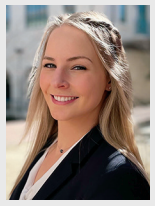
Limiting CT-Based Severity Staging Of COPD To A Single Inspiratory Acquisition Using Convolutional Neural Networks



Several methods for computed tomography (CT)-based severity staging of chronic obstructive pulmonary disease (COPD) utilize both inspiratory and expiratory acquisitions, which is not the clinical standard and increases patients' exposure to radiation. We assess the feasibility of using a convolutional neural network (CNN) to stage COPD using only inspiratory CT, relative to inspiratory-expiratory CT. We obtained 8,893 inspiratory and expiratory lung CT series and spirometry measurements from the COPDGene Phase I cohort. CNNs were trained to predict spirometry measurements (forced expiratory volume in one second [FEV1], FEV1 to forced vital capacity ratio [FEV1/FVC], percent predicted FEV1 [FEV1pp]) using clinical data and either single-phase or multi-phase CT as input. Spirometry predictions were then used to predict Global Initiative for Obstructive Lung Disease (GOLD) stage. ICCs for FEV1, FEV1 percent predicted, and FEV1/FVC were 0.76-0.77, 0.78-0.80, 0.70 for single-phase CNNs and 0.80-0.85, 0.83-0.85, 0.76-0.78 for multi-phase CNNs. ICCs and accuracies for single stage, within one stage, and diagnosis were 0.72, 65.2%-65.7%, 84.3%-85.8%, 79.7%-80.7% for single-phase CNNs and 0.77-0.78, 67.6%-67.9%, 87.7%-88.0%, and 81.8%-82.2% for multi-phase CNNs. These results suggest CNN-based COPD diagnosis and severity staging is feasible using single routine non-contrast inspiratory CT and has comparable diagnostic and staging accuracy with multi-phase CT.

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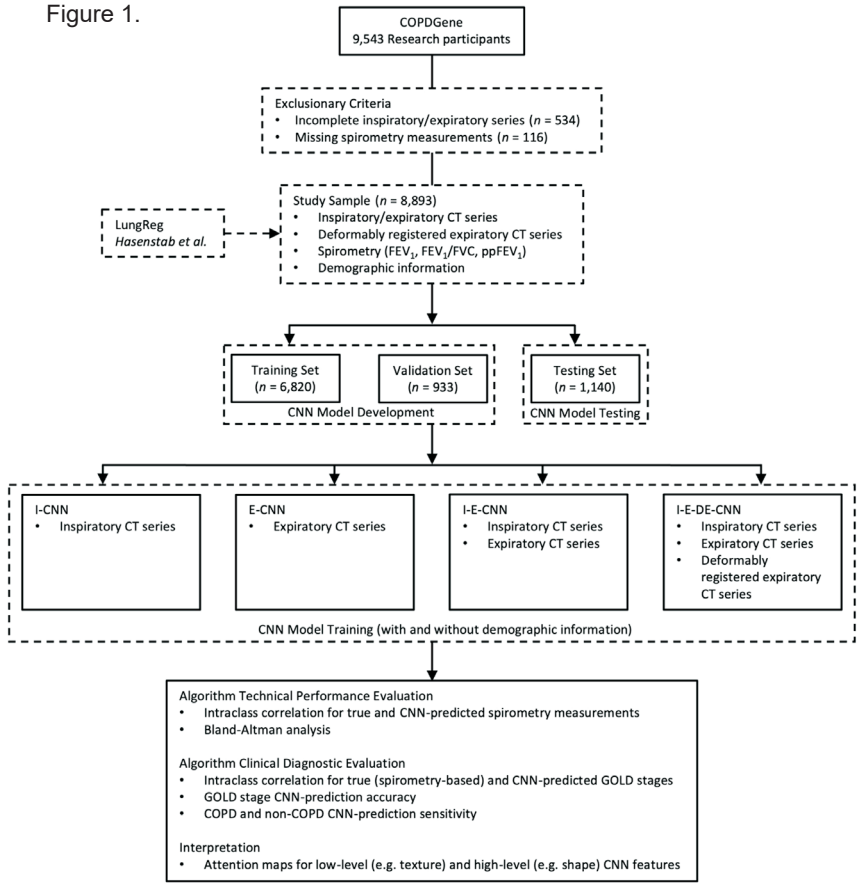
Figure 1.



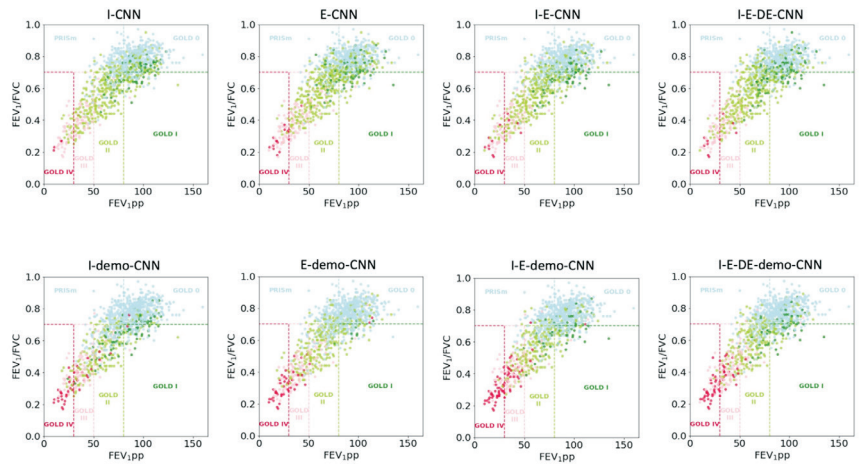


Figure 2.

Figure 3.

Figure 1: Overview of study design. GOLD = Global Initiative for Chronic Obstructive Lung Disease; CNN = convolutional neural network; I = inspiratory CT image; E = expiratory CT image; DE = deformably registered expiratory CT image; demo = demographic information; FEV1 = forced expiratory volume in one second; FEV1/FVC = ratio of FEV1 to forced vital capacity; FEV1pp = FEV1 percent predicted.

Figure 2: Relationship between spirometry-based Global Initiative for Chronic Obstructive Lung Disease (GOLD) stages from true and CNN-predicted spirometric values. CNN = convolutional neural network; I = inspiratory CT image; E = expiratory CT image; DE = deformably registered expiratory CT image; demo = demographic information; FEV1 = forced expiratory volume in one second; FEV1/FVC = ratio of FEV1 to forced vital capacity; FEV1pp = FEV1 percent predicted; PRISm = Preserved Ratio/Impaired Spirometry. Spirometric values are stratified to show true GOLD stage while points are colored by CNN-predicted GOLD stage. Model names are abbreviated based on model input.

Figure 3: Visualization of attention maps from the residual attention networks for the inspiratory (I-CNN) and expiratory (E-CNN) models. Attention maps for detecting low- and high-level features are displayed overlaying a single slice of the original input images. Overlay color indicates strength of attention ranging from low attention, i.e. blue, to high attention, i.e. dark red. One example for each Global Initiative for Chronic Obstructive Lung Disease (GOLD) stage is shown.