DVH parameters and optimization objectives were extracted from archived DVH reports. Data were analysed in SPSS.

Results

In 10.7% (n=19) of cases the auto-plan was directly accepted for treatment. In 46.9% (n=83) of cases, MUs were scaled before accepting the auto-plan. In 40.1% (n=71), the auto-plan was optimised further. In 2.3% (n=4) of all cases, the auto-plan was rejected entirely and a new plan was made manually. We could identify the following reasons for manual adaptations:

- *Bowel loop:* 14.7% of plans (n=26), a bowel loop was near the PTV. In 4 cases MU were scaled and 22 cases were optimised further.
- *Target coverage:* Upscaling of MUs (n=43) is done to improve target coverage. These auto-plans had a mean $V_{95\%}$ of 98.87±1.12%, upscaling resulted in a mean $V_{95\%}$ of 99.41±0.25% ($p<0.001$).
- *Hot or cold spots:* Downscaling of MUs (n=40) is mainly done to reduce the high dose volume. Before downscaling, auto-plans had a $V_{103\%}$ of 1.11±1.39%, downscaling resulted in a $V_{103\%}$ of 0.48±0.62% (p=0.002). In 22 cases additional objectives were required to counteract hot or cold spots in the plan.

Figure 1 shows PTV coverage of the auto-plan vs the clinical plan and denotes the reason for manual adaptation. These adaptations had no significant effect OAR mean dose (rectum, anal sphincter) ($p>0.141$). All manual plans were made due to the presence of a hip prosthesis or bowel loop.

Conclusion

Although, clinical plans were based on the auto-plan in 97.7% of cases, the direct acceptance rate of auto-plans, including a post-script for fine tuning, was low at 10.2%. Rescaling of MU's was the most performed adaptation, which is easily automated by adding an auto-prescribe step. Overall, the effects of plan adaptations were small and might not have been clinically relevant. These data give rise to further discussion between physicists, physicians and RTTs to provide inside into what manual adaptations would be clinically relevant. Development of automated decisions tools to identify non-optimal treatment plans may be of great value for improvement of auto-planning practice.

OC-0182 Automated (non-coplanar) beam selection for IMRT in young female lymphoma patients reduces OAR doses

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Purpose or Objective

There are as many variations in tumor location, shape and size in lymphoma patients, as in radiotherapy (RT) techniques clinically applied (Maraldo et al. Int J Radiat Oncol Biol Phys 2015, 92(1):151). This population might therefore benefit from patient-specific, computer selection of beam angles. We investigated the potential dosimetric advantages of automated beam angle selection (BAS), in both coplanar (CP) and non-coplanar (NCP) settings, for young mediastinal lymphoma females, with or without involvement of supraclavicular or axillar nodes, including bulky disease.

Material and Methods

A total of 23 patients were included with mediastinal lymphoma disease (PTV sizes: 97cc – 1308cc, median: 495cc; median age: 26 years). Erasmus-iCycle was used to automatically generate treatment plans with/without BAS. The applied optimization protocol as defined by the 'wish-list' containing the planning hard constraints and prioritized objectives was tailored to RT of young females, where late toxicity to breasts, heart, and lungs are of great concern. The prescription dose was 30 Gy. Coplanar (BAS-CP) and fully non-coplanar (BAS-fNCP) plans were generated (min. beams=5, max.=15), for couch and gantry angles that are possible at the treatment unit. The optimal number of beams and the most common couch positions were investigated. For a subgroup of 16 patients, CP IMRT plans were generated with the clinically used beam angles, typically 5-7 beams manually selected from (and close to) anterior and posterior directions (CLIN-CP).

Results

BAS-CP plans with the same number of beams as the CLIN-CP plans resulted in similar OAR doses for the same PTV coverage (V95%=98%), but lower integral patient dose (V15Gy, V20Gy). The addition of CP beams (10 vs 5) resulted in (1) improvements in heart and lung Dmean for all patients, on average -0.7 Gy (max. -2.4 Gy), and -0.8 Gy (max. -1.6 Gy) improvement respectively; (2) decrease in lung V5Gy by more than 5% for 6 patients; and (3) a decrease in patients with breast Dmean over 2 Gy (5 vs 8). BAS-fNCP plans showed further reductions in OAR doses relative to BAS-CP: (1) the average lung and heart Dmean were lower by 0.5 Gy and 0.7 Gy, respectively; (2) a decrease in heart Dmean >1 Gy was found for 8 patients (max. 2.4 Gy); (3) a decrease in lung Dmean ≥1 Gy for 5 patients (max. 1.9 Gy), along with reductions in lung V5Gy ranging from 6–20%, and (4) less patients with breast Dmean over 2 Gy (3 vs 5). BAS-fNCP with 15 beams resulted in the largest differences with CLIN-CP, with improvements (mean±SD) of -1.3±1.2 Gy (max. -3.6 Gy) and -1.2±0.7 Gy (max. -3.0 Gy) for the heart and lung Dmean, respectively, and 5% lower lung V5Gy on average (max. 20%), while the Dmean on both breasts was <2 Gy for 15/16 for BAS-fNCP, compared to 13/16 with CLIN-CP.

	N=16 patients			N=23 patients			N=23 patients		
	CLIN-CP	BAS-fNCP$_{15beams}$		BAS-CP$_{5beams}$	BAS-CP$_{10beams}$		BAS-CP$_{15beams}$	BAS-fNCP$_{15beams}$	
	Mean±SD	Mean±SD	*p*	Mean±SD	Mean±SD	*p*	Mean±SD	Mean±SD	*p*
Heart									
Dmean [Gy]	4.4±5.2	3.1±4.2	<0.001	5.5±5.6	4.8±5.1	<0.001	4.6±5.1	3.9±4.7	<0.001
Lungs									
Dmean [Gy]	6.9±3.2	5.7±2.8	<0.001	7.6±3.2	6.9±2.9	<0.001	6.7±2.8	6.2±2.8	<0.001
V5Gy [%]	35±15	29±14	<0.001	41±17	37±16	0.001	37±16	33±15	0.001
Right breast									
Dmean [Gy]	0.9±0.7	0.8±0.5	NS	1.6±1.3	1.3±1.1	0.006	1.3±1.1	1.1±0.9	0.003
Left breast									
Dmean [Gy]	1.2±0.9	1.0±0.7	NS	1.4±1.1	1.4±1.1	NS	1.4±1.1	1.2±1.1	0.01

Table. Dose metrics.
All plans normalized to PTV V95%=98%.
p values (Wilcoxon test) are given for the differences between the two plans on the left-hand side.
Statistically non-significant (NS): p > 0.05.

Conclusion

We successfully implemented automated planning for young female lymphoma patients. Patient-specific computer optimization of (non-coplanar) beam angles can significantly reduce doses to breast, lung and heart.

OC-0183 Multi-Institutional Evaluation of a Pareto Navigation Guided Automated Planning Solution

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Purpose or Objective

Automated treatment planning (AP) and multi-criteria optimization via Pareto navigation (MCO) are two important innovations within the field of radiotherapy

treatment planning, with AP promising step changes in planning efficiency, and MCO enabling a more intuitive exploration of competing trade-offs. Recently a novel fully automated solution (EdgeVcc), which incorporates MCO within the calibration process, has been developed in RayStation (RaySearch Laboratories, Stockholm, Sweden) using scripting and validated in a single institutional setting. This work presents results from a further study across two independent centers for prostate cancer and aims to evaluate the use of MCO in propagating automated solutions across institutions with differing planning techniques or aims.

Material and Methods

For each institution (I_A and I_B) 30 previously treated prostate cancer patients were randomly allocated into a calibration cohort (n=10) and validation cohort (n=20). A set of planning goals, comprising of constraints and trade-offs, were defined and the MCO guided calibration process performed on a single calibration patient. MCO enabled differing treatment options to be intuitively explored, with competing trade-offs balanced according to the institutional planning aims. The resultant automated solution was tested across all calibration patients, with planning goals or trade-off balancing (via MCO) refined as required. Following successful calibration, a single automated plan ($VMAT_{Auto}$) was generated fully autonomously for each patient in the validation cohort. $VMAT_{Auto}$ plan quality was compared against the previously treated clinical plan ($VMAT_{Clinical}$) quantitatively, using a range of DVH metrics, and qualitatively through blind review by an oncologist and dosimetrist pair based at the local institution.

Results

A summary of the quantitative and qualitative results is provided in Table 1, with example dose distributions provided in Figure 1. For both institutions automation led to statistically significant improvements across the majority of rectal dose metrics, and D98% for the low and intermediate (I_A only) dose PTVs. $VMAT_{Auto}$ reduced bladder doses for I_B but for I_A they were increased. There were also small differences in the conformality indices and D2% between the two techniques, with $VMAT_{Clinical}$ performing slightly better, however this did not prevent both institutions from demonstrating a clear preference towards $VMAT_{Auto}$. Across all study patients 92.5% and 95% of $VMAT_{Auto}$ plans were considered equivalent or better than $VMAT_{Clinical}$ by the reviewing oncologist and dosimetrist respectively.

Table 1 Dosimetric comparision of $VMAT_{Auto}$ and $VMAT_{Clinical}$ for institution A and B (mean ± standard deviation). Results in bold indicate statistically significant differences (p<=0.05). Dosimetrist plan rankings are provided in parenthesis where preference differs from the oncologist

		Institution A		Institution B	
	Metric	$VMAT_{Auto}$	$VMAT_{Clinical}$	$VMAT_{Auto}$	$VMAT_{Clinical}$
PTV60	D98% (Gy)	**58.8 ± 0.1**	**59.0 ± 0.2**	**59.0 ± 0.1**	**58.7 ± 0.3**
	D2% (Gy)	**61.3 ± 0.1**	**60.8 ± 0.3**	61.0 ± 0.1	60.9 ± 0.4
	CI	0.56 ± 0.03	0.57 ± 0.04	**0.60 ± 0.03**	**0.64 ± 0.04**
PTV57.5	D98% (Gy)	55.9 ± 0.1	55.5 ± 0.9	**55.7 ± 0.2**	**54.7 ± 0.2**
	D2% (Gy)	**59.9 ± 0.1**	**60.2 ± 0.4**	60.3 ± 0.13	60.1 ± 0.5
	CI	**0.56 ± 0.06**	**0.59 ± 0.09**	0.55 ± 0.07	0.55 ± 0.08
PTV48	D98% (Gy)	**46.5 ± 0.3**	**45.8 ± 0.5**	**46.5 ± 0.2**	**45.5 ± 0.7**
	D2% (Gy)	57.0 ± 0.4	57.3 ± 0.9	**57.2 ± 0.3**	**56.5 ± 0.9**
	CI	**0.71 ± 0.02**	**0.75 ± 0.03**	0.70 ± 0.02	0.68 ± 0.04
Rectum	V24.3Gy (%)	**47.2 ± 13.0**	**62.3 ± 10.4**	**51.9 ± 11.6**	**60.3 ± 10.3**
	V40.5Gy (%)	**23.0 ± 9.1**	**26.5 ± 8.9**	**28.2 ± 8.8**	**29.7 ± 8.4**
	V52.7Gy (%)	9.5 ± 2.8	10.4 ± 3.8	10.1 ± 3.0	10.4 ± 3.9
	V60.0Gy (%)	**0.0 ± 0.0**	**0.3 ± 0.4**	**0.0 ± 0.1**	**0.3 ± 0.4**
	DMean (Gy)	**25.3 ± 4.7**	**29.0 ± 4.3**	**28.3 ± 4.1**	**30.1 ± 3.3**
Bladder	V40.5Gy (%)	**25.3 ± 14.7**	**24.0 ± 14.1**	**15.5 ± 7.4**	**16.4 ± 7.4**
	V60.0Gy (%)	1.8 ± 1.6	2.3 ± 1.7	1.2 ± 0.9	1.1 ± 0.8
	DMean (Gy)	24.3 ± 9.3	23.8 ± 9.2	**17.4 ± 5.3**	**18.7 ± 5.7**
Beam MU	MU	**636.5 ± 35.8**	**570.0 ± 36.7**	**739 ± 53**	**640 ± 118**
Plan Ranking vs $VMAT_{Clinical}$	Plans Superior (%)	90%		65%	
	Plans Equivalent (%)	0%		30% (35%)	
	Plans Inferior (%)	10%		5% (0%)	

PTV suffix indicates prescribed dose in Gy

CI: Paddicks Conformity Index for the specified PTV.

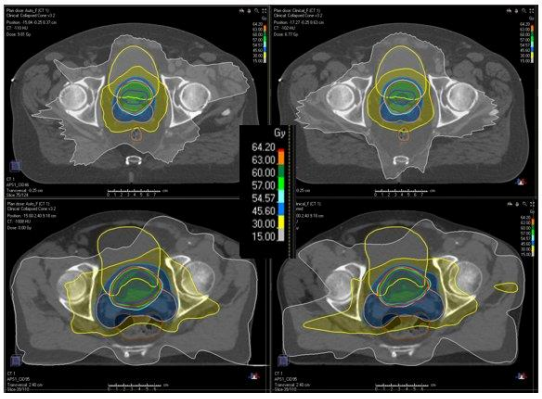

Figure 1: Example dose distributions for institution A (top) and institution B (bottom) with $VMAT_{Auto}$ to the left and $VMAT_{Clinical}$ to the right

Conclusion

An MCO guided automated planning solution has been successfully validated against clinical practice in two independent institutions. The novel calibration process enabled intuitive adaptation of automated protocols to an institution's individual planning aims and yielded plans more congruent with the oncologist's clinical preference.

OC-0184 Predicting patient specific treatment planning Pareto fronts based on anatomy only

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Purpose or Objective

Automated treatment planning is an effective solution to generate fast, consistent treatment plans on the Pareto front (PF). It leads to a single treatment plan that has a specific trade-off between conflicting objectives. Upfront knowledge of the PF will allow to direct automated planning to a plan with a non-standard trade-off tailored to the individual patient and helps with configuring new automated planning solutions. However, even with automatic planning systems a quick upfront estimate of the PF for every patient is clinically infeasible due to the large number of plans that needs to be generated. Since the PF in principle depends only on patient anatomy and delivery system, the purpose of this work is to demonstrate the feasibility of predicting the patient specific PF based only on patient anatomy since only the anatomy varies from patient to patient.

Material and Methods

The inhouse TPS Erasmus-iCycle was used to generate 42 treatment plans for 115 prostate patients delivering 60Gy in 20 fractions (4830 treatment plans in total). Erasmus-iCycle uses a wish list of prioritized objectives and per definition generates plans on the PF. Here 42 different wish lists were used to create treatment plans on the PF spanned by rectum Dmean, the homogeneity (parameterized by PTV-Dmax) and the conformity, defined as the Dmax at 1cm distance to the PTV. All plans were normalized such that PTV D99% = 95%. First, for all patients the obtained PFs were parameterized using three parameters per patient that were estimated using least squares fitting. Then, patient specific features were selected to predict the parameters of the PF based on patient anatomy, using support vector regression with radial basis function kernels. The features were the proportion of the rectum and average area of the patient outline at the slices of the PTV, the volumes of PTV and rectum and the radii corresponding to 1,10, 50, 90 and 99% overlap of the PTV-rectum overlap volume histograms. The model was trained on 80% of the patients