

Integrating Pretreatment CT Radiomics and Circulating Tumor Cells Using Machine Learning to Predict Survival After Immunoradiotherapy in Advanced Hepatocellular Carcinoma

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Abstract

Background This study aimed to evaluate the efficacy of adding PD-1 inhibitors to radiotherapy plus tyrosine kinase inhibitors (R+T+P) in advanced hepatocellular carcinoma (HCC) and to assess whether radiomics, circulating tumor cells (CTCs), and machine learning could improve outcome prediction. **Methods** A total of 295 patients with advanced HCC were included (R+T+P, n = 172; R+T, n = 123). For patients receiving R+T+P, predictive models were developed by integrating clinical variables, CT-based radiomic features, and CTC counts using machine learning algorithms. **Results** The R+T+P group achieved significantly longer median overall survival (mOS) and median progression-free survival (mPFS) than the R+T group (mOS: 27.8 vs. 20.1 months, P = 0.008; mPFS: 8.7 vs. 6.9 months, P = 0.014). Among the prognostic models, the Clinical – Radiomic – CTC nomogram outperformed the Clinical – Radiomic nomogram, showing a higher concordance index (0.789) and higher area under the receiver operating characteristic curves (AUCs) for 1-, 2-, and 3-year OS (0.889, 0.771, and 0.838, respectively). **Conclusion** PD-1 inhibitors combined with radiotherapy and TKIs significantly improved survival outcomes in patients with advanced HCC. Machine learning models integrating radiomics and CTCs provided robust individualized prognostic prediction, supporting risk stratification and clinical decision-making.

Keywords

Hepatocellular Carcinoma, Immunoradiotherapy, Radiomics; Circulating Tumor Cells, Machine Learning