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Knowledge-based RapidPlan Model for Breast using RapidArc

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INTRODUCTION

Breast treatment planning using with RapidArc require long planning time and the results depends significantly on user´s experience. A way to deal with these issues is to use knowledge-based methods for treatment planning which is becoming increasingly common. RapidPlan is a knowledge-based tool integrated in Eclipse v.15.5 planning system (Varian Medical System, Palo Alto, USA), which uses existing patient plans information (dose and anatomy) to estimate dose distributions on new plans (1).

AIM

To create and validate RapidPlan models for right and left breast using RapidArc in 20 fractions.

METHOD

100 breast RapidArc plans were selected to create two RapidPlan models (breast_left and breast_right). The plans were generated on Eclipse v15.5 (Varian) with 6MV of a Novalis Tx (Varian - BrainLAB) equipped with a high resolution multileaf, Figure 1. VMAT planning was based on the planning strategy presented by G.Nicolini et al (2), which consists of CT image duplication (original CT and modified CT). Both sets of images share the same planning structures, adding two planning structures to the modified CT: ring (structure for reduction of the dose to the contralateral breast and lung) and surface (structure for expansion of the fluence per motion 12mm outside the external contour), Figure 2. Photon optimization (PO) inverse planning algorithm was used with dose-volume constraints, as shown in Table 1. Once the inverse planning was finished, the plan was copied on the original CT where the CTVs and PTVs were cropped 5mm inside the external contour, (Figure 3). Treatment planning criteria were based on the publication by Zunino et al (3). Dose calculation was performed using a 2.5mm grid size with Anisotropic Analytical Algorithm (AAA) algorithm. The models were evaluated on the basis of goodness-of-fit statistics using the coefficients of determination (R^2: between 0 and 1, 1 indicating the best fit) and Chi-square (X^2: near 1, the best) test and the goodness-of-estimation statistics through the mean square error (MSE: close to 0, the best)(1). Geometric and dosimetric outliers were identified and removed from the models using statistical evaluation metrics such as Cook´s distance (CD), modified Z-score (mZ), studentized residual (SR) and areal difference of estimate (dA), and DVH, in-field DVH, regression and residual plots (1). For validation, 20 plans that integrate the models and 20 plans that do not were optimized with RapidPlan (close and open validation). Dosimetric parameters of interest were used to compare plans for heart, homolateral lung, contralateral lung and contralateral breast using the two-tailed Student test with significance level being 0.05 (4).

Figure 1. Novalis Tx

Volume	Restriction
zPTV_High_5600!	D95% > 53.2Gy
	D2% < 59.9Gy
zPTV_Mid_4600!	D95% > 43.7Gy
zPTV_Low_4300!	D95% > 40.9Gy
Spinal cord	D_{max} <= 3.5Gy
Homolateral lung	V10Gy < 50%
	V20Gy <= 10%
	V40Gy <= 3%
Contralateral lung	V5Gy < 10%
	V10Gy < 8%
Heart	D_{mean} <= 5Gy (breast left)
	D_{mean} <= 1.5Gy (breast right)
Liver	V20Gy < 20%
Contralateral breast	D_{max} <= 10Gy
	D_{max} <= 2Gy

Table 1. Dose-volume constraints for breast RapidArc

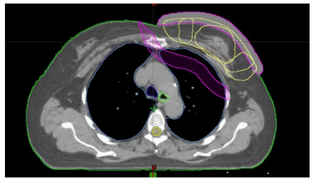

Figure 2. Auxiliary structures: Ring and surface on the modified CT

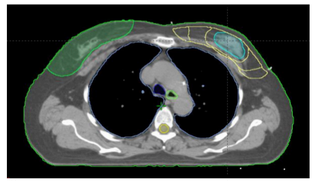

Figure 3. PTVs cropped from external contour on original CT

RESULTS

No over adjustment was produced in either of the generated models. For the most important OARs, the highest R^2 values of 0.510 and of 0.602 were for contralateral lung in the RapidPlan breast_right, and for the heart in the RapidPlan breast_left respectively. The lowest X^2 values were for the contralateral breast in the RapidPlan breast_right and for the heart in the RapidPlan breast_left, 1.021 and 1.026, respectively. Regarding the estimation power of the models, unfavorable values were not obtained (Tables 2 and 3). Figures 4a)-f) show the graphs resulting from in- field DVH, regression and residual for the heart in RapidPlan breast_right and RapidPlan breast_left respectively; Figures 5a)-f) show the graphs for the homolateral lung. These graphics illustrate the absence of outliers and the estimation ability of the model is good. Tables 4 to 7 summarize average values for parameters selected from open and closed validation. For closed validation significant differences were found in model breast_right for homolateral lung in favor of manual plans (all p <= 0.001) and for model breast_left for heart in favor of RapidPlan plans (all p < = 0.04) and homolateral lung in favor of manual plans (all p <= 0.022). For open validation in both models no statistically significant differences were obtained. Dose distribution comparison between Manual Plan and RapidPlan Plan for a plan in open validation are show In Figure 6, a) for breast right and b) for breast left.

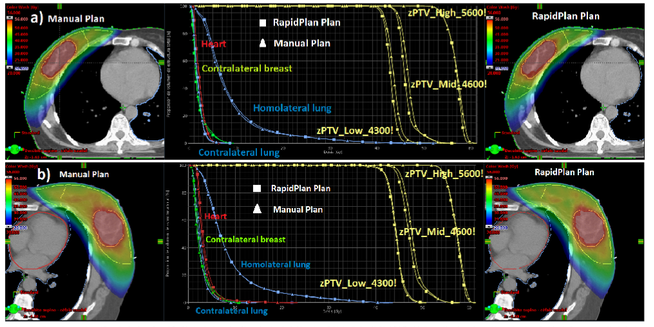

Figure 6. Dose distribution comparison between Manual Plan and RapidPlan Plan for a plan in open validation : a) for breast right and b) for breast left

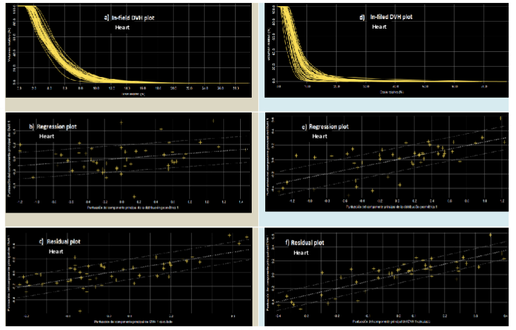

Figure 4. In-field DVH, regression and residual for heart in RapidPlan breast_right (a-c) and RapidPlan breast_left (d-f)

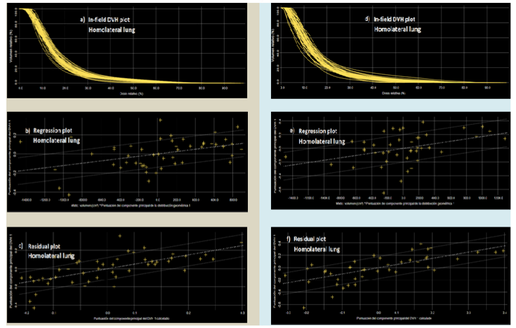

Figure 5. In-field DVH, regression and residual for lung in RapidPlan breast_right (a-c) and RapidPlan breast_left (d-f)

Structure	R^2	X^2	MSE
Heart	0.602	1.026	0.01
Spinal cord	0.396	1.074	0.14
Right lung	0.297	1.044	0
Left lung	0.410	1.084	0.05
Right breast	0.210	1.065	0.05

Table 2. R^2, X^2 and MSE results for RapidPlan breast_left

Structure	R^2	X^2	MSE
Heart	0.470	1.094	0.05
Liver	0.736	1.060	0.04
Spinal cord	0.319	1.081	0.16
Right lung	0.410	1.058	0.05
Left lung	0.510	1.084	0
Left breast	0.086	1.021	0.04

Table 3. R^2, X^2 and MSE results for RapidPlan breast_right

Structure	Parameter	MP	RP	p value
zPTV_High_5600!	D95%[Gy]	54.6 ± 0.4	54.4 ± 0.3	0.066
	D2%[Gy]	60.2 ± 0.7	59.8 ± 0.4	0.055
zPTV_Mid_4600!	D95%[Gy]	44.2 ± 0.4	44.7 ± 0.4	0.007
zPTV_Low_4300!	D95%[Gy]	42.1 ± 0.4	41.9 ± 0.3	0.154
Heart	D8%[Gy]	4.7 ± 0.5	4.8 ± 0.6	0.718
	Mean[Gy]	2.4 ± 0.1	2.4 ± 0.3	0.907
Spinal cord	Max[Gy]	3.8 ± 0.2	4.0 ± 0.5	0.245
Left lung	D20%[Gy]	3.0 ± 0.4	2.8 ± 0.2	0.131
	D10%[Gy]	3.9 ± 0.6	3.7 ± 0.4	0.386
Right lung	D50%[Gy]	6.8 ± 0.3	7.1 ± 0.4	0.001
	D20%[Gy]	11.7 ± 0.6	12.1 ± 0.6	0.001
	D10%[Gy]	15.8 ± 0.9	16.5 ± 1.1	< 0.001
Left breast	Max[Gy]	8.9 ± 1.6	8.6 ± 2.0	0.410
	Mean[Gy]	2.1 ± 0.2	2.1 ± 0.1	0.578

Table 4. Closed validation for RapidPlan breast_right (MP: Manual plan, RP: RapidPlan)

Structure	Parameter	MP	RP	p value
zPTV_High_5600!	D95%[Gy]	55.1 ± 0.6	54.5 ± 0.4	0.013
	D2%[Gy]	60.1 ± 0.9	60.0 ± 0.5	0.769
zPTV_Mid_4600!	D95%[Gy]	44.6 ± 0.5	45.8 ± 0.8	< 0.001
zPTV_Low_4300!	D95%[Gy]	42.1 ± 0.5	42.9 ± 0.7	0.006
Heart	D8%[Gy]	5.8 ± 1.2	5.0 ± 0.6	0.040
	Mean[Gy]	3.4 ± 0.5	3.1 ± 0.4	0.019
Spinal cord	Max[Gy]	4.2 ± 0.6	3.9 ± 0.3	0.126
Left lung	D50%[Gy]	5.9 ± 1.1	6.4 ± 0.7	0.006
	D20%[Gy]	11.0 ± 1.2	12.0 ± 0.7	0.022
	D10%[Gy]	15.8 ± 1.4	17.0 ± 1.5	0.015
Right lung	D20%[Gy]	3.7 ± 0.4	3.5 ± 0.3	0.118
	D10%[Gy]	4.8 ± 0.6	4.9 ± 0.8	0.677
Right breast	Max[Gy]	8.6 ± 1.7	11.1 ± 1.4	0.006
	Mean[Gy]	2.2 ± 0.3	2.4 ± 0.1	0.776

Table 5. Closed validation for RapidPlan breast_left (MP: Manual plan, RP: RapidPlan)

Structure	Parameter	MP	RP	p value
zPTV_High_5600!	D95%[Gy]	54.5 ± 0.7	54.5 ± 0.7	0.161
	D2%[Gy]	60.1 ± 0.5	59.8 ± 0.8	0.244
zPTV_Mid_4600!	D95%[Gy]	44.6 ± 0.7	44.4 ± 0.6	0.356
zPTV_Low_4300!	D95%[Gy]	41.9 ± 0.6	41.5 ± 0.6	0.059
Heart	D8%[Gy]	2.5 ± 0.5	2.7 ± 0.5	0.467
	Mean[Gy]	1.5 ± 0.3	1.6 ± 0.3	0.582
Spinal cord	Max[Gy]	3.7 ± 0.5	4.0 ± 0.4	0.117
Left lung	D20%[Gy]	2.9 ± 0.3	2.7 ± 0.3	0.124
	D10%[Gy]	3.8 ± 0.6	3.6 ± 0.7	0.188
Right lung	D50%[Gy]	6.9 ± 0.7	7.1 ± 0.4	0.581
	D20%[Gy]	12.3 ± 1.7	12.1 ± 1.2	0.575
	D10%[Gy]	17.2 ± 2.3	17.1 ± 1.9	0.864
Left breast	Max[Gy]	9.5 ± 2.0	10.0 ± 2.2	0.078
	Mean[Gy]	2.4 ± 0.4	2.2 ± 0.3	0.207

Table 6. Open validation for RapidPlan breast_right (MP: Manual plan, RP: RapidPlan)

Structure	Parameter	MP	RP	p value
zPTV_High_5600!	D95%[Gy]	54.6 ± 0.7	54.6 ± 0.7	0.176
	D2%[Gy]	60.0 ± 0.4	60.0 ± 0.4	0.593
zPTV_Mid_4600!	D95%[Gy]	44.8 ± 0.4	44.6 ± 0.5	0.071
zPTV_Low_4300!	D95%[Gy]	42.1 ± 0.4	42.0 ± 0.5	0.480
Heart	D8%[Gy]	5.1 ± 1.0	4.8 ± 0.8	0.433
	Mean[Gy]	2.8 ± 0.6	2.7 ± 0.5	0.410
Spinal cord	Max[Gy]	3.6 ± 0.4	3.8 ± 0.4	0.323
Left lung	D50%[Gy]	5.9 ± 0.8	6.0 ± 0.6	0.799
	D20%[Gy]	11.5 ± 1.5	11.6 ± 1.2	0.828
	D10%[Gy]	16.2 ± 2.2	16.1 ± 1.9	0.686
Right lung	D20%[Gy]	3.3 ± 0.5	3.5 ± 0.5	0.003
	D10%[Gy]	4.4 ± 0.7	4.8 ± 0.7	0.003
Right breast	Max[Gy]	9.7 ± 2.7	10.0 ± 2.5	0.441
	Mean[Gy]	2.2 ± 0.3	2.3 ± 0.3	0.156

Table 7. Open validation for RapidPlan breast_left (MP: Manual plan, RP: RapidPlan)

CONCLUSIONS

Two RapidPlan models for RapidArc breast were successfully implemented. The use of RapidPlan models has the potential to improve the efficiency of the treatment planning process while ensuring that high quality plans are developed.

REFERENCES

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(3) Zunino, S., et al. "Breast Sub-Volumes: Preliminary Results of a New Concept to Gradually decrease the Dose from the Tumor Bed to the Peripheral Breast Using Simplified IMRT". Global Journal of Breast Cancer Research, 2015, 3, 27-32.
(4) Fogliata, A., et al. "RapidPlan Knowledge Based Planning: Iterative Learning Process and Model Ability to Steer Planning Strategies." *Radiation Oncology*, vol. 14, no. 1, 2019.