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Possibilities and limitations of left breast IMRT techniques in practice IMRT S&S versus VMAT

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ABSTRACT

Introduction: The purpose of this manuscript is to compare dosimetry differences based on two types of radiotherapy plans for postoperative left breast cancer. In particular, based on a clinical dosimetric study, intensity-modulated radiation therapy (IMRT) and volumetric-modulated Arc Therapy (VMAT) plans were implemented in 10 cases of postoperative left breast cancer patients and nodes.

Material and Methods: In our study, the prescribed dose was 50 Gy to the target volume delivered in 25 fractions of 2 Gy. The dose objectives at the PTV (Planning Target Volume) and the OAR (Organs at Risk) are detailed in Table 1. The main objective was to respect a good coverage of the target volume (PTV). For the contralateral lung, contralateral breast, and heart, the objective was to achieve the lowest possible dose.

Results: For target volume coverage (PTV): Table 1 and Table 1 show that all the dosimetric criteria are met regardless of the technique. The PTV volume receiving at least 95% of the prescribed dose is lower than 95% with a major contribution of the VMAT technique compared to the S&S IMRT technique of 2.6%. The maximum dose received by the PTV is lower in VMAT than in S&S IMRT by 0.4%. For the SROs: the result is similar in both techniques, however a decrease of 1.7% of the dose received by the homolateral lung receiving at least 20 Gy is noted in favor of the S&S IMRT technique (Table 2). The dose to the heart is generally higher with VMAT, with a maximum difference of 22.2% for the heart volume receiving at least 10 Gy. Regarding treatment time, it is reduced from 11 min with S&S IMRT to 2 min with VMAT.

Conclusions: We have shown that for the treatment of breast cancer, the VMAT technique offers better dose conformation at the PTV and lower peak doses compared to S&S IMRT, For the homolateral lung, contralateral breast, and healthy tissues, VMAT allows a decrease of the doses received compared to IMRT S&S but this is accompanied by an increase of the dose received by the heart for the volume of the heart receiving at least 10 Gy, this is also accompanied by a very significant reduction of the treatment time in favor of the VMAT technique.

Key words: Breast cancer, dosimetry, PTV, OAR, VMAT, IMRT

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INTRODUCTION

Radiation therapy has become one of the vital measures in the postoperative treatment of breast cancer. It is also the most important means of improving the rate of local tumor control, as well as reducing the complication of normal tissue. The scope of radiation therapy mainly covers the chest wall and lymph nodes at positions above and below the collarbone. The technology of radiation therapy is more complex, and to avoid overlap and omission of adjacent radiation, reducing radiation damage to normal tissues without missing the target area should be considered a basic requirement for radiation therapy [1].

The IMRT treatment technique has become a standard in many clinical locations including ORL and prostate cancers, and the use of IMRT in the particular case of breast irradiation is still widely discussed [2]. Discussions focus in particular on the long-term clinical effects.

The use of IMRT with stationary beams has been widely discussed in the literature and many authors have demonstrated its feasibility and even its dosimetry contribution compared to non-intensity-modulated techniques. This article aims to compare the dosimetry differences based on two types of radiotherapy plans for postoperative left breast cancer. In particular, based on a clinical dosimetry study, Intensity-Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) plans [3,4]. In 10 postoperative patients with left breast cancer and indication for irradiation, irradiation of the entire left mammary gland, the left Supra Clavicular (SC) area, and the left Internal Mammary Chain (IMC) was performed. The analysis focused on the evaluation of dose distributions, including the efficiency of the treatment plans. The analysis focused on the evaluation of dose distributions, including the efficiency of the treatment plans.

This paper aimed to compare the dosimetry parameters and to obtain the most superior radiotherapy technique, i.e., to obtain the optimal dosimetry distribution of the target and to minimize the dose delivered to the lung by designing three radiotherapy plans for a certain case.

MATERIALS AND METHODS

Dose description

Case selection:

The study was carried out in a random heterogeneous series of

10 patients of radiotherapy for breast cancer in our hospital in February 2017 and February 2020, treated by IMRT (Intensity Modulated Radiation Therapy (Step and Shoot (S&S)), and VMAT (Volumetric Modulated Arc Therapy), presenting carcinoma glandular breast with lymph node extension (sus clavicular) after lumpectomy, the dose prescription was 50 Gy to the target volume: PTV (Planning Target Volume) delivered in 25fractions of 2 Gy, 99% of the CTV is expected to receive at least 95% of the prescription dose (47.50Gy). The clinical constraints are as follows: VTC ≤ 107%, minimum dose ≥ 95%.

The dose objectives at the PTV and the Organ at Risk (OAR) are detailed in (Table 1). The main objective was to achieve good coverage of the Planning Target Volume (PTV). For the contralateral lung, contralateral breast, and heart, the objective was to achieve the lowest possible dose.

Patients were positioned supine on an inclined plane with their arms raised above their heads (Figure 1). Volume delineation was performed from Computed Tomographic (CT) images with a slice thickness of 3 mm taken in the treatment position according to the RTOG (Radiation Therapy Oncology Group) contouring recommendations.

The PTV corresponds to the left breast, the supraclavicular areas, and the MIC. The PTV is defined from the CTV with a 3D margin of 5 mm limited to the external contour. The defined SROs are homolateral lung, contralateral lung, heart, and contralateral breast.

Planning dosimetry

Two processing ballistics using 6 MV X-ray photon beams delivered on an Agility gas pedal with 160 MLC were compared: an IMRT S&S type ballistic and a VMAT type ballistic [5, 6]. The TPS used is MONACO (version 5.11.02) and the Monte Carlo algorithm for S&S ballistics uses 7 beams distributed between (350°, 310°, 135°, 0°, 45°, 90°, and 180°) [7]. In VMAT 2 arcs from 300° to 240° and from 240° to 300° depending on the minimum segment size of 6 cm^2 and 4 MU minimum per segment.

NB

The same constraints were used for both treatment techniques. All the treatment plans in this chapter were made by the same operator.

RESULTS

Distribution of the dose

Figure 2 shows that: the VMAT technique allows a better conformation of the doses to the target volume: PTV (red arrows

Tab. 1. Dose targets defined for IMRT S&S and VMAT

Structure name	Cost function	Threshold (gy)	Iso constraint
Ptv50	Target penalty		48
	Quadratic overdose	52	0.02
Lung left	Parallel	5	60
	Parallel	20	30
Lung right	Parallel	5	6
	Parallel	4	10
Oesophageal	Quadratic overdose	47	0.08
Heart		8	0.08
Brest right	Parallel	5	40
	Parallel	25	10
Spinal cord	Serial		20
Spinal cord PRV	Serial		23
Body	Quadratic overdose	43.5	0.1
Body	Quadratic overdose	40.5	0.6

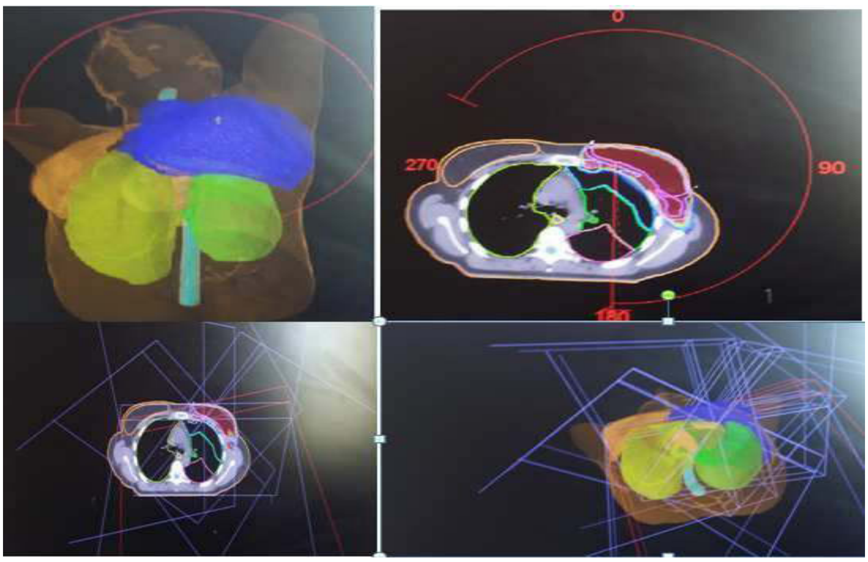

Fig. 1. Representation of the treatment ballistics used (PTV=sein, CMI, axilosuc er susclav (left)) for IMRT S&S (bottom) and VMAT (top) ballistics

in the clinical case), the volume of the PTV receiving doses greater than or equal to 104% of the prescribed dose (52 Gy) is lower with VMAT than with S&S IMRT. Figure 3 represents the HDV obtained on the PTV and the main OARs. It can be seen that the two curves differ between the two techniques: the curves representing the doses received by the PTV, the heart and the contralateral breast in VMAT are above those obtained in S&S IMRT, and the curve representing the dose received by the homolateral lung is below that obtained in S&S for doses higher than 5 Gy, we also notice that the curve representing the dose received by the heart in VMAT is above that obtained in S&S IMRT and the curve representing the dose received by the contralateral lung in VMAT is below that obtained in S&S IMRT.

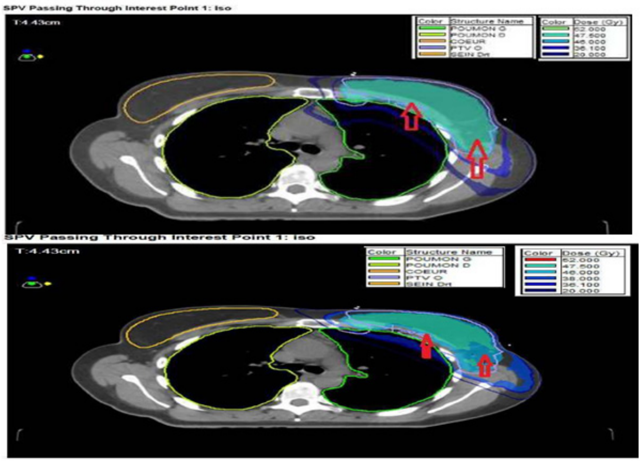

Fig. 2. Dose distribution in axial planes obtained in S&S IMRT (bottom) and VMAT (top). PTVs are shown in blue

For the PTV, the table shows that all dosimetric criteria are respected whatever the technique and also are respected for the OAR. The volume of PTV receiving at least 95% of the prescribed dose is less than 95% with a major contribution of VMAT compared to IMRT S&S is 0.97%. The maximum dose received by PTV is lower in VMAT than in IMRT S&S by 0.4%. Regarding SROs, Table 2 shows that S&S IMRT allows a decrease in the dose received by the homolateral lung with a decrease of 1.7% for the lung volume receiving at least 20 Gy. The dose to the heart is generally higher in VMAT, with a maximum difference of 3.32% for the heart volume receiving at least 5 Gy.

The efficiency of the treatment plan

Treatment time is reduced from 11 min in S&S IMRT to 2 min in VMAT.

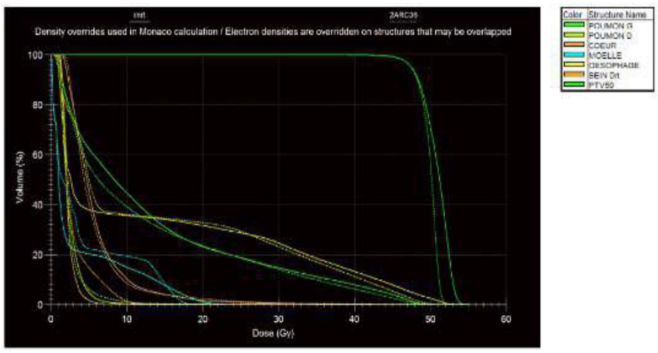

Fig. 3. HDV obtained in S&S IMRT (solid line) and VMAT (dashed line)

Tab. 2. Dosimetric comparison between S&S and VMAT plans, values obtained on two patients for mammary gland irradiation

Techniques		VMAT	SS	Relative gap(%) ((XVMAT-XSS)/XSS) 100
PTV 50		PTV = (Breast left, Susclave and CMI) + 5mm		
HI		1.12 ± 0.1	1.06 ± 0.09	
D95 % (GY)		46 .85 ± 1.22	47 .3 ± 1.97	0.0097
D98 % (GY)		44 .95 ± 1.87	45 .85 ± 1.92	0.02
D2% (GY)		53.13 ± 1.22	52.6 ± 1.08	0.01
Dmean % (Gy)		50.83 ± 1 .6	59.98 ± 0.86	0.003
OAR Technical	**Techniques**	**VMAT**	**SS**	**P value**
Spinal cord	D2%(Gy)	16 ± 1.429	17 ± 2.887	0.7967
	Dmean(Gy)	19.85 ± 1.75	21.01 ± 2.77	0.9771
PRV Spinal Cord	D2 % (Gy)	18.17 ± 1.429	20.6 ± 1.887	0.7967
	Dmean (Gy)	22.85 ± 2375	24.01 ± 2.77	0.9771
Infected lung	Dmean (Gy)	13.11 ± 3.669	14.62 ± 3.373	0.901
	V5 (Gy) (%)	53.75 ±3.05	60.27 ± 3.08	0.952
	V10 Gy (%)	36.6 ± 3.553	42.56 ± 4.545	0.822
	V20 Gy (%)	22.57 ± 4.932	24.52 ± 4.884	0.715
	V30 Gy (%)	13.53 ± 2.877	15.72 ± 2.424	0.523
Contralateral lung	Dmean (Gy)	2.11 ± 1.669	3.62 ± 1.373	0.901
	V5 (Gy) (%)	3.75 ±1.05	2.27 ± 1.08	0.952
	V10 Gy (%)	1.06 ± 1.553	0.56 ± 0.545	0.822
Contralateral Breast	Dmean (Gy)	3.11 ± 1.09	2.62 ± 1.03	0.901
Heart	V5 (Gy) (%)	33.75 ±2.05	36.27 ± 2.08	0.952
	V10 Gy (%)	14.06 ± 1.553	12.56 ± 2.545	0.822
	V20 Gy (%)	7.06 ± 1.553	9.56 ± 2.545	0.622
	V30 Gy (%)	5.06 ± 1.553	8.56 ± 2.545	0.722
	Dmean (Gy)	7.06 ± 1.553	8.56 ± 2.545	0.622

DISCUSSION

The comparison made in this study suggests a better dose conformation to the PTV in VMAT technique compared to the IMRT S&S technique [8,9]. While the dose to the OARs in the two planes was similar, the volumes in the IMRT and VMAT planes become almost similar from 150 Gy onwards, while the doses to the homolateral lung, contralateral breast, and other healthy tissues except the heart are independent of the technique used [8,10].

Concerning the study of the dose received by OARs located at a distance from the treated area (lens, gonad, and thyroid): no difference (difference less than or equal to 1 cGy) was measured between the two techniques. It is important to emphasize that the evaluation of low doses and the associated risk is very important in the case of breast cancer treatment in women who are sometimes young, given their increasingly long survival [8,10,11].

In this study, the dose delivery time in VMAT was divided by 3.9 compared to that in IMRT S&S. Treatment times for VMAT reported in the literature range from 1.2 min to 4 min compared to 1.2 min to 3 min in our study. The limitation of treatment time is essential in the case of breast cancer treatment. Indeed, the position, on an inclined plane with the arms raised, is often uncomfortable for the patients, which can increase the risk of intra-fraction movements [12].

In addition, a major problem in the context of irradiation is the consideration of the respiratory motion. In the current practice, simple solutions have been developed for IMRT treatment by stationary beams according to two approaches: the first one consists of the inclusion in the optimization process of a virtual extension of the area to be treated beyond the skin [13], the second approach consists in a minimal angulation of the inclined plane to be able to perform CBCT (Cone Beam Computed Tomography).

Finally, to establish more generalizable results, an increase in both the number of patients and the clinical scenarios studied is essential.

CONCLUSION

We have shown that for the treatment of left breast cancers, the VMAT technique offers a better dose conformation at the PTV as well as lower peak doses compared to S&S IMRT. For the homolateral lung, contralateral breast, and healthy tissues, VMAT allows a decrease in the dose received compared to S&S IMRT but this is accompanied by an increase in the dose received by the heart. There is no difference between the two techniques regarding the doses received by organs outside the treatment field. We also demonstrated the potential of VMAT to limit treatment delivery time to 3 min which would allow for better treatment reproducibility. Despite this theoretical advantage of VMAT over IMRT S&S for the treatment of left breast cancer, particular attention must be paid to respect the dose objectives, in particular the coverage of the target volume whatever the technique used.

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