Predicting Treatment Response in Patients with Hepatocellular Carcinoma Treated with Y90 Radioembolization Using Deep Learning

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Introduction

Because only a minority of patients with hepatocellular carcinoma (HCC) meet criteria for curative surgical/transplant therapy, Yttrium-90 radioembolization (Y90-RE) has become an alternative, established therapy. During Y90-RE, radioactive particles are injected into the tumor-feeding vessels, increasing patient survival when cytotoxic doses are achieved. Response is often determined on follow-up imaging at 3-6 months, during which, the tumor can progress or metastasize if not adequately treated. This study aims to predict which patients will have complete treatment response using a deep convolutional neural network (DNN), and in doing so, highlight patients that may benefit from earlier follow-up or additional therapy.

Hypothesis

We hypothesize that a DNN can accurately classify Y90-RE treatments in patients with HCC as complete response/dead tumor or incomplete response/residual disease.

Methods

After IRB approval, a retrospective analysis was conducted in patients with HCC who received Y90-RE between 12/2014 and 1/2019 at a single institution. 77 patients with 103 lesions met the inclusion criteria: three or fewer tumors, pre- and post-treatment MRI, and no prior Y90-RE. Lesions were divided into complete (n=57) or incomplete response (n=46), based on reports from 3-month post-treatment MRI. Lesions were hand-segmented on pre-treatment arterial phase MRI to determine lesion location and on post-treatment arterial phase MRI to determine slice-wise response. Immediate post-Y90-RE Bremsstrahlung SPECT was used as a proxy for treatment area and dose. Lesions were divided by MRN into a 90% training set for 5-fold cross-validation, and a 10% hold-out test set. The final test model was an average ensemble of the models and thresholds from the best epochs across all 5 folds (Figure 1). Slice-wise classification results were compared against the current standard of care for post-Y90-RE analysis, partition modeling, using sensitivity, specificity, accuracy, and area under the receiver operating characteristic curve (ROC-AUC).

Results

Five-fold cross-validation results for the ensemble model were sensitivity 0.73±0.29, specificity 0.70±0.14, accuracy 0.75±0.09, and ROC-AUC 0.79±0.12; and for the partition model were sensitivity 0.36±0.34, specificity 0.80±0.40, accuracy 0.63±0.04, and ROC-AUC 0.62±0.09. Test set results for the ensemble model were sensitivity 0.32, specificity 0.85, accuracy 0.65, and ROC-AUC 0.66; results for the partition model were sensitivity 0.03, specificity 0.99, accuracy 0.62, and ROC-AUC 0.57 (Figure 2).

Conclusion

The deep learning algorithm had a 16% higher ROC-AUC for predicting immediate, post-radioembolization treatment response in patients with HCC compared to the current best method. This algorithm has the potential to highlight patients that may benefit from earlier follow-up or additional therapy.

Figure(s)

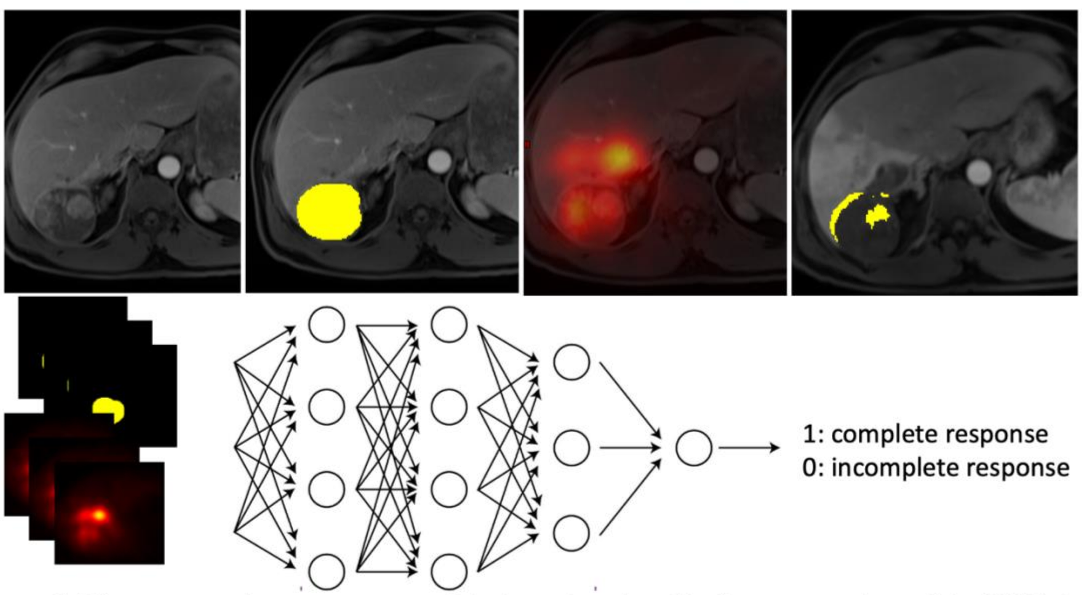

Figure 1. The top row demonstrates arterial phase imaging (first), segmentation of the HCC (second), bremsstrahlung SPECT overlayed on the arterial phase imaging (third), and post-treatment segmentation of the residual enhancing component of the HCC (fourth). The bottom row demonstrates the input to the neural network (timm-skresnext50_32x4d; input size = 192 x 192 x 6 with 3 grouped lesion maps and 3 grouped bremsstrahlung maps, batch size=16, gradient accumulation=4, dropout=0.1, epochs=3), with the output as a value between 0 and 1 converted to 1 or 0 based on a validation threshold.

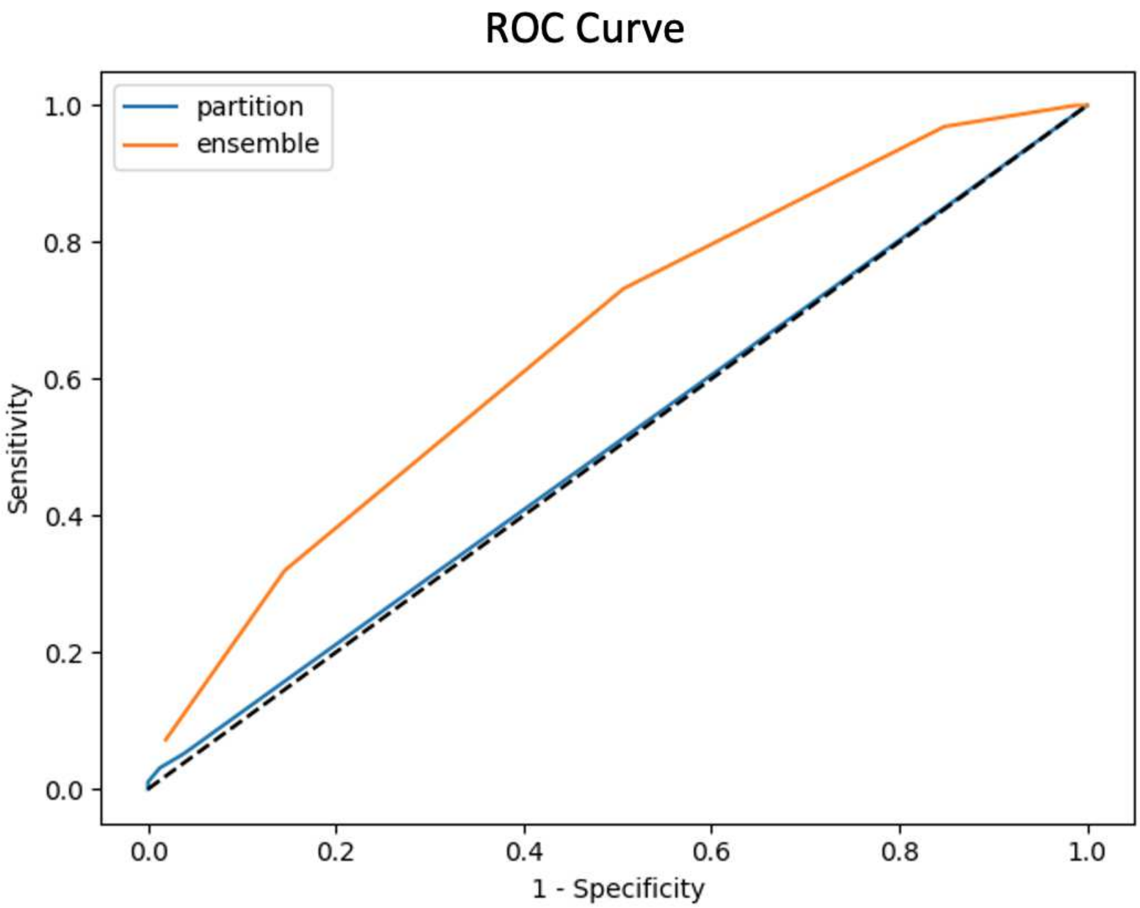

Figure 2. Receiver operating characteristic curve for predicting slice-wise treatment response after Y90 radioembolization therapy in patients with hepatocellular carcinoma.

Keywords

Applications; Artificial Intelligence