 Gy
Heart	protocol	No more than 10 %		≤ 25 Gy
	variation	Mean		≤ 5Gy
Lt lung	protocol	% that can receive 20 Gy		≤ 35%
Rt lung		15%		5 Gy
Rt breast	variation	No more than 10%		5 Gy
Lungs		35%		20 Gy
Spinal Cord				45 Gy
Esophagus		mean		< 34 Gy
Dmax				< 110 %

Table 2. Dose parameters and priorities for planning optimization

Structure	Volume (%)	Dose (cGy)	Priority	Structure	Volume (%)	Dose (cGy)	Priority
PTV	0	103% of Rx dose	125	**Lt Lung**	75	490	110
	0	103% of Rx dose	125		65	990	75
	98	101% of Rx dose	140		40	1900	75
	98	101 % of Rx dose	140	**Rt Lung**	15	490	80
CTV	95-98%	Rx + 25	90		mean	300	80
Esophagus	Mean	1100	45	**Lungs**	30	1900	60
Heart	Mean	600	75		55	490	75
	10	2800	75	**Ring**	0	Rx dose	110
Rt Breast	0	50% of Rx dose	60	**Liver**	Mean	700	45
	10	480	75	**NTO**			150

Figure 1. Bar graph of mean CI

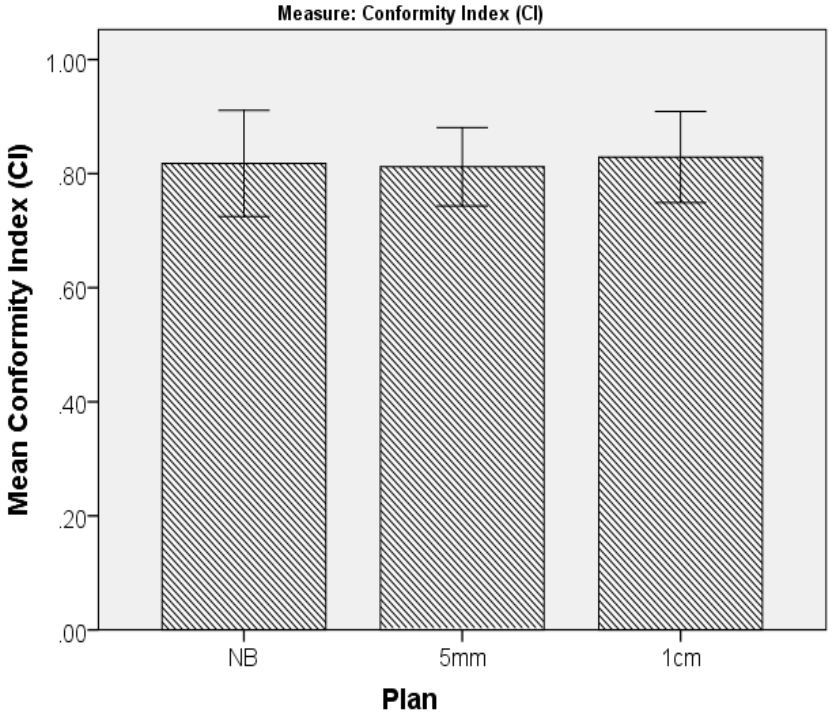

Figure 2. Bar graph of mean HI

Figure 3. Bar graph of mean SkinV5

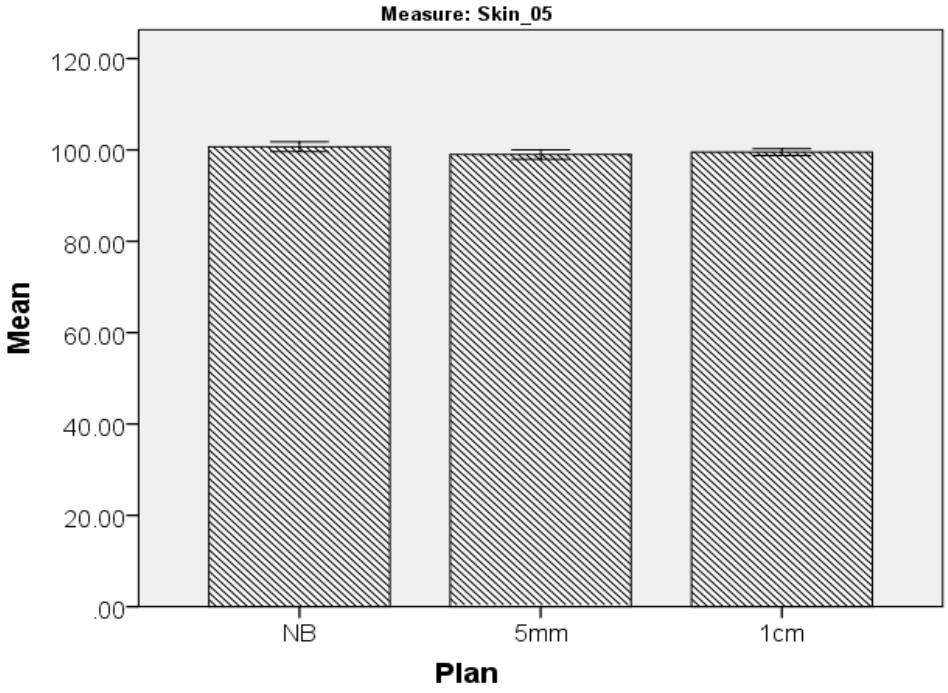

Figure 4. Bar graph of mean skinV85