From Dose Plane to Gamma Passing Rate Using Convolutional Neural Networks, a Rapid QA for Online Adaptive Radiotherapy

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Purpose: To develop and evaluate a convolutional neural network (CNN) that predicts portal dosimetry gamma passing rate (GPR) directly from predicted dose plane images, providing rapid QA support for online adaptive radiotherapy (OART), where measurement-based QA may be impractical.

Methods: A retrospective dataset of 209 delivery fields from 87 prostate IMRT patients treated on a Halcyon linac was analyzed. Predicted portal dose planes were used as CNN inputs, while measured portal dosimetry QA GPR values (1 mm/2% gamma criteria) served as ground truth. A stricter gamma criterion was selected to improve sensitivity. Model performance was evaluated using three-fold cross-validation with mean absolute error (MAE) as the primary metric, and RMSE and R^2 as secondary metrics.

Results: The model showed consistent agreement between predicted and measured GPR across folds. Mean MAE was 2.76%, RMSE was 3.55%, and mean R^2 was 0.38. Performance remained stable across clinically relevant GPR ranges, including values near institutional QA thresholds.

Conclusions: CNN-based prediction of portal dosimetry GPR from dose plane data is feasible and may provide rapid QA decision support when measurement-based QA is not practical, such as in OART. With larger datasets and expansion to additional treatment sites, broader clinical use may be possible.

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INTRODUCTION

In online adaptive radiotherapy (OART), conventional measurement-based QA is not feasible once an adaptive plan is generated at the treatment console, and adapted plans are often delivered without equivalent QA due to time and workflow constraints. This work introduces a deep learning approach that rapidly estimates gamma passing rate (GPR) directly from predicted dose planes when physical measurements are impractical. A convolutional neural network was developed in R using the *oro.dicom* library and evaluated on 209 delivery fields from 87 prostate cancer patients treated with IMRT on a Halcyon linear accelerator. Predicted portal dose planes served as model inputs, with measured portal dosimetry QA gamma passing rates evaluated using 1 mm/2% criteria as ground truth. The method is intended as a screening and decision-support tool for efficient QA in time-constrained OART workflows.

METHODS AND MATERIALS

A retrospective dataset of 209 delivery fields from 87 prostate cancer patients treated with IMRT on a Halcyon linear accelerator was analyzed. Predicted portal dose planes generated by the treatment planning system were used as input to CNN models [1]. Corresponding measured portal dosimetry QA (PDQA) gamma passing rates, evaluated using 1 mm/2% gamma criteria, served as ground truth. A stringent gamma criterion was selected to increase sensitivity to delivery and modeling variations, as standard clinical criteria (e.g., 2 mm/2% or 2 mm/3%) resulted in uniformly high passing rates with limited dynamic range. Model performance was assessed using three-fold cross-validation. Mean absolute error (MAE) was the primary metric. Root means square error (RMSE) and coefficient of determination (R^2) reported as secondary metrics.

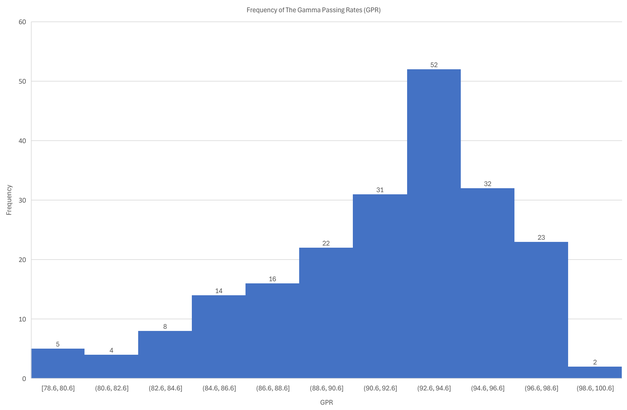

Figure 1. Distribution of Measured Gamma Passing Rates

RESULTS

Across cross-validation folds, the model demonstrated consistent agreement between predicted and measured gamma passing rates. The mean MAE was 2.76%, and the mean RMSE was 3.55%, indicating low prediction error across clinically relevant GPR ranges. The mean R^2 was 0.38, reflecting moderate correlation in the presence of delivery and measurement variability inherent to portal dosimetry. Prediction performance was stable across folds and included delivery fields with GPR values near institutional QA action thresholds.

Table 1. Cross Validation Results

Mean Absolute Error	2.76
Root Mean Square Error	3.55
Coefficient of Determination	0.375

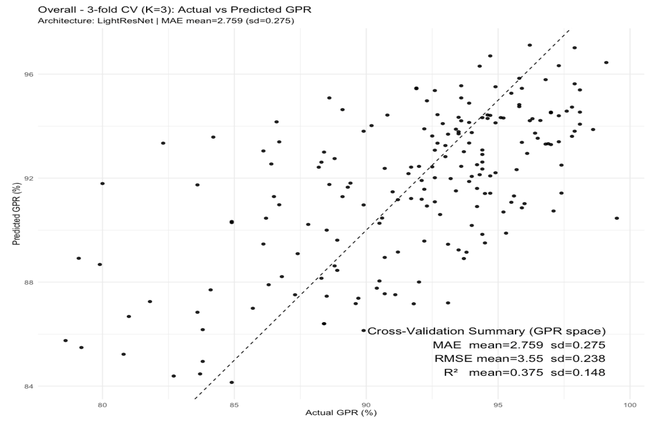

Figure 2. Overall Cross Validation Plot, Actual vs Predicted GPR.

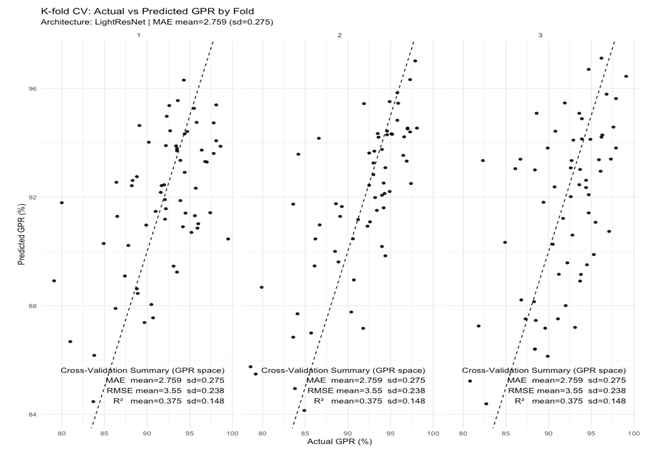

Figure 3. Per fold Cross Validation Plot, Actual vs Predicted GPR

DISCUSSION

This work represents an important early step toward implementing data-driven quality assurance tools for online adaptive radiotherapy. The primary significance of this study is not only the present model itself, but the demonstration that meaningful QA-related information can be learned directly from predicted dose plane data using deep learning techniques. Establishing this proof of concept creates a foundation for future development of fast, clinically practical screening tools that could assist physicists in time-constrained adaptive workflows. As adaptive treatments continue to expand, the need for efficient methods to evaluate plan deliverability and identify potentially problematic cases will become increasingly important.

This framework can be further strengthened through expansion to larger and more diverse datasets, inclusion of additional treatment sites with different anatomical and dosimetric characteristics, and evaluation across multiple delivery platforms and linac vendors. Incorporating machine-specific parameters, delivery log information, or other complementary inputs may also improve predictive reliability and clinical usefulness. Multi-institutional validation will be especially valuable for assessing generalizability across different planning systems and workflow environments. With continued refinement, this approach has the potential to evolve into a robust decision-support tool that complements conventional measurement-based QA and helps streamline adaptive treatment processes in routine clinical practice.

CONCLUSIONS

This study demonstrates the feasibility of estimating portal dosimetry gamma passing rates directly from predicted dose plane information in clinical scenarios where measurement-based QA is not feasible, such as OART. The proposed approach provides rapid, quantitative QA decision support without additional measurements. With larger datasets and extension to additional treatment sites, broader clinical applicability is anticipated.

REFERENCES

1. **He K, Zhang X, Ren S, Sun J.** Deep residual learning for image recognition. *CVPR.* 2016.