JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

# Prediction of 3D dose distributions with deep learning for automatic treatment planning of scanned proton therapy

A. BARRAGÁN-MONTERO [1], M. HUET-DASTARAC[1], S. TERUEL-RIVAS[1], K. SOURIS[1], D. NGUYEN[2], S. JIANG[2], J.A. LEE[1], E. STERPIN[1,3]
1 Molecular Imaging Radiation Oncology (MIRO), UCLouvain, Brussels, Belgium
2 Medical Artificial Intelligence and Automation Lab (MAIA), UTSouthwestern, Dallas, USA
3 Radiation Oncology Department, KULeuven, Leuven, Belgium

## INTRODUCTION

**Deep neural networks** (DNN) are becoming a popular tool for automatic treatment planning in radiation therapy, with promising results for VMAT and IMRT treatments [1,2]. These DNN models are able to **predict the optimal three-dimensional dose distribution for a given patient**, by learning from a database of previously treated patients. The output dose can later be used to **automatically generate a treatment plan**, removing all human intervention and associated variability, which ensures high plan quality.

## AIM

**Proton therapy** could greatly benefit from the power of DNN, especially nowadays, when the centers with accumulated clinical experience in proton planning are very few and the number of new centers is growing. However, the feasibility of DNN dose prediction for proton therapy remains to be addressed. The present work is the first to investigate the use of DNN for dose prediction of scanned proton therapy for **head and neck (H&N) cancer**.

## METHOD

**Model architecture**

The model is based on the popular **UNet**, a type of convolutional neural network able to include local and global features from the input images, but including **dense connections** to achieve a more efficient feature propagation. The details of the network has been described elsewhere [1, 2] and are shown in Figure 1. We used **14 input channels** including the CT, binary masks for CTV (voxel equal to the prescription dose) and 12 relevant organs (voxel equal to 1).


Figure 1. Model architecture

**Database**

A set of **62 H&N cancer patients** treated with **pencil beam scanning**, with the same beam configuration (4 beams), was used for training (50 patients) and testing (12 patients). All plans were generated in **RayStation v8a** (RaySearch Laboratories, Sweden), using **robust optimization with 4 mm for setup errors and 3% for range errors**. The prescription dose was equal to 50Gy - 54.25Gy for the CTVlow, and 70Gy for CTVhigh.

**Model training**

The stability of the model was evaluated by using a **5-fold cross-validation** (40 training patients and 10 for validation). Right-left flipping of the images was used for data augmentation. All operations were done with a RTX 2080ti GPU of 11 GB dedicated RAM.

## RESULTS

Figure 2 shows the box plots for the average error on the mean dose for the different volumes. The volumes with bigger error were the larynx, right parotid, right submandibular gland (SMG R) and trachea. Figure 3 shows the Dice coefficient values for the isodose lines. Overall the prediction matches the clinical dose with a Dice similarity index above 0.9, but the 70-80% isodose region remains harder to predict, with a Dice that decreases to 0.8. Figure 4 shows an example of the dose distributions for a selected patient.


Figure 2. Box plots for the difference between the Dmean on the real dose and Dmean on the predicted dose for the CTVs and organs, expressed as percentage of the prescription dose for the CTVhigh, i.e., (Dmean_real - Dmean_pred)/70Gy

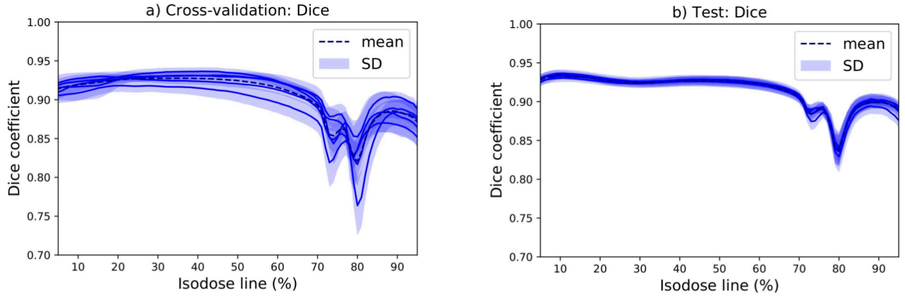


Figure 3. Dice similarity indices of the isodose volumes from 5% to 95% of the prescription dose (solid blue lines), together with their corresponding average for all cross-validation folds (dashed line) and standard deviation (color wash), for cross-validation (a) and test (b) set.

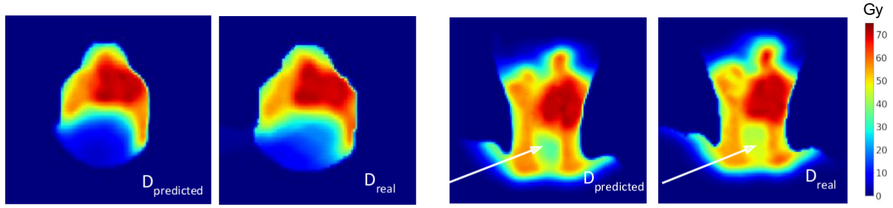


Figure 4. Real and predicted dose distributions in the axial plane (left) and coronal plane (right) for a selected test patient

## CONCLUSIONS

This work demonstrated the feasibility of using DNN to predict proton dose distributions, which can later serve for high quality automatic dose planning. Future work will focus on improving the prediction in the dose region around the 70-80% isodose line, which remains the region with most uncertainty.

## REFERENCES

[1] D. Nguyen, X. Jia, D. Sher, et al., 3D radiotherapy dose prediction on head and neck cancer patients with a hierarchically densely connected U-net deep learning architecture, Phys. Med. Biol. 64(6), 065020 (2019)

[2] A. Barragán-Montero, D.Nguyen, W. Lu, et al., Three-dimensional Dose Prediction for Lung IMRT Patients With Deep Neural Networks: Robust Learning From Heterogeneous Beam Configurations, Med. Phys 46(8):3679-3691 (2019 )

## ACKNOWLEDGEMENTS

A. Barragán and K. Souris are funded by the Walloon region (PROTHERWAL / CHARP, Grant No. 7289, and MECATECH / BIOWIN, Grant No. 8090, respectively). J. Lee is a Senior Research Associate with the F.R.S.-FNRS

## CONTACT INFORMATION

ana.barragan@uclouvain.be

**Social media**

Follow MIRO lab on Twitter by scanning the QR code