

# Can Machine Learning Optimization (MLO) Auto Planning Clinically Replace Multi-Criteria Optimization (MCO) Manual Planning in Complex Pancreatic VMAT with Dose Painting?

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## INTRODUCTION

- Auto planning is one of the most promising candidates for clinical implementation of machine learning in radiation oncology.
- What is Machine Learning Optimization (MLO)?
  - An auto planning platform in RayStation TPS, first introduced in version 8B<sup>1,2</sup>
  - Combines machine learning dose prediction and optimization with dose mimicking
  - Produces directly deliverable intensity modulated photon or proton plans
- Machine learning dose prediction engine uses a Random Forest model
  - Learns spatial dose distribution from training plans
  - Infers 3D dose on a new patient, predicting not only voxel dose, also probability distribution function (PDF) of dose in each voxel
- Generalized dose-volume rules are used to mimic predicted dose
  - Each set of rules is called a strategy, each model can have multiple strategies
  - Directly deliverable plan is created for a specified treatment machine
- Post processing can further personalize dose distribution
  - Unachieved goals can be further optimized in standard optimization
  - Automated fine-tune function, introduced in 10A, allows preserving achieved DVH
- Quality of MLO models depends on quality of training plans
  - Multi-criteria optimization (MCO) is the state-of-the-art manual planning algorithm
  - MLO models trained by MCO plans have intrinsic knowledge of MCO quality
- The MGH AI lab developed the first MCO-trained MLO models
  - Previously reported MLO models for liver and lung SBRT
- Motivations to build an MLO model for pancreatic VMAT with dose painting
  - Sufficient patient number for the dose painting protocol: 5880/5040 cGy in 28 fx
  - Expanding our MLO application from single to complex dose patterns
- Challenges for auto planning of high-dose GI protocols in abdomen
  - Boost Rx (5880 cGy) much higher than max dose limit to GI organs (5400 cGy)
  - Very difficult for DVH-driven auto planning to manage small hotspot in large organs
  - MLO has intrinsic advantage on GI hotspots, as it predicts voxel dose and its PDF

## AIM

- To investigate if MLO auto planning can clinically replace MCO manual planning in complex pancreatic VMAT with dose painting.

## METHOD

- Model trained by 108 MCO-VMAT plans in RayStation for an Elekta Agility machine
  - Rx: 5040 cGy in 28 fx to whole pancreas with 5880 cGy painted to boost volume
  - Clinical goals on an GI organ (stomach, duodenum, small or large bowel): at most 0.0 cm<sup>3</sup> >5400 cGy, at most 0.1 cm<sup>3</sup> >5000 cGy for part outside PTV\_5040
- Strategy validated on 10 patients with various boost volumes and locations
  - Priorities: CTV/PTV\_5040, GI inside PTV, CTV/PTV\_5880, GI outside PTV
- Validated model independently tested on 18 consecutive patients in RayStation 10A

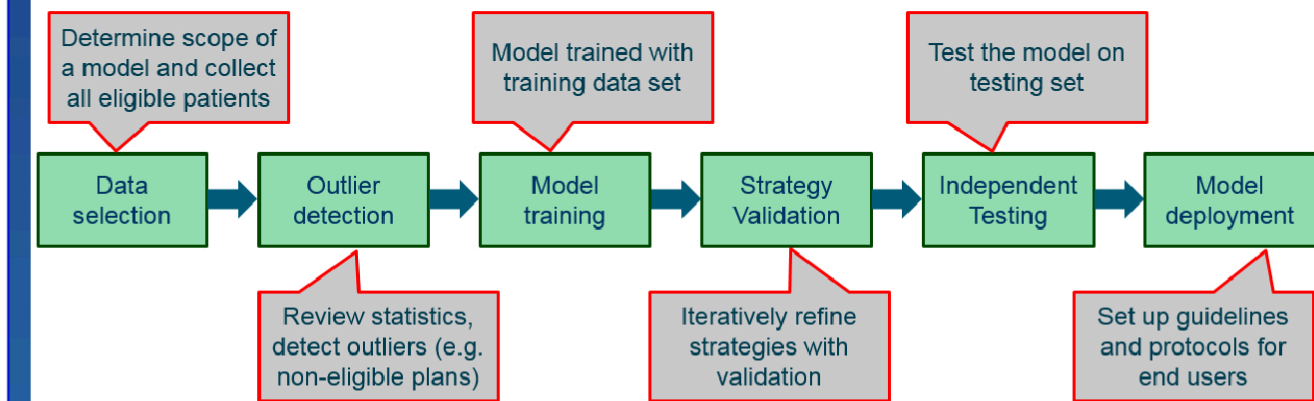


Figure 1. Workflow chart for clinical implementation of MLO

## RESULTS

- As shown in Table I, compared to the MCO manual plans, MLO auto plans provide
  - Slightly higher coverage for CTV\_5040, PTV\_5040, CTV\_5880, and slightly lower for PTV\_5880
  - Slightly lower volume of GI organs within PTV (GI\_in\_PTV) receiving 5400 cGy
  - Moderately higher volume of GI organs outside PTV (GI\_ex\_PTV) receiving 5000 cGy, as a result of strategy being designed to prioritize coverage of CTV\_5040 and PTV\_5040.
  - Major deviation from clinical goal (MLO:MCO): CTV\_5040 (0:1), PTV\_5040 (2:2), CTV\_5880 (2:2), PTV\_5040 (5:5), GI\_in\_PTV (4:3), GI\_ex\_PTV (13:5, by intention, since it's easier to fix afterwards)

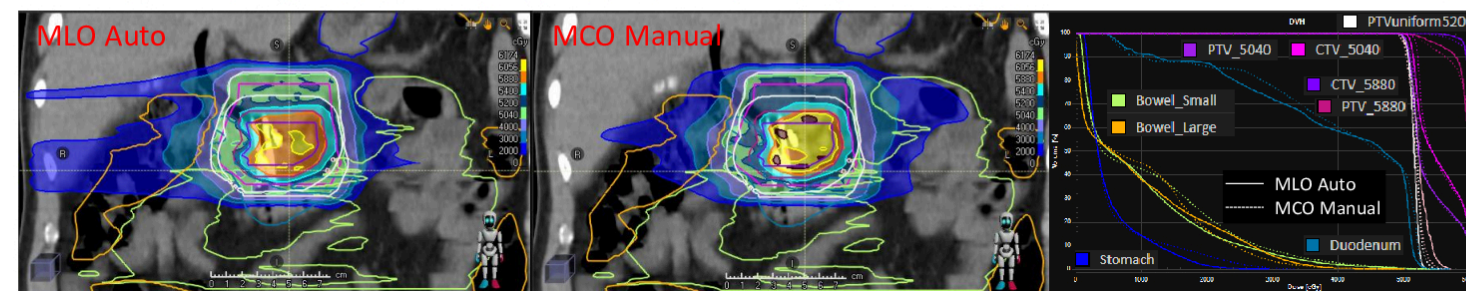


Figure 2. Comparison of dose distribution and DVH between the MLO auto plan and MCO manual plan for patient 14. The two plans provided very similar target coverage and organ dose. PTVuniform5200 (in white), defined as PTV\_5040-(PTV\_5880+1cm), was used in the strategy limit the spread of 5200 cGy (max dose limit to GI organs in conventional pancreatic treatment of 5040 cGy). The MLO auto plan performed better at limiting the spread of 5200 cGy than the MCO manual plan.

## CONCLUSIONS

- MLO can provide 1-click auto plan with similar quality to MCO.
- Auto plan can be further personalized in post processing.
- MLO can potentially replace MCO with increased efficiency.

## REFERENCES

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2. I. G. van Bruggen, R. G. J. Kierkels, M. Holmström, D. Lidberg, K. Berggren, S. Both, J. A. Langendijk, F. Löfman, E. W. Korevaar, "Fully automated treatment planning of deliverable VMAT by machine learning dose prediction and mimicking optimization in HNC", ICCR abstract, 2019.

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## CONTACT INFORMATION

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Table I. Comparison of six key clinical goals between MLO and MCO plans. Minor and major deviations from the goal are highlighted.

ROI	CTV5040		PTV5040		CTV5880		PTV5880		GI_in_PTV		GI_ex_PTV	
Metric	V50.4 (%)		V50.4 (%)		V58.8 (%)		V58.8 (%)		V54 (cc)		V50 (cc)	
Goal	99		95		99		95		0.00		0.00	
Minor	<99		<95		<99		<90		>0.10		>0.40	
Major	<98		<93		<95		<80		>0.20		>0.80	
Patient	MLO	MCO	MLO	MCO	MLO	MCO	MLO	MCO	MLO	MCO	MLO	MCO
1	99.88	99.99	97.02	97.71	98.01	98.15	89.19	91.52	0.05	0.00	2.07	0.83
2	99.63	93.23	94.39	79.28	99.89	98.64	89.22	78.43	0.02	0.00	1.18	0.01
3	99.81	99.97	96.80	94.54	99.30	99.65	87.60	93.17	0.00	0.00	0.36	0.07
4	99.74	99.02	94.90	89.56	99.20	99.77	79.07	88.54	0.18	0.01	2.39	0.02
5	99.72	99.87	96.40	93.41	99.68	100.00	84.28	87.04	0.00	0.00	0.70	0.06
6	99.79	99.94	94.44	93.85	99.55	98.98	86.15	83.58	0.11	0.00	0.85	0.66
7	99.79	99.78	94.12	94.68	99.11	99.60	83.23	92.83	0.25	0.88	2.16	3.27
8	99.44	100.00	91.42	95.28	97.53	99.54	78.79	90.78	0.28	1.81	1.38	1.78
9	99.96	99.63	96.69	95.55	99.82	99.85	90.57	91.01	0.05	0.00	0.55	0.01
10	99.81	99.73	95.38	94.22	99.94	99.97	89.18	92.35	0.02	0.00	1.68	0.11
11	99.96	99.96	94.24	95.01	97.94	96.83	81.88	84.70	0.14	0.00	3.37	1.95
12	99.97	99.93	99.97	94.14	97.49	99.96	88.93	87.25	0.02	0.00	3.06	0.09
13	99.63	99.88	94.73	95.00	99.75	99.73	86.35	86.35	0.05	0.00	1.86	0.19
14	99.75	99.97	97.27	97.09	97.57	95.26	85.01	80.89	0.10	0.00	0.87	1.58
15	99.52	99.71	96.28	94.52	90.35	82.77	72.08	65.67	0.88	0.80	0.26	0.09
16	99.54	99.97	93.79	95.00	99.68	96.79	81.25	74.73	0.62	0.11	2.06	0.78
17	99.92	99.93	94.82	95.00	97.18	95.23	78.69	73.57	0.12	0.01	1.72	0.71
18	98.48	99.88	88.31	95.00	79.10	72.11	56.16	52.16	0.06	0.10	0.14	0.57
AVG	99.69	99.47	95.05	93.82	97.28	96.27	82.65	83.03	0.16	0.21	1.48	0.71