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Analysing breast dose in female mediastinal lymphoma patients who received radiotherapy: a retrospective audit

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Original Article

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Abstract

Introduction: Second primary breast cancers are among the most common risks to female patients who have received radiotherapy for mediastinal lymphoma.

This study aims to audit breast dose in women who received mediastinal radiotherapy for lymphoma and compare the combined dose parameter values measured to those in the literature.

Methods: Twenty-three patient datasets from 2017 to 2021 were obtained. Inclusion criteria, such as female gender and 30Gy prescription dose, were applied. Target volumes were delineated using involved site radiotherapy and planned on Eclipse (Varian, Palo Alto, CA) using either fixed field or VMAT. Breast contours were retrospectively outlined according to RTOG/EORTC guidance and descriptive statistics were used to compare findings to those from the literature.

Results: Differences were found in V4gy, V5Gy and mean dose compared to the literature with mean dose being 2Gy in the literature and 4Gy in this audit.

Conclusions: Breast dose parameter values between patients in this study vary due to multiple factors. These include the treatment delivery method used and the position of the treatment field in relation to the location of breast tissue. Mean dose and $V_{4\%}$ and $V_{5\%}$ to breast tissue found in this study differ from that found in the literature. This study highlights the importance of accurate contouring and optimising breast tissue when possible.

Introduction

It is well documented that female patients with mediastinal lymphoma who are treated with radiotherapy have an increased risk of developing a second primary breast cancer[1–10]. The risk of developing a second primary breast cancer from lymphoma radiotherapy depends upon the amount of dose received, with respect to the volume of tissue exposed[2,9,10]. This means that variations in target delineation and treatment delivery techniques affect dose received by breast tissue and other organs at risk (OARs)[2–10].

Acknowledgement of the late effect risk of developing second primary cancers, alongside other late toxicities, led to a drive to further reduce the size of the treatment volumes for patients receiving radiotherapy for mediastinal lymphoma. Initially, this meant going from an extended field radiotherapy (EFRT) technique covering most of the thorax with shielding for the lungs to involved field radiotherapy (IFRT) technique, which primarily involved just the localised region of original disease-involved nodes pre chemotherapy[3,4] (Figure 1). In a trial originally investigating the efficacy of IFRT[5], 1064 patients with early-stage unfavourable Hodgkin lymphoma were randomised to be prescribed either 30Gy EFRT or IFRT after receiving 4 cycles of chemotherapy. No significant differences were found in overall survival, freedom from treatment failure and progression-free survival at the 10 years follow up. Moreover, treatment with IFRT had a significantly lower rate of acute toxicity, with a non-statistically significant lower rate of secondary malignancies in patients compared to EFRT[5,6]. This led to IFRT becoming the gold standard in radiotherapy for treating nodal lymphomas in the UK from 2003 onwards[4].

When computerised positron emission tomography (PET)-CT was implemented to aid diagnosis and staging, the full extent of disease-involved nodes could be visualised. It is known that most reoccurrences of lymphoma begin in the initially involved nodes[7,9,10]. Therefore, it was hypothesised in several studies that treating only the initially involved nodes highlighted from the PET-CT scan could provide an equally effective treatment for lymphoma to IFRT in terms of disease-free survival, but with a further reduced dose to OAR[7,9,10]. This led to the development of the treatment delineation technique involving node radiotherapy (INRT) where only the involved nodes, highlighted from the PET-CT scan, are treated (Figure 1)[3,7,9,10]. For INRT, it is

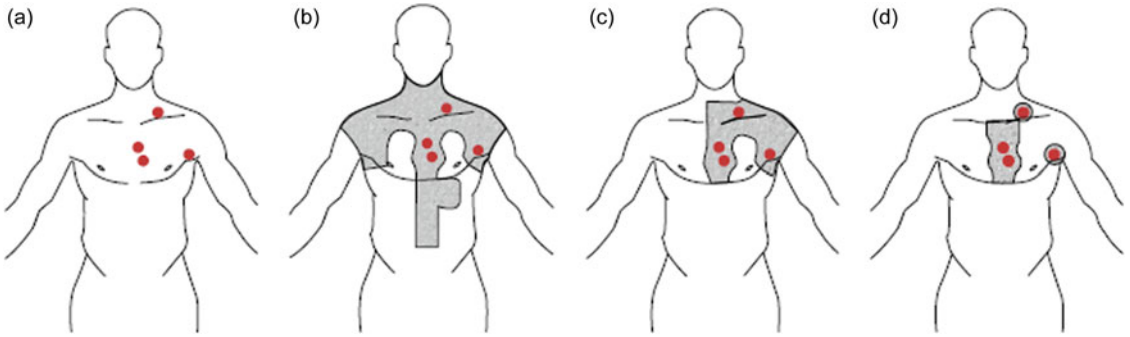

Figure 1. Taken from Witkowska *et al*, (2015)[3] shows the differences in radiotherapy target delineation techniques. (a) shows involved lymph nodes, (b) shows an extended field technique, (c) shows involved field radiotherapy and (d) shows involved nodal radiotherapy.

required that the PET-CT scan take place in the original radiotherapy treatment position, which is ideal as it enables reproducibility of position on treatment[9]. However, this is not always possible due to differences in equipment size and suitability and appointments and equipment being spread out across differing treatment centres,[8] which led to the development of involved site radiotherapy (ISRT), which is a less rigid version of INRT that does not require the PET-CT to take place in the radiotherapy treatment position, meaning the Gross Tumour Volume (GTV) information may not be fully optimal[8]. To this end, this can also mean that a larger Clinical Target Voume (CTV) is contoured compared to INRT for ISRT, based on clinical judgement and the imaging information available[9]. Both INRT and ISRT are currently recommended by the International Lymphoma Radiation Oncology Group for treatment of lymphoma patients[9,10].

Currently, the Author's Centre does not routinely record breast doses for female patients receiving radiotherapy for supra-diaphragmatic lymphoma. Therefore, risks of a second primary breast cancer locally to these patients are unquantified. Although the aforementioned changes to target delineation and treatment delivery methods have been introduced to reduce dose to breast tissue, there is still an increased risk of second primary breast cancer at lower doses, even reportedly as low as 0·24Gy[11]. Moreover, second primary breast cancers from lymphoma radiotherapy are more likely to be triple-negative and or bilateral than de novo primary breast cancers[10,12]. This means these women are more likely to have a worse prognosis at diagnosis[10,12,13]. Therefore we decided to audit breast dose in previously treated patients to allow for potential future investigations of risk and follow up care interventions to take place.

The aim of this study was to audit breast dose in women who have received external beam radiotherapy for nodal lymphoma involving the mediastinum at a single UK Cancer Centre and compare those to the literature.

The Objectives of this study were to:

- Extract dose parameter values from suitable plans for comparison between patients.
- Compare the combined dose parameter values found in this study to those in similar studies.

Methodology

Patient selection

A retrospective audit was conducted for female patients up to the age of 36 who were previously treated with external beam radiotherapy (EBRT) for nodal lymphoma involving the mediastinum. Patients were sourced from the trust's Aria (Varian Medical Systems, Palo Alto, CA) patient database by utilising a database search report for patients who had lymphoma with mediastinal involvement between 2017 and 2021. Patients with lymphoma in the mediastinum were the focus of this study, due to the proximity of the mediastinum to the breast. Furthermore, examining patients with mediastinal lymphoma allows for comparison between studies found in the literature review as most studies examining breast dose in lymphoma patients focussed on patients with mediastinal involvement[10,13]. Patients up to the age of 36 were selected initially due to the known increased risk of breast cancer[14]. This left only 7 patients who would have been eligible for inclusion into the audit out of the 23 patients treated with EBRT for mediastinal lymphoma. To expand the number of suitable patients for a larger sample size, the inclusion criteria were amended to instead include female-only patients of any age, due to women of all ages having breast tissue, along with a 30Gy prescription, and confirmed mediastinal involvement in their patient notes. Exclusion criteria included male patients, with incomplete breast tissue on their scan data due to a reduced amount of or incomplete amount of breast tissue on the CT dataset. Patients with no mediastinal involvement documented in their notes were excluded to enable comparison with other studies and due to a likelihood of limited breast tissue receiving dose for these patients and a prescription dose which was not 30Gy was also excluded to enable uniform comparison between patients without prescription dose influencing breast dose. All patients underwent a pre-radiotherapy CT scan of 3 mm slice thickness. Ethics approval was obtained from the author's centre prior to data collection.

Plan information

Treatment plans used in this study were originally used for patient treatment and no changes were made to any of the original planning decisions. All treatments were planned in Eclipse v15·6 (Varian Medical Systems, Palo Alto, CA) using the Acuros dose algorithm. Treatment planning staff at the trust provided training on using Eclipse for the author to extract data from plan dose-volume histograms from the treatment plan and in utilising the contouring tools to outline breast tissue. Plans selected were either Intensity Modulated Radiotherapy (IMRT) fixed field or VMAT plans.

The dose parameters used for this study encompassed those at both lower and higher doses namely V_{4Gy}, V_{5Gy}, V_{20Gy}, $D_{1\%}$, and mean dose[13,15–19]. These parameters were utilised in the literature and allowed for effective comparison to other studies[13,15–19]. Descriptive statistics were utilised to enable comparison between patients. All plans utilised the target delineation method ISRT[3,8–10].

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Table 1. The number of plans for the different treatment delivery methods used

Treatment delivery method used	Variation	Number of plans (n = 23)
Fixed fields	3D-CRT 2 static MLC fields (2 lateral fields)	1
	3D-CRT 3 static fields with wedges (2 anterior and 1 posterior field)	1
	IMRT 3 fields (oblique angles)	1
VMAT	1 Arc	1
	2 Arcs	15
	2 Partial Arcs	2
	3 Arcs	2

Table 2. Clinical attributes from patients >36 years of age including those who had their breast tissue contoured prior to this audit

Patient number	Breast contoured previously	Breast dose optimisation objectives in place	Age at time of first fraction of EBRT	Treatment delivery method used
3	No	No	27	VMAT
5	No	No	32	3D-CRT
7	Yes	Yes	20	VMAT
9	No	No	35	VMAT
11	No	No	34	VMAT
12	Yes	No	29	VMAT
18	Yes	Yes	30	VMAT
20	No	No	30	IMRT
23	No	No	26	VMAT

Acceptable dose limits to the PTV were between 95% and 107% in accordance with International Commission on Radiation Units and Measurements (ICRU) guidelines[20]. All plans selected for contouring were anonymised and copied to enable contouring of breast tissue. To allow for accurate anatomical boundaries to be adhered to in terms of contouring and enable repeatability in future studies, breast contouring in this study was conducted using a combination of RTOG and ESTRO breast contouring guidelines[21,22].

Results were recorded as either combined or separate breasts within the literature[13,15–19]. Therefore, to allow for comparisons between all studies within the review, breast dose results were reported as both combined and separate breasts in this audit. Patients with breast contours already outlined had new contours produced using the RTOG/ESTRO guidelines to ensure consistency in results[21,22]. Combined breast contours were made by combining the left and right breast contours as a new structure.

Results

Patient information

The Aria database search post application of inclusion and exclusion criteria resulted in 23 eligible patients for selection. All plans selected were planned at 6MV. IMRT and VMAT separation data are found in Table 1. Three patients out of the 23 had breast contours already produced in their structure sets. These three patients were all 34 years of age or under at time of treatment. Two of these three patients had breast-related optimisation objectives in place to reduce dose to the breast tissue (Table 2). One patient's plan was combined with their replan to form a single new plan.

Table 3. Descriptive statistic combined results for each dose parameter for the left breast (n = 23)

Descriptive statistic	V_{4Gy} (%)	V_{5Gy} (%)	V_{20Gy} (%)	$D_{1\%}$	Mean dose (Gy)
Mean	39·097	33·691	1·644	15·812	4·321
Median	39·865	37·343	0·569	18·762	5·031
Maximum	88·732	81·479	9·871	30·199	8·815
Minimum	0·000	0·000	0·000	0·495	0·160
Range	88·732	81·479	9·871	29·704	8·655

Table 4. Descriptive statistic combined results for each dose parameter for the right breast (n = 23)

Descriptive statistic	V_{4Gy} (%)	V_{5Gy} (%)	V_{20Gy} (%)	$D_{1\%}$	Mean dose (Gy)
Mean	35·841	30·617	1·541	14·799	4·077
Median	30·129	23·075	0·000	14·667	3·096
Maximum	88·811	85·624	12·714	33·607	9·811
Minimum	0·000	0·000	0·000	0·456	0·140
Range	88·811	85·624	12·714	33·151	9·671

Table 5. Descriptive statistic combined results for each dose parameter for the combined breasts (n = 23)

Descriptive statistic	V_{4Gy} (%)	V_{5Gy} (%)	V_{20Gy} (%)	$D_{1\%}$	Mean dose
Mean	37·587	32·551	1·557	17·700	4·201
Median	40·564	32·831	0·353	18·072	4·396
Maximum	84·258	78·000	6·849	33·175	8·418
Minimum	0·000	0·000	0·000	0·478	0·150
Range	84·258	78·000	6·849	32·697	8·268

Plan Analysis

Data for each patient regarding their individual dose parameter values can be found in Appendix 1–3. Means, medians, maximum and minimum values and ranges were calculated for each dose parameter for the left, right and combined breasts, using all plans. These can be found in Tables 3–5. Box plots of Interquartile range (IQR) data for each parameter for each breast were constructed to illustrate the distribution of the data (Figures 2 & 3).

Little difference in dose is noted between left and right breasts (Tables 3–5), (Figure 2). A greater volume of breast tissue is receiving around V_{4Gy} and V_{5Gy} compared to V_{20Gy} and a larger

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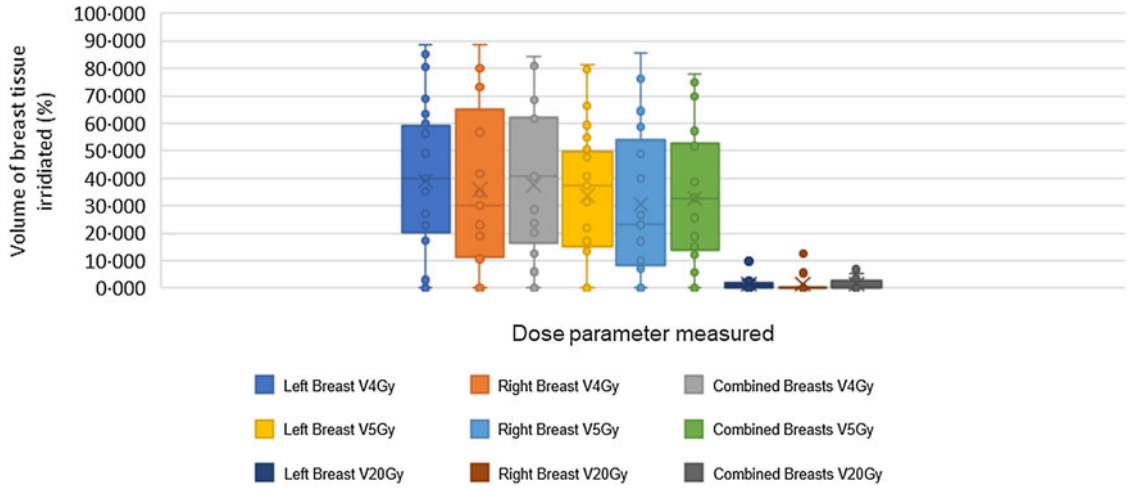

Figure 2. Comparison of range of volume in % of breast tissue irradiated to V4Gy, V5Gy and V20y for the right, left and combined breasts.

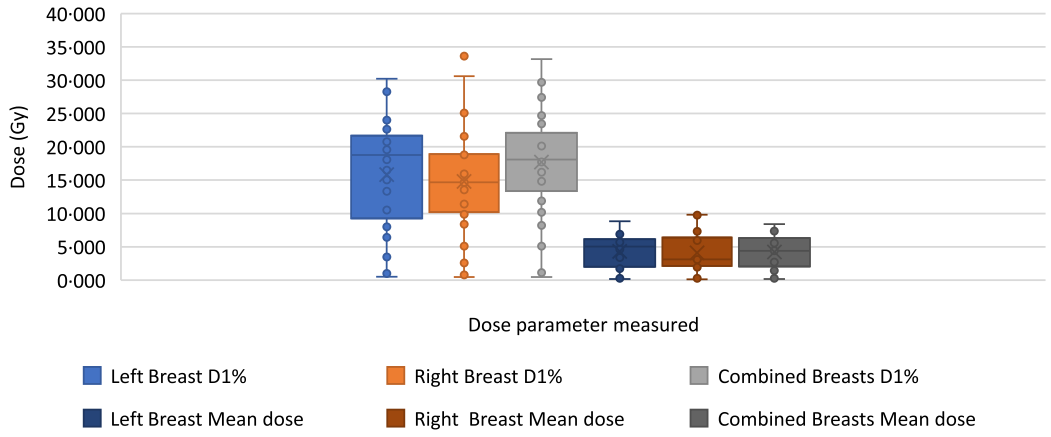

Figure 3. Comparison of range between D1% and mean dose to breast tissue for the right, left and combined breasts.

range in values for V_{4Gy} and V_{5Gy} can also be noted compared to V_{20Gy} (Figure 2). There is also a large range for right, left and combined breasts in terms of $D_{1\%}$ (Tables 3–5) (Figure 3). Mean dose to breast tissue for the overall data appears to be just around 4Gy (Tables 3–5) (Figure 3).

A difference in V_{4Gy} and V_{5Gy} can be seen between fixed-field IMRT and VMAT treatment for left, right and combined breast data (Figure 4) in terms of the range and spread of the data. There is not much difference between treatment delivery modalities for V_{20Gy} (Figure 4). A large range can also be seen for the $D_{1\%}$ data with some values close to the prescription dose and some close to no dose received (Figure 5). There also appears to be a difference in mean dose received between fixed-field IMRT and VMAT (Figure 5).

Visual differences in the amount of breast tissue irradiated were well observed on aria between patients (Figures 6–8). Moreover, differences were noted between the contouring produced for this audit and that previously present on some patients (n = 3) (Figure 9)

Discussion

Trends in data in this audit suggest that there is little difference in breast dose received between left and right breasts (Figures 2 & 3). Previous studies reported differences in breast dose between left and right breasts in mediastinal-involved patients with a 30Gy prescription[13,15,23]. Koeck *et al.*, found all parameters measured in all plans were greater for the left breast than the right[23]. Conversely, Voong *et al.*, found similar values for the left and right breasts for each parameter measured[15]. The reasons behind these trends are not mentioned in these studies. However, it is important to note that breast tissue is not the primary target of treatment delivery for as the volume of individual or combined breast tissue irradiated is dependent upon field margin locations required to treat the target volume, which in turn is dependent on disease location, extent and each centre's target volume margining used. It is also dependant on individual and combined breast contours, sizes, and geometric positions in relation to the location of the fields (Figure 6–8) with these factors being variable for all treatment techniques and patients. Therefore, there is always going to be variation between patients and between studies examining left, right and combined breast dose parameter values.

Differences in volume of breast tissue irradiated and mean dose between fixed-field IMRT and VMAT were noted within this study (Figures 4 & 5). Previous studies have suggested that the delivery technique does play a role in dose to breast tissue with VMAT resulting in an increased mean dose and V_{4Gy} of breast tissue compared to other forms of IMRT[24,25]. Furthermore, FF-IMRT

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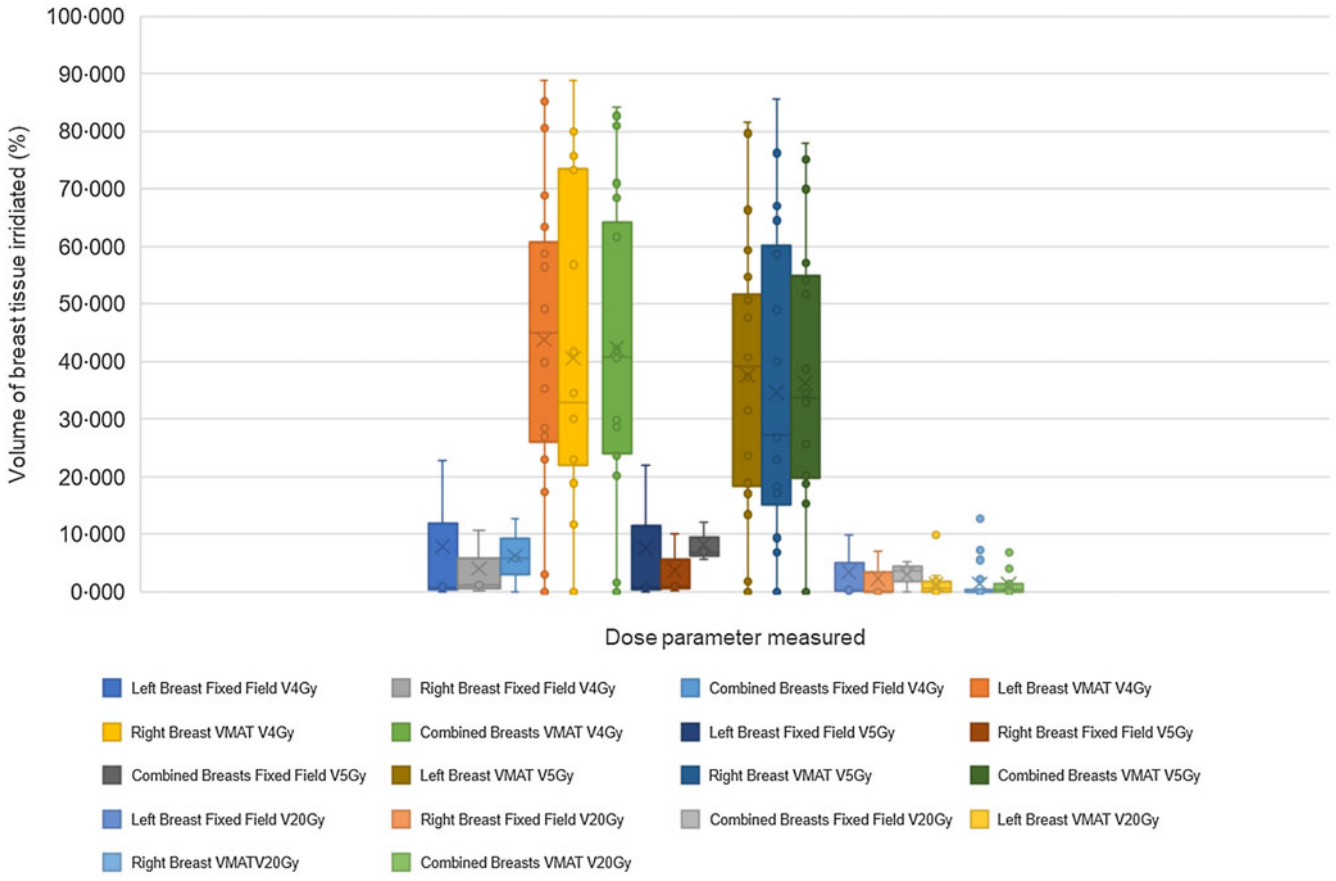

Figure 4. Shows a comparison between the volume in (%) of breast tissue irradiated to V4Gy, V5Gy and V20y for the right, left and combined breasts split between fixed-field IMRT (n = 3) and VMAT (n = 20) treatment.

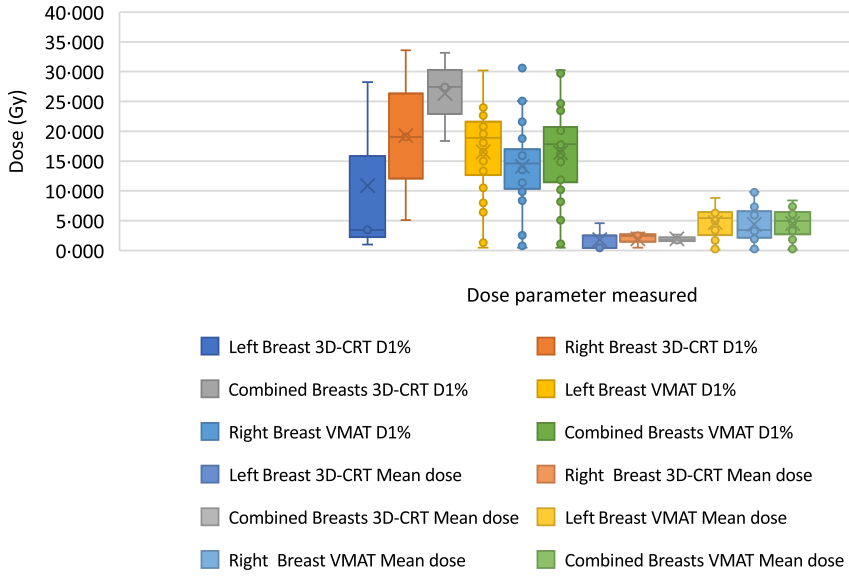

Figure 5. Shows a comparison between D1% and mean dose to breast tissue for the right, left and combined breasts split between fixed-field IMRT (n = 3) and VMAT (n = 20) treatment.

was found to increase median and low doses but reduce higher doses compared to 3D-CRT[23]. A more recent study however, utilising ISRT, suggests there is little difference between 3D-CRT and VMAT, although this compared a parallel opposed pair at 0° and 180° which would avoid most of the breast tissue, but could lead to higher doses in other areas[17]. The data in this study suggest mean dose and V_{4Gy} are higher for VMAT patients (Figures 4 & 5). However, the data for fixed-field IMRT in this study is based upon just three patients and utilises a combination of IMRT and 3D-CRT patients. Moreover, in two of the three fixed-field IMRT

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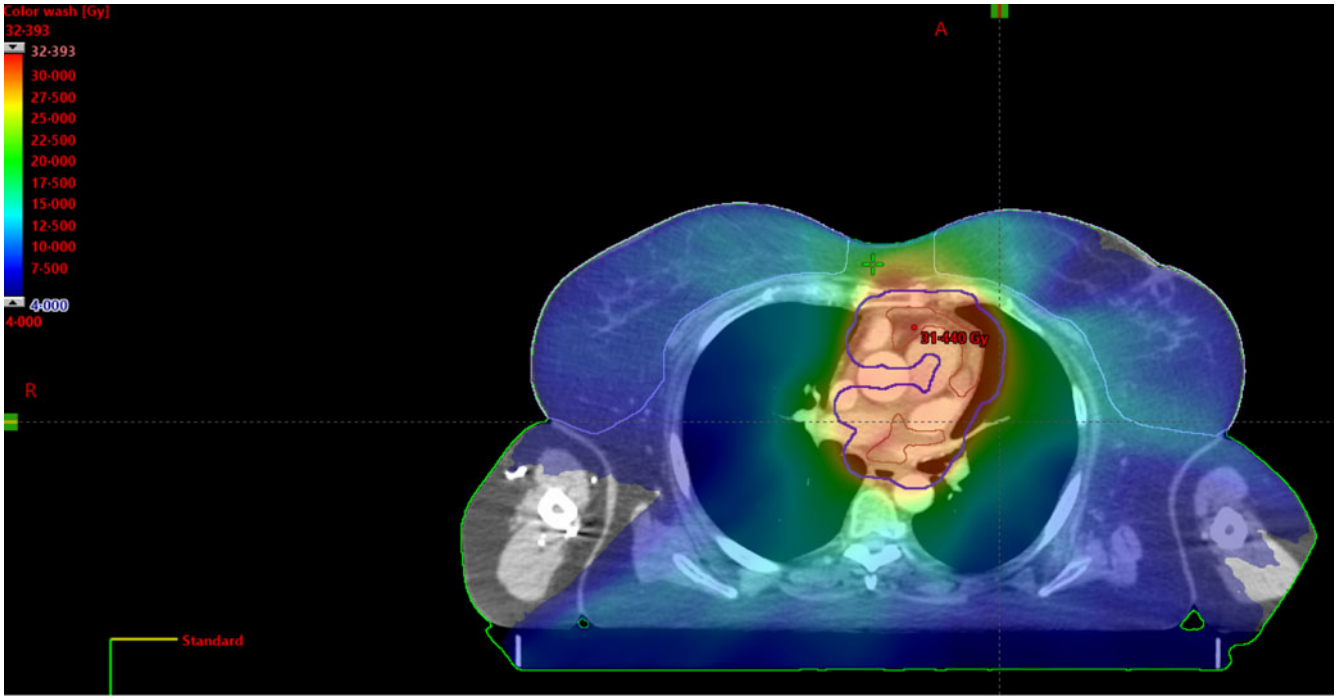

Figure 6. Dose colourwash showing the amount of breast tissue receiving ≥4Gy in an axial view for a VMAT plan for a patient receiving external beam radiotherapy for mediastinal lymphoma. Breast tissue is contoured in lilac. PTV is outlined in bold purple.

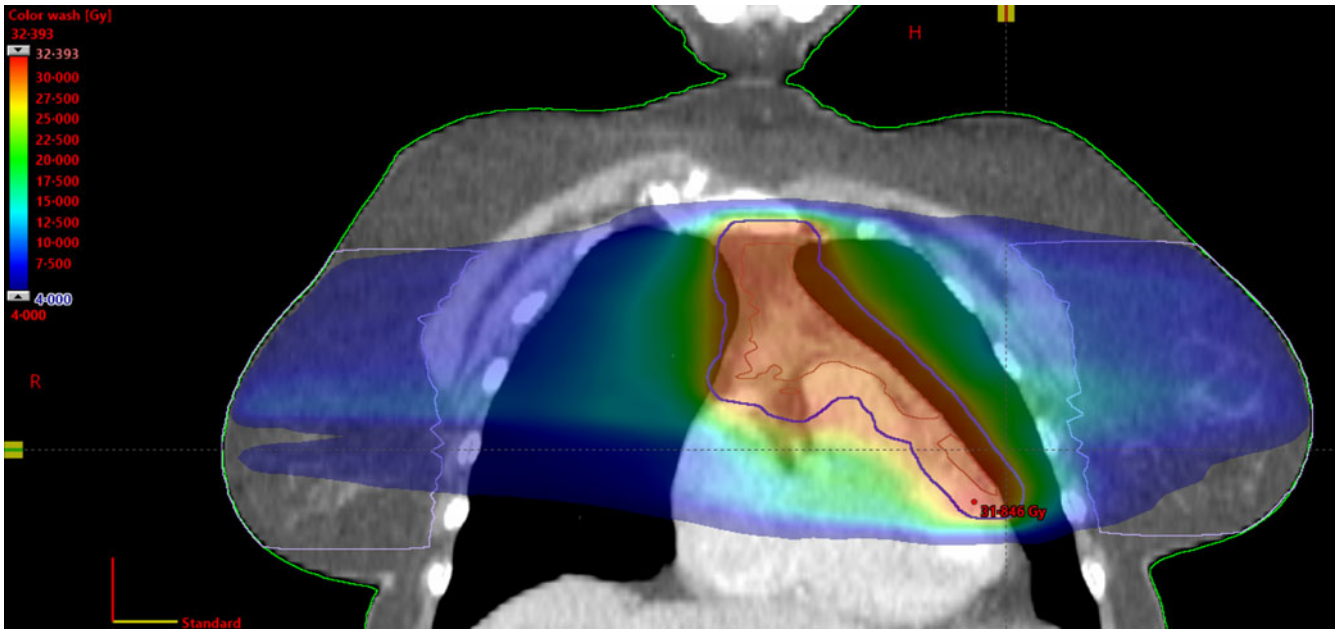

Figure 7. Dose colourwash showing the amount of breast tissue receiving ≥4Gy in a coronal view for a VMAT plan for a patient receiving external beam radiotherapy for mediastinal lymphoma. Breast tissue is contoured in lilac. PTV is outlined in bold purple.

plans, breast dose was taken into consideration by the planners of the original plan in efforts to reduce breast dose in one patient and avoid a singular breast in another due to previous XRT (Figure 8). Additionally, within this study, two patients received partial arcs and the number of arcs varied between one and three for some patients (Table 3). This could also have influenced dosimetry to breast tissue. Therefore, the comparisons displayed within this data between these factors should be taken very tentatively.

Data from previous studies that utilised ISRT to treat mediastinal lymphoma, within 0·6Gy of a 30Gy prescription dose, can be found within (Table 6)[13,15–19]. Differences can be noted between the audit data and the literature, most notably in terms of

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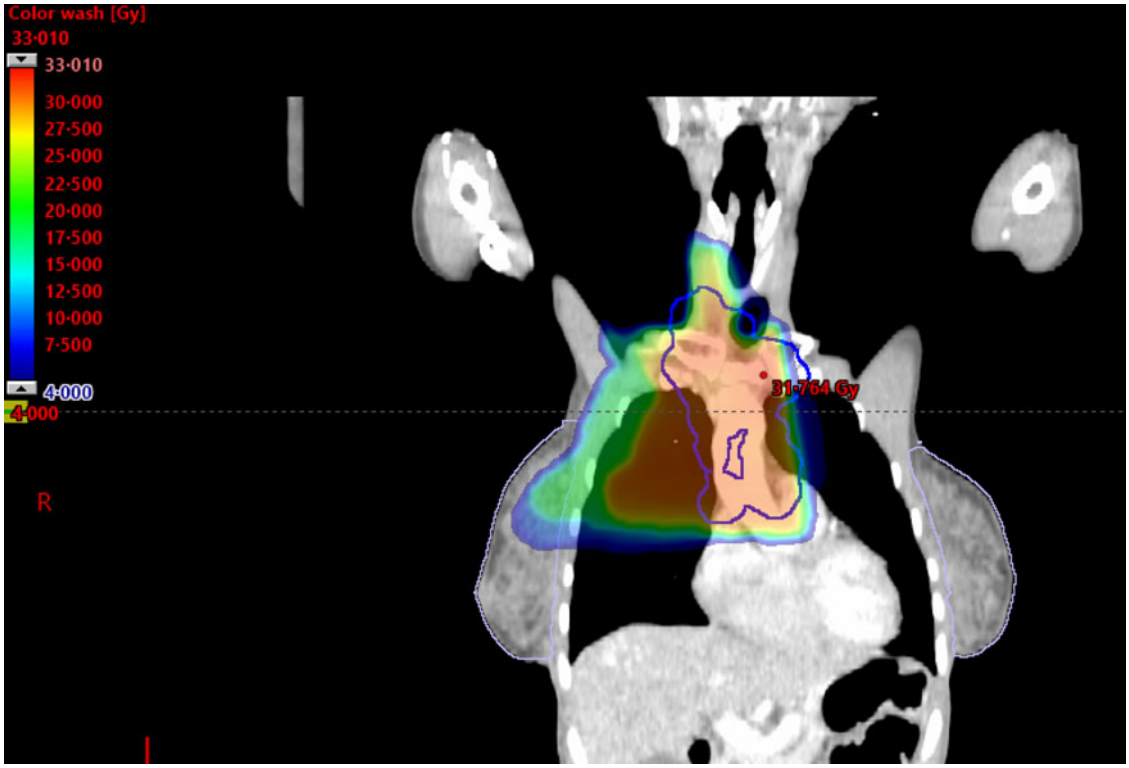

Figure 8. Dose colourwash showing the amount of breast tissue receiving ≥4Gy in a frontal view for a VMAT plan for a patient receiving external beam radiotherapy for mediastinal lymphoma with the left breast receiving a greater proportion of dose ≥4Gy than the right breast due to the method of plan construction. Breast tissue is contoured in lilac. PTV is outlined in bold purple.

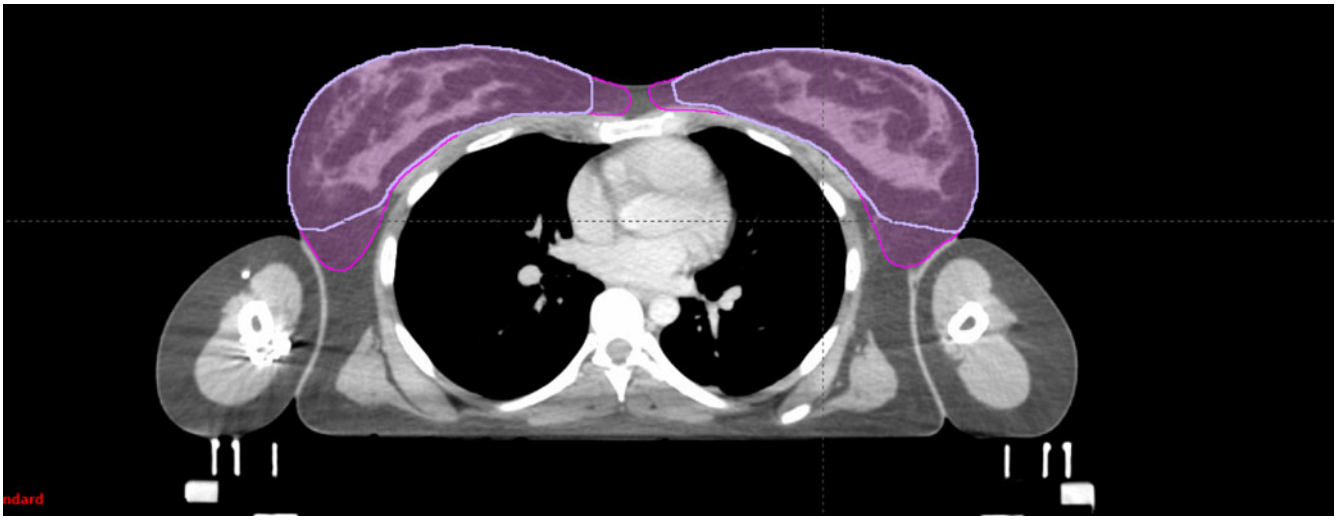

Figure 9. Differences in contour between the original contouring of breast tissue (pink) and the new contouring produced for this audit (lavender).

$V_{4\%}$ and $V_{5\%}$ and mean dose (Table 6). It is important to mention that the literature data compiled in the above table contains data from studies utilising different treatment delivery methods, which have previously been noted to alter dose to breast tissue[13,15–19,24,25].

Differences observed between the overall combined data in this study such as a higher mean dose compared to that found within the literature (Table 6) could be partially due to this audit being primarily composed of VMAT-planned patients that did not utilise breast tissue as optimisation structure during the planning process (Table 1 & 2), as done in other VMAT planned studies[15,17]. This could have instigated a higher dose VMAT-induced dose bath across breast tissue in these patients compared to the other studies which either utilised either a fixed-field Anterior-Posterior-Posterio-Anterior (AP-PA) approach, preventing a widespread

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Table 6. Shows involved site radiotherapy planned data extracted from articles extracted from the literature along with data from the results of this audit for comparison

Data Source	Treatment delivery technique utilised	Number of female patients and number of plans	Breast	Mean dose, and minimum & maximum values and/or standard deviation (Gy)	$V_{4\%}$ mean and minimum and maximum values and/or standard deviation (%)	$V_{5\%}$ mean and minimum and maximum and/or standard deviation (%)	$V_{20\%}$ mean and minimum and maximum and/or standard deviation (%)	$D_{1\%}$ or D_{max} mean and minimum and maximum and/or standard deviation (%)
Murray *et al*, 2016[11]	3D-CRT (APPA)	15 (1 ISRT plan)	Right breast	0·73 (0·17-4·5)	–	0 (0-19·59)	0 (0-9·28)	–
			Left Breast	2·15 (0·24-8·3)	–	6·67 (0-44·3)	4·29 (0-16·7)	–
Voong *et al*, 2014[15]	'Butterfly' IMRT vs 3D-CRT (APPA)	9 (1 Buttertfly IMRT and 1 3DCRT AP-PA planned per patient)	Right Breast	1·92 (APPA), 2·28 (IMRT)	–	7·5 (APPA), 13·7 (IMRT)	3·7 (APPA, 3·8 (IMRT)	–
			Left Breast	2·38 (APPA), 2·42 (IMRT)	–	8·4 (APPA), 11·2 (IMRT)	4·9 (APPA, 4 (IMRT)	–
Kriz *et al*, 2015[16]	APPA vs IMRT 5 field vs IMRT 7 field.	5 (12 plans per patient (3D CRT APPA fields, 5 or 7 field IMRT plans and Free breathing or DIBH scans)	Right Breast	0·57 ± 0·37 (DIBH, APPA), 0·77± 0·92 (non-DIBH APPA) 1·19 ± 0·52 (DIBH IMRT 5 field), 1·22 ± 1·08 (non- DIBH IMRT 5 field) 2·54 ± 0·94 (DIBH IMRT 7 field), 2·3 ± 1·53 (non- DIBH IMRT 7 field)	–	–	–	27·12 ± 8·65 (DIBH, APPA, D_{max}), 27·54 (non-DIBH, APPA, D_{max}) 19·33 ± 2·75 (DIBH, IMRT 5 Field, D_{max}), 20·11 ± 3·16 (non- DIBH IMRT 5 field, D_{max}) 15·86 ± 2·35 (DIBH IMRT 7 field D_{max}), 17± 4·0 (non- DIBH IMRT 7 field D_{max})
			Left breast	2·01 ± 3·03 (DIBH, APPA), 2·80 ± 3·98 (non-DIBH APPA) 2·44 ± 2·79 (DIBH IMRT 5 field), 2·82 ± 3·56 (non- DIBH IMRT 5 field) 3·23 ± 2·35 (DIBH IMRT 7 field) 3·38 ± 3·06 (non-DIBH IMRT 7 field)	–	–	–	30·26 ± 2·06 (DIBH, APPA, D_{max}), 25·42 ± 11·67 (non-DIBH, APPA, D_{max}) 24·12 ± 4·37 (DIBH, IMRT 5 Field, D_{max}), 22·65 ± 9·34 (non- DIBH IMRT 5 field, D_{max}) 19·54 ± 5·26 (DIBH IMRT 7 field, D_{max}), 19·65 ± 8·57 (non- DIBH IMRT 5 field, D_{max})
Edvarsson *et al*, 2019[17]	3D-CRT (APPA) vs VMAT vs IMPT	19, (6 plans per patient)	Right Breast	1·9 (0·4-8·5) (non-DIBH, 3D-CRT),2·3 (0·5-9·9) (DIBH, 3D-CRT) 1·4 (0·4-5·3) (non-DIBH, VMAT), 2·1 (0·4-5·1) (DIBH, VMAT)	–	–	–	–
			Left breast	2·1 (0·3-10) (non-DIBH, 3D-CRT), 1·6 (0·5-5·6) (DIBH, 3D-CRT) 2·2 (0·5-7) (non-DIBH, VMAT), 2·3 (0·5-5·3) (DIBH, VMAT)	–	–	–	–

Table 6. (*Continued*)

Filippi *et al*, 2015[18]	3D-CRT (APPA) vs VMAT	25 (2 plans per patient 1 3DCRT and 1 VMAT)	Combined breasts	1·02 ± 0·97 (3D-CRT), 0·74 ± 0·63 (VMAT)	3·47 ± 4·09 (3D-CRT), 5·40 ± 6·58 (VMAT)	–	–	–
Scorsetti *et al*, 2020[19]	VMAT vs IMPT	20 (1 plan each)	Combined breasts	4·7 ± 2·5 (VMAT)	–	–	–	20·6 ± 5·0 (VMAT) ($D_{1\%}$)
Audit Data	Fixed field and VMAT	23 (3 IMRT and 20 VMAT)	Right breast	4·077 (0·140 – 9·811)	35·841 (0 - 88·811)	30·617 (0 -85·624)	1·541 (0 -12·714)	14·799 (0·456 – 33·607) ($D_{1\%}$)
			Left breast	4·321 (0·160 - 8·815)	39·097 (0 -88·732)	33·691 (0 - 81·479)	1·644 (0 -9·871)	15·812 (0·495 – 30·199) ($D_{1\%}$)
			Combined breasts	4·201 (0·15 – 8·418)	37·587 (0 -84·258)	32·551 (0 – 78·0)	1·557 (0 – 6·849)	17·7 (0·478 - 33·175) ($D_{1\%}$)

low-dose bath from occurring, or had objectives in place to reduce dose to breast tissue with their multi-field IMRT or VMAT plans[15,17,23]. Differences in contouring technique used could also impact this as most studies did not mention the method they utilised. Differences were noted in this work between patients with breast contours already produced compared to ones outlined utilising the RTOG & ESTRO guidelines (Figure 7)[20,21].

Further work would be required to investigate the full clinical impact of the dosimetric differences noted between the data in this audit and other studies, which could be prudent for the younger patients within this group of patients. It has been suggested previously that for patients at the age of 20, 0·1Gy received to breast tissue can increase the lifetime risk of developing breast cancer by 0·4%[26]. Moreover, secondary breast cancers present the highest absolute excess risk of all secondary malignancies for women receiving supradiaphragmatic radiotherapy for Hodgkin's lymphoma according to epidemiological data[27].

It would be beneficial therefore to monitor breast dose in future for female patients receiving EBRT for mediastinal lymphoma and encompass dose to breast tissue in treatment planning algorithms. Due to the increased risk of secondary breast cancer and depending on other clinical factors patients who have received EBRT for mediastinal lymphoma could potentially be invited to begin breast screening process at an earlier age[14]. It is notable to mention that there did not appear to be clear differentiation when it came to why some patients had breast contouring and or optimisation objectives in place, as other patients with similar clinical attributes (such as age and stage) were not contoured or optimised with regard to breast dose in this audit. Position of the target volume in relation to breast tissue, however, may have played a role in some cases but not all patients without prior contours (Table 2).

Fundamentally, it is important to state that the risk of all secondary malignancies must be weighed against each other and against the risk of other conditions when considering patient treatment. As target delineation and delivery techniques change, doses received by OAR also change (Figure 1)[13,17,23–25]. The treatment method chosen and construction of the dose objective optimisation algorithms should be based on an individual patient case basis. This decision for each individual should therefore consider individual clinical factors such as gender, age and other comorbidities, which may influence risk of secondary malignancy, alongside position of OAR's in the treatment area[27].

A novel way to reduce the volume of breast tissue in field could be to utilise an angled board for immobilisation. This was not utilised in this cohort but has been used in previous studies that demonstrated reduced dose to breast tissue from treatment delivery by positioning breast tissue further inferiorly[15]. However, utilising such a method for treatment delivery for VMAT patients may induce some potential collision-related issues due to the extension of the patient's elbows vertically and laterally. Moreover, it has primarily been tested in conjunction with 'butterfly technique' IMRT, and therefore, it is difficult to determine the full extent of its sole impact from this data[15].

Unfortunately, there were a limited number of fixed-field IMRT patients that could be utilised to enable a more comprehensive comparison between the treatment delivery techniques utilised. Further audits in future may benefit from making a wider array of retrospective plans on a large cohort of patients to enable a more expansive comparison and enable greater testing of different fixed-field IMRT or VMAT variations

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to reduce dose to breast and other OAR and make results more generalisable with wider utility.

Conclusion

In conclusion, breast dose parameter values between patients in this study vary due to multiple factors. These include the treatment delivery method used and the position of the treatment field in relation to the location of breast tissue. Mean dose and $V_{4\%}$ and $V_{5\%}$ to breast tissue found in this study differ from that found in the literature, but this may be due to the choice of optimisation objectives at the planning stage and the contours utilised for the breast tissue. This study highlights the importance of accurate contouring and optimising breast tissue when possible. Further studies could be carried out to standardise some optimisation objectives for patients receiving radiotherapy for mediastinal lymphomas to determine to what extent breast dose could be minimised.

Competing interests. The authors declare none.

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Appendix

Appendix 1: shows all the data for the left breast for all patients

Patient number	V_{4Gy} (ratio of volume (%))	V_{5Gy} (ratio of volume (%))	V_{20Gy} (ratio of volume (%))	$D_{1\%}$ (Gy)	Mean dose (Gy)
1	0·000	0·000	0·000	1·000	0·427
2	23·014	18·890	0·134	13·339	2·313
3	80·500	66·294	0·780	19·558	7·299
4	49·814	40·701	2·008	23·069	5·951
5	0·900	0·784	0·278	3·456	0·444
6	63·362	50·618	0·001	16·472	5·852
7	56·405	47·622	9·871	30·199	7·356
8	59·899	48·731	0·359	18·762	6·298
9	68·831	59·332	1·712	21·604	6·864
10	3·020	1·867	0·000	6·428	0·869
11	41·012	37·343	2·866	23·982	5·031
12	35·257	31·433	2·210	21·717	4·968
13	26·947	17·036	0·000	8·012	2·656
14	49·133	41·735	0·491	18·995	5·795
15	0·000	0·000	0·000	0·495	0·160
16	39·865	37·563	1·008	20·004	5·207
17	58·713	54·743	0·646	18·063	5·708
18	85·245	79·660	39442 e-005	15·029	7·383
19	17·325	13·398	0·000	10·507	1·704
20	22·826	22·054	9·857	28·255	4·606
21	88·732	81·479	2·697	22·656	8·815
22	28·416	23·613	1·240	20·771	3·401
23	0·020	0·000	0·000	1·314	0·281

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Appendix 2: shows all the data for the right breast for all patients

Patient number	V_{4Gy} (ratio of volume (%))	V_{5Gy} (ratio of volume (%))	V_{20Gy} (ratio of volume (%))	$D_{1\%}$ (Gy)	Mean dose (Gy)
1	0·152	0·144	0·007	19·046	2·451
2	24·118	18·374	0·000	11·389	2·159
3	88·811	85·624	2·195	21·583	9·744
4	75·763	65·016	12·714	30·619	9·811
5	10·663	10·162	6·963	33·607	2·99
6	74·162	64·494	0·000	16·359	6·525
7	23·619	17·149	0·316	15·913	2·869
8	81·162	67·005	0·062	16·092	6·68
9	56·820	48·940	0·410	18·789	5·986
10	0·417	0·281	0·000	2·560	0·379
11	42·910	40·342	5·564	25·086	6·226
12	11·702	9·386	0·000	11·738	2·058
13	30·129	23·075	0·000	8·370	3·096
14	34·524	26·753	0·000	13·539	3·626
15	0·000	0·000	0·000	0·456	0·14
16	41·683	39·963	7·201	25·105	6·983
17	18·863	6·886	0·000	10·527	2·801
18	80·006	76·221	0·000	14·667	7·332
19	22·993	17·095	0·000	9·854	1·942
20	1·236	1·020	0·000	5·113	0·501
21	73·311	58·652	0·000	14·534	5·941
22	31·296	27·599	0·000	14·670	3·25
23	0·000	0·000	0·000	0·766	0·281

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Appendix 3: shows all the data for the combined breasts for all patients

Patient number	V_{4Gy} (ratio of volume (%))	V_{5Gy} (ratio of volume (%))	V_{20Gy} (ratio of volume (%))	$D_{1\%}$ (Gy)	Mean dose (Gy)
1	0·073	6·947	0·003	18·371	1·400
2	23·568	18·788	0·006	11·864	2·229
3	84·258	75·048	1·431	20·713	8·418
4	61·649	51·644	6·849	30·262	7·698
5	5·922	5·613	3·716	33·175	1·753
6	68·455	57·183	0·000	16·417	6·171
7	40·564	32·831	5·246	29·695	5·184
8	70·972	58·232	0·203	17·949	6·496
9	62·757	54·123	1·060	20·134	6·427
10	1·650	1·036	0·000	5·095	0·612
11	41·818	38·652	4·044	24·670	5·550
12	24·150	21·000	1·165	20·318	3·590
13	28·609	20·207	0·000	8·187	2·887
14	42·095	34·477	0·249	17·719	4·740
15	0·000	0·000	0·000	0·478	0·150
16	40·786	38·774	4·091	23·440	6·103
17	40·756	33·104	0·353	16·188	4·396
18	82·677	78·000	0·215	14·843	7·358
19	20·209	15·285	0·000	10·172	1·826
20	12·715	12·207	5·239	27·435	2·684
21	80·939	69·929	1·336	20·798	7·367
22	29·872	25·591	0·614	18·072	3·325
23	0·010	0·000	0·000	1·113	0·253

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