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

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PROBLEM & MOTIVATION

Lung cancer is the leading cause of cancer-related death worldwide; early detection is critical to survival.

AI screening models report aggregate accuracy, masking dangerous performance gaps across nodule subtypes.

Ground-glass nodules (GGNs) represent early-stage, highly treatable adenocarcinoma but are radiographically subtle and frequently missed.

Systematic underdetection of these lesions delays diagnosis at the window of highest survivability.

METHODOLOGY

Analyzed 1,018 CT scans from LIDC-IDRI and 294 CT scans from LNDb, classifying 2,080 nodules by morphology: GGO, part-solid, and solid.

3D CNN trained on 14×14×14 voxel patches with patient-level 80/20 train-test split.

Morphology-stratified sensitivity analysis controlling for nodule size and anatomical location.

Improved model uses balanced sampling and multi-task learning jointly trained on morphology and malignancy detection.

RESULTS

GGO AUC	PS AUC	Overall AUC
0.79→0.93	0.66→0.72	0.87→0.93
+0.14	+0.06	+0.06

Baseline AUC was lowest for GGOs (0.79) and part-solid nodules (0.66), confirming morphology-dependent disparity.

MTL with joint morphology and malignancy training showed the greatest AUC gain concentrated in the GGO subgroup.

CONCLUSIONS & IMPACT

AI detection performance varies significantly by nodule morphology, revealing a hidden source of clinical bias.

Morphology-aware training substantially improves detection of early-stage lesions that standard models miss.

Regulatory evaluation of medical AI should include subgroup-specific auditing, not just aggregate metrics.

Future work will validate on external datasets and integrate Grad-CAM to visualize subtype-specific detection differences.