Unsupervised Method of Automatic Lesion Segmentation and Quantification of Pathological COVID-19 Lung Tissue on Computed Tomography Scans

Department of Anesthesiology and Critical Care, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, PURM Funded Research (COL 2023)

Jiacheng Shen[1], Marc Connell[1], Yi Xin[1], Kevin T. Martin[1], Sarah E. Gerard[1], Paolo Delvecchio[1], Shiraz Humayun[1], Mehrdad Pourfathi[1], Ankit Kayastha[1], Giacomo Bellani[1], Rahim R. Rizi[1], Maurizio Cereda[1]

Introduction

Quantitative CT characterization of COVID-19 patients plays an important role in informing prognostication and treatment plans. Pulmonary lesion segmentation from the surrounding non-pathologic tissue is a critical step in CT analysis. Previous lesion segmentation methods in COVID-19 CT utilized supervised approaches involving manual segmentation, which is expensive, time-consuming, prone to bias, and requires radiology experts. Therefore, introducing an unsupervised segmentation method can greatly improve the efficiency of image analysis workflows and offer clinicians a valuable tool during pandemic conditions with high patient volumes.

Lesion Segmentation Processing

CycleGAN, a cycle-consistent generative adversarial network, is trained to convert COVID-19 scans into their "healthy" equivalents without manual fixation. Subtraction of generated control images from their corresponding original CT scans yielded maps of pathological tissue, without background lung parenchyma, fissures, airways, or vessels. These maps could then construct 3D lesion segmentations used for further automated quantitative characterization of COVID-19 lesions. We then explore several other uses of this technology including whole-lung segmentation, patient matching, and data augmentation.

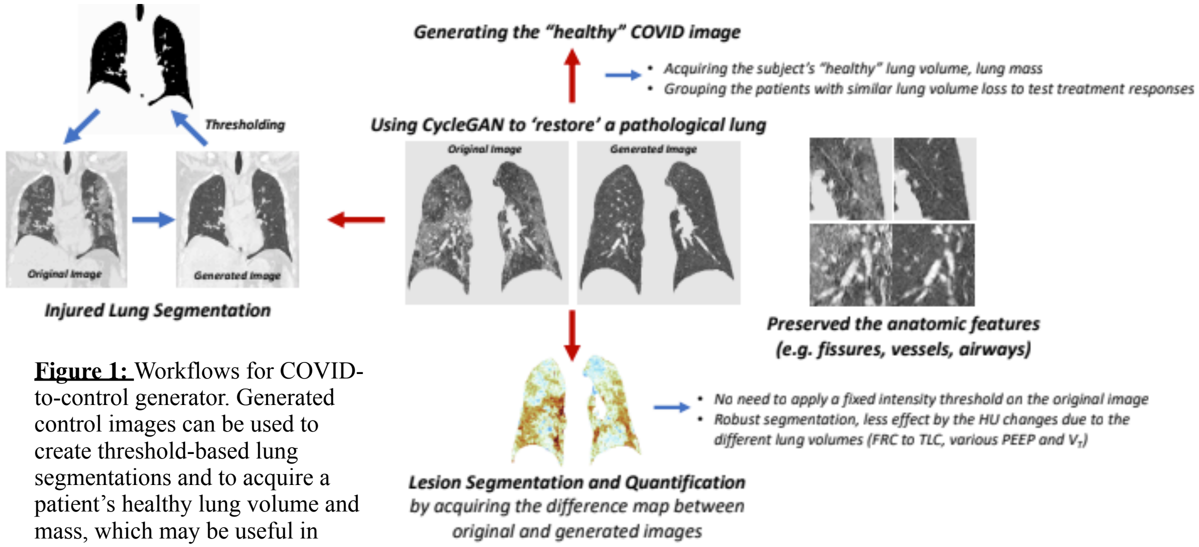
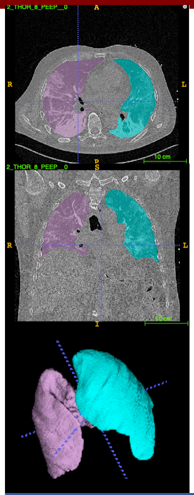


Figure 1: Workflows for COVID-to-control generator. Generated control images can be used to create threshold-based lung segmentations and to acquire a patient's healthy lung volume and mass, which may be useful in grouping patients to test treatment responses.

Dataset



COVID-19 Group: De-identified chest CT scans from 53 patients with SARS-CoV-2 infections from University of Milano-Bicocca and the Hospital of San Gerardo.
Control Group: 87 inspiratory chest CT scans from 28 unique patients from the COPDGene dataset.

Figure 2: Representative CT scans of COVID-19 patients (axial & coronal view with mask) and the model generated model. A set of control models were generated manually to determine whether the COVID-to-control generator altered scans with normal radiological features.

Conclusion

To our knowledge, this is the first approach that describes unsupervised COVID-19 lesion segmentation. The scale of data available to be used in this technique is not limited by the resources required to obtain manual segmentations; it can improve simply by retraining the model on more unmodified clinical data. With more training, this model will continue to improve in its performance, and can help diagnose COVID-19 patients faster with better treatment managements, lowering mortality in the ICU.