Multicriteria optimization treatment planning for lung cancer radiotherapy: preliminary study for MCO-based auto-planning

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PURPOSE:

To investigate the potential of multicriteria optimization (MCO) for automating lung cancer treatment planning. This study aims to compare clinical plans with manually generated MCO plans using a universal list of objectives and constraints, serving as a study towards MCO-based plan automation for left lung cancers.

BACKGROUND:

Multicriteria Optimization (MCO) is a planning tool that allows users to explore multiple optimized VMAT plans simultaneously, each representing a different balance of clinical trade-offs. MCO presents a range of Pareto-optimal plans, enabling dosimetrists and or physicians to interactively select the most appropriate one based on patient-specific goals. Using the automated script, planning time may be reduced and allow for greater production by dosimetrists.

Currently, MCO has been released to the clinical sites for single phased prostate as well as whole pelvis patient cases in University of Maryland. This automated script for LT Lung is yet to be released to the clinic as it is still in the development phase. This work is the initial validation of the new script.

METHODS:

Ten retrospective lung cancer patients treated with VMAT were randomly selected from our institution's database. Using RayStation, we developed a universal list of objectives and constraints to generate MCO plans with the same arc angles as the clinical plan for a direct comparison.

MCO Planning:

For each patient, a balanced Pareto plan was created and converted to a deliverable plan. Additional post-processing optimization was added using the external contour to further control dose fall-off outside the target, and the PTV was utilized to control the max dose and uniformity. The user however will simply run the automated script in RayStation.

Tradeoff Objectives	
PTV	Uniform Dose 6000 cGy
External	Dose- Fall-Off 5700-3000, 0.6cm
External	Dose- Fall-Off 3000-0, 10cm
Lungs	Max EUD 0 cGy, Parameter A 1
SpinalCord	Max EUD 0 cGy, Parameter A 1
Esophagus	Max EUD 0 cGy, Parameter A 1
Heart	Max EUD 0 cGy, Parameter A 1

Constraints	
PTV	Max DVH 6300 cGy to 1% of Volume
PTV	Min DVH 6000 cGy to 99% of Volume
CTV	Min DVH 6000 cGy to 99% of Volume
GTV	Min DVH 6000 cGy to 99% of Volume
ITV	Min DVH 6000 cGy to 99% of Volume

Post Processing Objectives

Function	Constraint	Dose	ROI	Description	Robust	Weight	Value
Physical composite objective							
Mimic dose		Plan		Dose reference function		30	
Max dose		Plan	External	Max dose 6180 cGy		100.00	
Dose fall-off		Plan	External	Dose fall-off [H]6000 cGy [L]3000 cGy, Low dose distance 1.00 cm		40.00	
Uniform dose		Plan	PTV	Uniform dose 6000 cGy		60.00	

CONCLUSION:

This study demonstrates the feasibility of using MCO auto-planning for VMAT LT Lung cases and its ability to generate clinically acceptable plans with minimal user interference. Further expansion of the patient dataset will help refine the parameters needed for automated generation of lung plans.

RESULTS:

MCO Plans consistently demonstrate a slightly lower average and V6000cGy[%] when evaluating the target volumes (GTV & PTV).

ROI	Metrics	MCO mean	MCO stdev	Clinical mean	Clinical stdev	P value	Significance	n
GTV	Average Dose (cGy)	6118.088	31.113	6153.918	26.335	0.006	**	10
	Max Dose (cGy)	6322.294	111.318	6322.689	72.836	1.000	NS	10
	Min Dose (cGy)	5943.749	46.488	5996.631	55.257	0.020	*	10
	V6000cGy[%]	99.609	0.303	99.919	0.142	0.008	**	10
PTV	Average Dose (cGy)	6077.878	22.231	6133.099	13.778	0.002	**	10
	Max Dose (cGy)	6495.502	79.386	6395.390	75.669	0.002	**	10
	Min Dose (cGy)	4475.453	507.184	4782.568	582.200	0.193	NS	10
	V5700cGy[%]	98.926	0.742	99.485	0.721	0.037	*	10

MCO plans however portray efficiency in sparing OAR's such as the esophagus, spinal cord, heart, and in general throughout the External contour of the patient.

ROI	Metrics	MCO mean	MCO stdev	Clinical mean	Clinical stdev	P value	Significance	n
External	Average Dose (cGy)	740.430	281.988	786.348	294.775	0.002	**	10
	Max Dose (cGy)	6508.344	92.319	6395.390	75.669	0.002	**	10
	Min Dose (cGy)	0.075	0.192	0.103	0.230	0.139	NS	10
Esophagus	Average Dose (cGy)	1686.738	777.463	1957.843	629.906	0.037	*	10
	Max Dose (cGy)	5425.830	1254.079	5724.143	885.170	0.037	*	10
	Min Dose (cGy)	26.874	26.133	27.022	27.028	0.922	NS	10
	V6000cGy[%]	8.730	8.986	8.072	7.738	0.735	NS	10
Heart	Average Dose (cGy)	1358.478	723.365	1515.548	813.647	0.027	*	10
	Max Dose (cGy)	6055.571	722.994	6080.757	638.401	0.625	NS	10
	Min Dose (cGy)	184.516	234.253	211.871	246.906	0.193	NS	10
	V3000cGy[%]	11.745	8.150	14.991	12.928	0.084	NS	10
	V4500cGy[%]	4.426	3.023	5.077	3.581	0.086	NS	10
Spinalcord	Average Dose (cGy)	597.298	323.122	945.401	471.509	0.002	**	10
	Max Dose (cGy)	2593.964	1097.443	2979.874	965.034	0.020	*	10
	Min Dose (cGy)	1.403	1.241	1.803	1.745	0.193	NS	10
	V4800cGy[cc]	0.000	0.000	0.000	0.001	0.317	NS	10
Lungs	Average Dose (cGy)	1237.632	313.530	1261.362	303.884	0.375	NS	10
	Max Dose (cGy)	6060.019	1165.660	6076.028	942.708	0.492	NS	10
	Min Dose (cGy)	27.833	35.257	29.225	36.454	0.105	NS	10
	V2000cGy[%]	19.121	7.834	20.216	7.809	0.105	NS	10
	V5000cGy[%]	4.386	3.161	4.565	3.276	0.214	NS	10

Figure 1: Axial and Sagittal 2D image/DVH comparison of an MCO vs Clinical LT Lung VMAT plan.

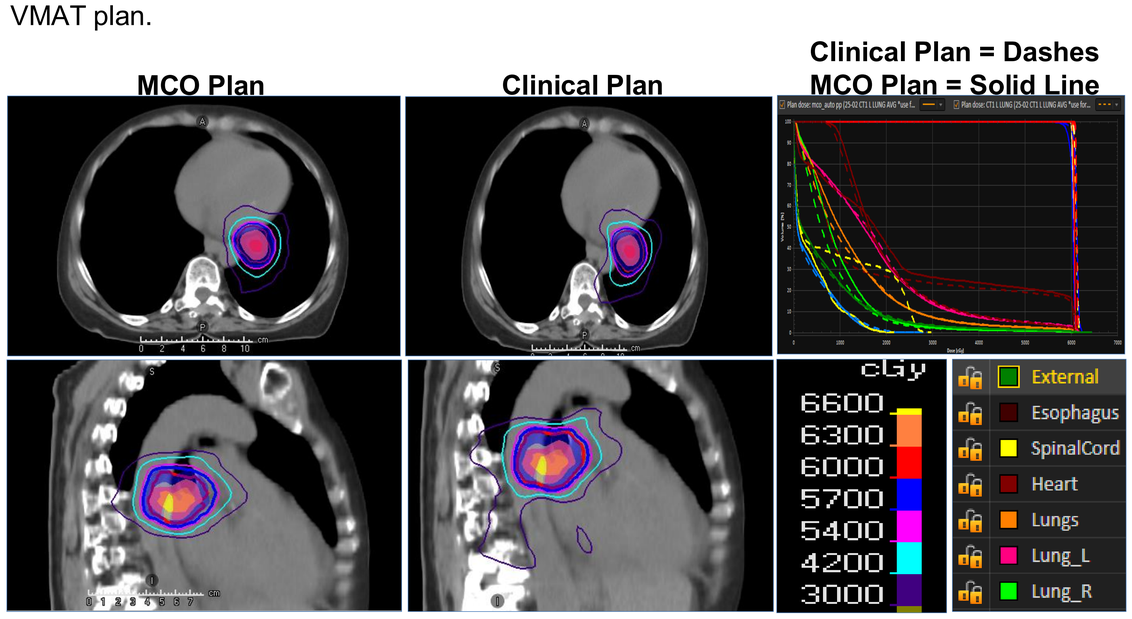
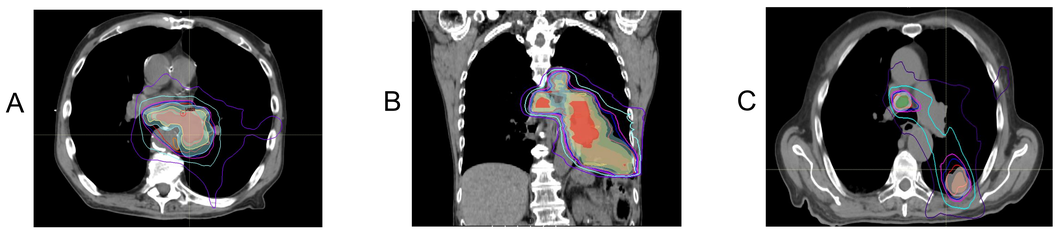


Figure 2. Contra-indications MCO automation: Contra-indications to MCO are shown in larger and irregularly shaped tumors, with a tradeoff of a greater max point (>109%), and a broader 50% isodose line beyond the target volume as shown in figures A-C below.



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