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Multi-Strategy Machine Learning Auto Planning for Liver SBRT: Improving Quality, Consistency and Efficiency for a Complex Treatment

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INTRODUCTION

- Machine learning optimization (MLO) is an automated planning platform in RayStation treatment planning system, first introduced in version 8B[1,2]
- MLO combines machine learning with optimization to produce directly deliverable intensity modulated photon or proton plans
- Machine learning engine uses a Random Forest model to
  - Learn spatial dose distribution from training plans, and
  - Infer 3D dose on a new patient, predicting not only voxel dose, also probability distribution function (PDF) of dose in each voxel.
- Optimization uses generalized dose-volume rules to refine dose, each set of rules is called a strategy, each model has multiple strategies
- Post processing allows fine tuning towards clinical goals

AIM

To develop a multi-strategy MLO model that can auto plan liver SBRT lesions at various locations to provide similar or improved dosimetric quality over manual planning using multi-criteria optimization (MCO).

METHOD

- Training set: 34 IMRT + 41 VMAT plans, all MCO
  - Originally planned in RayStation 4.0, 4.7, 5.0, 8A, since 12/2014
  - Treated on Elekta Agility and Varian TrueBeam, both having 5-mm MLC
  - Rx: 50 Gy in 5 fx, with no substantial compromise on CTV coverage
- Multi-strategy MLO model, producing auto plans by one click
  - One strategy balancing PTV coverage and organ dose,
  - Four specialized in sparing chest wall, heart, gastrointestinal organs and lung.
  - Model output: VMAT plans using 3 arcs and 6 MV FFF on TrueBeam
- Independent testing on 11 new patients, originally 7 IMRT + 4 VMAT
  - Best one-click auto plan (referred to as pre-processed) was selected for posting processing (post-processed) in standard optimization
  - Pre- and post-processed MLO plans compared to clinical MCO plan

RESULTS

For all five patients with a lesion close to (but not abutting) an organ (chest wall, heart, small bowel, stomach and lung), the balanced auto plan provided similar quality to the clinical manual plan and was preferred over the specialized auto plan. For four patients with a lesion abutting an organ (one for kidney and three for chest wall), the auto plan (balanced plan preferred for all but one lesion abutting chest wall) only needed a simple processing on one clinical goal. The last two patients had a large lesion, one abutting chest wall, the other abutting lung and close to heart. The specialized plan was preferred and needed processing of two clinical goals (PTV coverage + chest wall or heart dose).

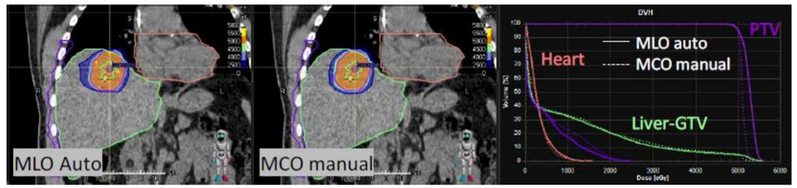

Figure 1 shows an MLO auto plan that was clinically acceptable with all clinical goals fulfilled. The lesion is not abutting any organs, so that the balanced strategy was used. The auto plan provided higher PTV coverage (95.6% vs. 95.0%) with lower dose to normal liver (9.8 vs. 10.2 Gy).

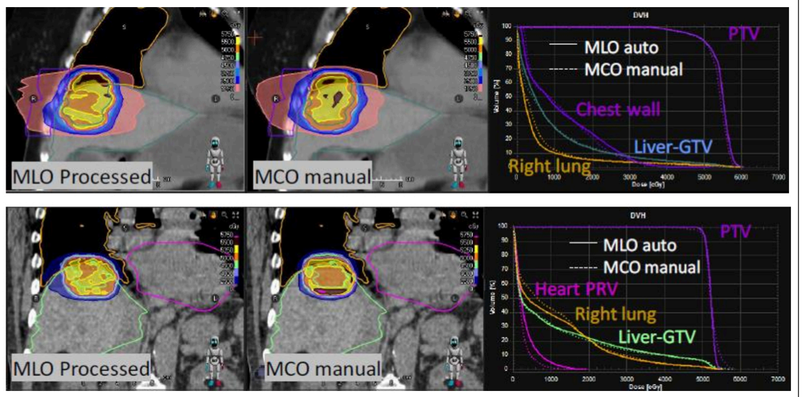

Figure 2 compares the auto and manual plans for the only two patients that required post processing on two clinical goals (i.e., the most challenging cases for MLO). The top patient has a lesion abutting chest wall and was planned with the specialized chest wall strategy. The simple post processing included boosting the PTV coverage and lowering the chest wall V40. The bottom patient has a lesion abutting the lung and close to the heart PRV and was planned with the specialized lung strategy. The simple post processing included boosting of PTV coverage and suppressing the maximum dose to the heart PRV (heart+5mm). After post processing, both MLO plans provided similar target coverage and organ sparing to the clinical MCO manual plans.

CONCLUSIONS

With little or no human involvement, the multi-strategy MLO model trained by MCO plans can produce auto plans matching the quality of clinical MCO plans for liver SBRT lesions at various locations.

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