Noninvasive KRAS mutation estimation in colorectal cancer using a deep learning method based on routine CT imaging

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Abstract
Background: The detection of KRAS gene mutations in colorectal cancer (CRC) is key to the optimal design of individualized therapeutic strategies. The noninvasive prediction of the KRAS status in CRC is challenging. Deep learning (DL) in medical imaging has shown its high performance in diagnosis, classification, and prediction in recent years. In this paper, we investigated predictive performance by using a DL method with a residual neural network (ResNet) to estimate the KRAS mutation status in CRC patients based on routine pre-treatment contrast-enhanced CT imaging.

Methods: We have collected a dataset consisting of 157 patients with pathology-confirmed CRC who were randomly divided into a training cohort (n = 117) and a validation cohort (n = 40). We developed an ResNet model that used portal venous phase CT images to estimate KRAS mutations in the axial, coronal, and sagittal directions of the training cohort and validated the model in the validation cohort. Several groups of expended ROI patches were generated for the ResNet model, to explore whether tissues around the tumor can contribute to cancer assessment. We also explored a radiomics model with the random forest classifier (RFC) to predict KRAS mutations and compared it with the DL model.

Results: The ResNet model in the axial direction achieved the higher area under the curve (AUC) value (0.90) in the validation cohort and peaked at 0.93 with an input of “ROI and 20-pixel” surrounding area. In the training cohort, the AUC was 0.945 (sensitivity: 0.75; specificity: 0.94), and in the validation cohort, the AUC was 0.818 (sensitivity: 0.70; specificity: 0.85). In comparison, the ResNet model showed better predictive ability.

Conclusions: Our experiments reveal that the computerized assessment of the pre-treatment CT images of CRC patients using a DL model has the potential to precisely predict KRAS mutations. This new model has the potential to assist in noninvasive KRAS mutation estimation.

Keywords: Colorectal Neoplasm, Mutation, Deep Learning

Full Text

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However, the manuscript can be downloaded and accessed as a PDF.

Figures
Figure 1

The flow chart of ROI-patch generation. A minimum circumscribed rectangle is established around each irregular ROI. Then, the boundary of the minimum rectangle is equally expanded with an interval of 10 pixels. This procedure is repeated for the three orthogonal directions (axial, sagittal, and coronal body).
The structure of the employed residual neural network. There are six identity blocks, a pooling layer, a fully-connected layer and a softmax. Each identity block has three convolutional layers. The kernel size of all the convolution layers is 5 x 5. ReLu are adopted after every convolutional layer.
Figure 3

ROC curves for four KRAS mutations predicted by the residual neural network and radiomics models. (a) ResNet and radiomics predictions on different input in axial direction. (b) ResNet predictions on different input in coronal direction. (c) ResNet predictions on different input in sagittal direction.
The line chart of AUC values for each CNN with different inputs. ResNet model in the axial direction reached the higher AUC value compared with the coronal and sagittal positions.

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