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Automatic Lung Analysis for COVID-19 Patients

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Objectives: Coronavirus disease 2019 (COVID-19) is an infectious lung disease affecting more than 124 million individuals worldwide as of Mar 28, 2021, and still significantly impacts our daily life. In 2020, we presented an automatic lung analysis workflow to analyze lung function quantitatively at the lung lobe level [1]. To further support and contribute to COVID-19 analysis, we extended our work and developed a fully automatic research prototype analysis workflow for lung fissure delineation and opacity detection.
Methods: The deep learning system consists of deep reinforcement learning landmark detection, deep image to image network work for lung fissure delineation, and a Dense-UNet for opacity feature extraction and detection for COVID-19 cases. The algorithm was trained with over 8000 chest CT image volumes, including 1400 COVID-19 cases. The algorithm was validated using both an in-house testing dataset of 200 cases, and a completely unseen dataset, the first batch of 120 cases from the RSNA International COVID-19 Open Radiology Database (RICORD). Two types of correlations, Pearson's Coefficient and Kendall's Tau, were used in statistical analysis for datasets with adequate image quality. The lung lobe mask and opacity mask were then overlapped with PET/SPECT images for automatic quantifications to produce quantitative results in each lung lobe and opacity region in the respective lobe for both CT and PET/SPECT images.
Results: The automatic lung analysis workflow completed successfully for all patient datasets. For the in-house testing dataset, the Pearson Coefficient between the percentage of opacity predicted and the ground truth is 0.95. For the 104 datasets with adequate image quality in RICORD, the mean and standard deviation of the percentage of infectious opacity in the whole lung (segmented in our workflow) is 31.8±26% for our segmentation and 33.5±30% for the annotation. The Pearson's Coefficient is 0.765 ($p<.0001$), and Kendall's Tau is 0.720 ($p<.0001$). RICORD dataset consists of annotations from 3 different teams, therefore, we further investigated the inter-team variability of annotation. The Pearson's Coefficients are 0.765($p<.0001$) for team 1, 0.670($p<.0001$) for team 2, and 0.827($p<.0001$) for team 3. The percentages of volume (CT) and activity (PET/SPECT) of opacity region in each lung lobe are provided for functional analysis.
Conclusion: The image quality plays a critical role in the accuracy of segmentation. Our automatic segmentation shows reasonable and acceptable results with the completely unseen RICORD public dataset of relatively suboptimal reconstruction quality from multiple vendors. The quantification of both anatomical and functional information provides the ability to (1) analyze lung lobe level function and opacity infection for COVID patients and (2) monitor treatment effectiveness by comparing the functional change before and after treatment.
[1] Gao, Fei, et al. "Evaluation of Automatic Lung Lobe Segmentation for SPECT/CT LungVQ Image Analysis." Journal of Nuclear Medicine 61.supplement 1 (2020): 1489-1489.

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