Morphology-Dependent Disparities in Deep Learning-Based Lung Nodule Detection

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Lung cancer remains the leading cause of cancer-related mortality worldwide, and early detection significantly improves survival outcomes. Subsolid pulmonary nodules, including ground-glass nodules (GGNs) and part-solid nodules (PSNs), often represent early-stage adenocarcinoma and differ in radiographic appearance from solid nodules. Although deep learning models have achieved high overall performance in automated lung nodule detection, results are typically reported as a single aggregate metric without stratification by morphology. This study evaluated whether a 3D convolutional neural network (CNN) demonstrates morphology-dependent disparities in detection sensitivity using the LIDC-IDRI dataset. Over 1,000 CT-derived 3D nodule volumes with expert annotations were analyzed. Nodules smaller than 3.0 mm were excluded, and images were normalized to preserve contrast differences. Data were split into 80% training and 20% testing sets with patient-level separation. The baseline model achieved 80% accuracy and 93% sensitivity on independent testing. However, stratified analysis revealed significantly lower sensitivity for GGNs compared to solid nodules. Logistic regression confirmed morphology as an independent predictor of detection failure ($p < 0.05$). To address this disparity, a morphology-aware training approach was introduced, improving detection performance for ground-glass nodules. The model was further extended to jointly predict morphology and malignancy, demonstrating the potential of explicit morphology modeling to enhance cancer detection. These findings highlight the importance of evaluating AI systems across clinically meaningful subgroups and suggest that morphology-aware approaches can improve equitable early-stage lung cancer identification.

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