Predicting optimal plan dose distributions of total marrow irradiation using deep learning model

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INTRODUCTION

Total marrow irradiation (TMI) using intensity modulated radiation therapy has been used in place of conventional total body irradiation as the conditioning regimen in hematopoietic cell transplantation. It's a challenging iterative process to optimize the plan and balance between the planning-target-volume(PTV) coverage and organ-at-risk (OAR) dose-sparing.

To our knowledge, this is first study to implement deep learning based dose prediction on total marrow irradiation (TMI). A TMI plan includes multiple targets (Ribs, Lymph Node (LN), Spinal cord, Spleen, Liver, Vertebrae extremities (Bone), Brain, Skull, testes) and OARs (Lungs, Heart, Esophagus, Parotids, GI, etc). Due to the proximity of some targets to OARs, the coverage of some PTVs (PTV_Ribs, PTV_Bone, PTV_LN) has to be sacrificed to meet OAR constraints. For example, the coverage of PTV_Ribs (V20) ranges from 35% to 70% in our dataset. The large uncertainty of the PTV dose makes the plan optimization more difficult.

AIM

This feasibility study aims to implement and test convolutional neural network (cnn) deep learning model to accurately predict the optimal TMI plan dose distribution and to help plan optimization.

METHOD

Fourteen Helical Tomotherapy TMI plans with 20Gy/10fx prescription doses were collected. The study focused on predicting thoracic region dose with 6 PTV structures and 4 OARs. In this area, navigating the trade-off between PTV_Ribs, PTV_Lymph nodes, PTV_Bone coverage and sparing the Lungs, esophagus is most difficult. Below is a data summary

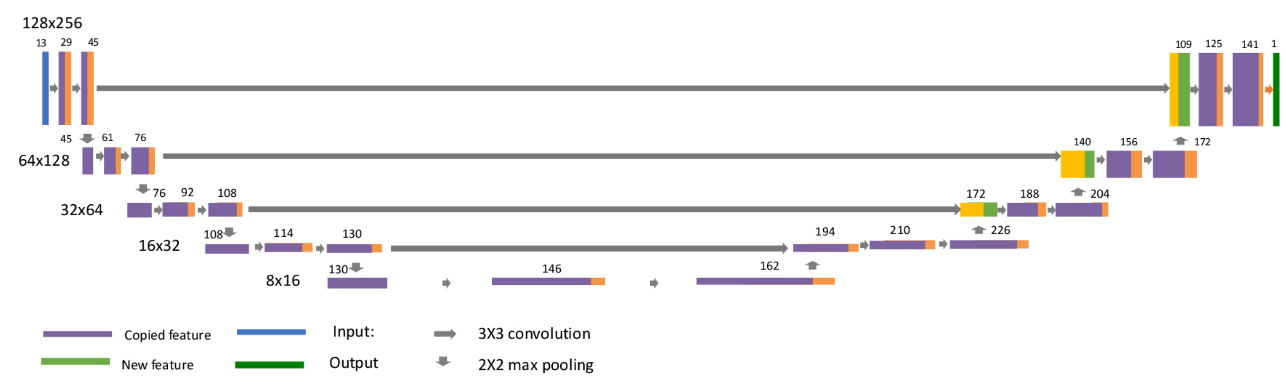
- Training patients: 10
- Testing patients: 5
- Total slices: 330
- Image size: 128 x 256 pixel
- Slice thickness: 2.5cm
- Treatment region: thoracic

METHOD (CONT)

Deep learning model

1. Unet Dense Model with both 3x3 convolution layers and 2x2 max pooling layes
2. Epochs = 2500. Batch size= 16, loss function = Mean Square Error
3. Trained on NVIDIA RTX2070 GPU card
4. Train on 2D slices

Deep learning Unet Dense network structure



RESULTS

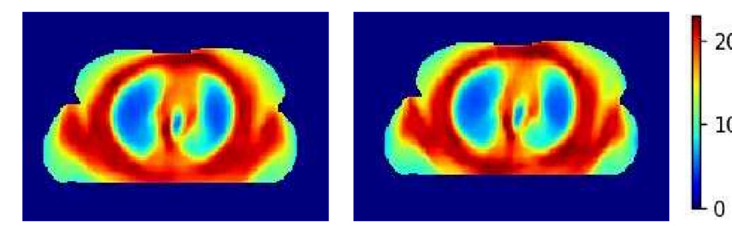
The total training time is around 2.5 hours. The training error is around 0.2 (mean square error on each pixel.

A full list of average absolute differences ($|D_{predict} - D_{true}|/D_{true}$) for test dataset can be found in Table 1

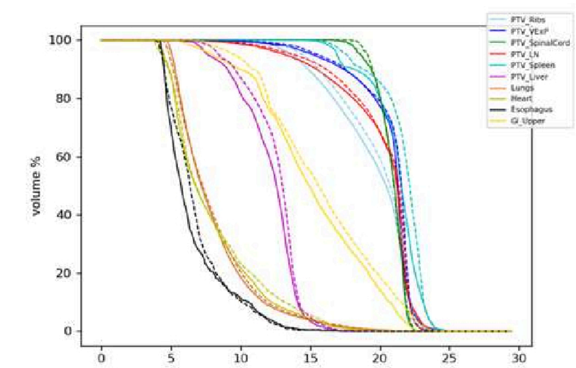
	PTV_Rib	PTV_Bone	PTV_SpCord	PTV_LN	PTV_Spleen	Lungs	Heart	Esophagus
Dmean	2.10%±0.81%	1.18%±0.70%	1.92%±1.39%	1.74%±1.56%	2.42%±0.22%	3.29%±2.66%	5.96%±3.24%	8.61%±3.82%
Dmax	1.54%±0.85%	4.30%±1.08%	2.91%±1.77%	2.63%±1.58%	4.05%±4.37%	2.22%±1.47%	2.79%±1.47%	6.15%±3.48%
D95	7.33%±2.96%	2.36%±0.96%	3.66%±2.71%	10.65%±10.79%	2.98%±1.05%			

RESULTS (CONT)

Predicted dose and true dose comparison for a representative patient



plan DVH comparison between true and predicted dose for a representative patient



CONCLUSIONS

Convolutional neural network models are promising to accurately predict the optimal dose distribution for complex multiple target/multiple dose-level TMI plans. This can help derive optimization objectives and reduce unnecessary treatment planning time. Further model development and test on a larger patient cohort is warranted..

REFERENCES

. "3D radiotherapy dose prediction on head and neck cancer patients with a hierarchically densely connected U-net deep learning architecture", D Nguyen, X Jia, D Sher, M Lin, Z Iqbal, H Liu, S Jiang. Physics in Medicine & Biology

CONTACT INFORMATION

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