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Utilizing Deep Learning for Comprehensive Lung and Lesion Quantification in Computerized Tomography Amidst Inconsistent Ground Truth

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Abstract

Computed Tomography (CT) imaging plays a pivotal role in diagnosing, characterizing, predicting outcomes, and tracking disease progression in individuals affected by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Yet, for a consistent and dependable assessment of pulmonary irregularities, precise segmentation and quantification of both the complete lung and lung lesions (anomalies) in chest CT scans of COVID-19 patients are indispensable. Regrettably, the manual segmentation and quantification of extensive datasets can prove time-intensive and yield low levels of agreement both between different observers and within the same observer, even among experienced radiologists.

Keywords: CT • Covid-19 • Diagnosis

Introduction

Accurately segmenting all lesions within a large area of interest in a single high-resolution chest CT scan can be a time-consuming process, often spanning several hours. Consequently, automated segmentation techniques are indispensable for unleashing the full potential of CT imaging in both preclinical and clinical investigations related to COVID-19. Several deep learning-based segmentation methods have emerged to automate the segmentation of both the entire lung and lung lesions. Notably, there is a dual-branch combination network (DCN) designed for COVID-19 diagnosis, capable of simultaneously performing diagnostic classification and lesion segmentation. Additionally, a federated, semi-supervised learning framework for COVID-19 lung-lesion segmentation has been developed, capitalizing on shared model weights, which proved more effective compared to fully supervised approaches with traditional data sharing. Another noteworthy innovation is the novel COVID-19 lung-lesion segmentation deep network known as Inf-Net, engineered to automatically identify abnormal regions within chest CT slices. Experimental findings underscore the enhanced learning capabilities and performance achieved by the semi-supervised Inf-Net framework [1].

Numerous deep learning-based segmentation methods have emerged to automate the segmentation of both the entire lung and lung lesions (abnormalities). For example, a dual-branch combination network (DCN) has been introduced for COVID-19 diagnosis, capable of performing diagnostic classification and lesion segmentation simultaneously. Furthermore, a federated, semi-supervised learning framework has been developed for COVID-19 lung-lesion segmentation, effectively leveraging shared model weights in comparison to fully supervised approaches with conventional data sharing. Another innovative contribution is the introduction of Inf-Net, a deep network specifically designed for COVID-19 lung-lesion segmentation, automating the identification of abnormal regions in chest CT slices. Experimental results underscore the improved learning capabilities and performance achieved through the semi-supervised Inf-Net framework [2].

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Literature Review

Computed tomography (CT) imaging is extensively employed in the diagnosis, characterization, and monitoring of diseases, including COVID-19. Precise segmentation and quantification of both the entire lung and lung lesions within chest CT images of COVID-19 patients are indispensable for ensuring a consistent and dependable assessment of pulmonary irregularities. However, manual segmentation and quantification can consume valuable time and yield low inter- and intra-observer consensus, even among seasoned radiologists. In this context, automated segmentation methods rooted in deep learning have garnered significant attention. Multiple deep learning-based segmentation techniques have been put forth to automate the segmentation of both the entire lung and lung lesions. Notably, a dual-branch combination network (DCN) was introduced for COVID-19 diagnosis, capable of concurrently performing diagnostic classification and lesion segmentation. This approach has demonstrated promising outcomes in accurately delineating lung lesions in COVID-19 patients. Similarly, a federated, semi-supervised learning framework was devised for COVID-19 lung-lesion segmentation. Leveraging shared model weights within this framework led to enhanced performance compared to fully supervised scenarios with traditional data sharing. Another noteworthy innovation is the creation of Inf-Net, a novel deep network explicitly tailored for the automatic identification of abnormal regions within chest CT slices. The semi-supervised Inf-Net framework was found to augment the model's learning capability and overall performance [3].

Deep learning-based segmentation methods hold the potential to substantially elevate the precision and efficiency of lung segmentation and lesion quantification in CT images. A fundamental advantage of deep learning lies in its capacity to discern intricate features and patterns within data, thus enabling accurate segmentation and quantification of lung irregularities. Furthermore, deep learning-based techniques facilitate the complete automation of CT image segmentation, diminishing the necessity for manual intervention and enhancing overall efficiency. Nevertheless, it's important to acknowledge that deep learning-based segmentation methods demand substantial quantities of labeled data for training, a task that can be challenging to accomplish, especially when dealing with COVID-19 imaging data. Additionally, the inconsistent nature of ground truth data in COVID-19 imaging can pose a hurdle for deep learning-based approaches. Nonetheless, various strategies have been proposed to confront these challenges, including the adoption of semi-supervised and transfer learning methods [4].

Discussion

Deep learning-based segmentation methods hold considerable potential for achieving precise and efficient quantification of the entire lung and lung lesions in CT imaging, particularly within the context of COVID-19. These techniques have the capacity to facilitate the diagnosis, monitoring, and prognostication of COVID-19 patients and may extend their utility to broader applications within the realm of medical imaging. However, addressing the challenges associated with acquiring labeled data and handling the variability in ground truth data in COVID-19 imaging remains an imperative research endeavor.

To create a fully automated deep learning-based segmentation and quantification approach tailored for non-human primates (NHP), an extensive dataset of NHP chest CT scans annotated with lung and lesion regions could serve as the foundation for training a deep neural network. The methodology might initiate with preprocessing the NHP chest CT scans, encompassing noise reduction, normalization, and resizing to ensure uniformity in image size and quality. Subsequently, the deep neural network could undergo training on this preprocessed dataset, aiming to accurately segment both the complete lung and lung lesions. This neural network could comprise multiple convolutional layers, featuring pooling and activation functions to extract pertinent features from the input CT images. The concluding layer might constitute a segmentation layer, producing a binary mask outlining the lung and lesion regions. Assessing the trained model's performance on a validation dataset and fine-tuning hyperparameters would be crucial steps to optimize the model's effectiveness [5,6].

Conclusion

Once the model has undergone training and validation, it can be harnessed for the automated segmentation and quantification of both the complete lung and lung lesions in NHP chest CT scans. This method can be deployed across a substantial NHP cohort to derive quantitative metrics encompassing lung volume, density, and lesion burden. These metrics can be invaluable for disease progression monitoring, treatment efficacy assessment, and providing insights into preclinical investigations. In essence, a fully automated deep learning-based method, tailored specifically for NHPs, for whole lung and lung lesion segmentation and quantification holds substantial promise, offering distinct advantages over manual segmentation techniques, notably heightened efficiency, uniformity, and precision. This approach possesses the potential to advance our comprehension of lung diseases in NHPs and contribute to the development of innovative therapies for human respiratory ailments.

Acknowledgement

None.

Conflict of Interest

None.

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