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Application of Deep Learning for Whole-Lung and Lung-Lesion Quantification in Computerized Tomography despite Inconsistent Ground Truth

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Abstract

Computed Tomography (CT) imaging is a crucial tool for diagnosing, characterizing, prognosticating and monitoring disease progression in patients infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). However, to evaluate lung abnormalities in a consistent and reliable manner, accurate segmentation and quantification of both the entire lung and lung lesions (abnormalities) in chest CT images of COVID-19 patients is necessary. Unfortunately, manual segmentation and quantification of a large dataset can be time-consuming and have low inter- and intra-observer agreement, even for 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 take several hours. Hence, automated segmentation methods are crucial for unlocking the full potential of CT imaging in preclinical and clinical research on COVID-19. Many deep-learning-based segmentation methods have been proposed for automated segmentation of the whole lung and lung lesions. Regarding lung lesions, a dual-branch combination network (DCN) for COVID-19 diagnosis that can simultaneously achieve diagnostic classification and lesion segmentation has been proposed. A federated, semi-supervised learning framework for COVID-19 lung-lesion segmentation has also been developed. That framework was effective via shared model weights, compared with fully supervised scenarios with conventional data sharing. A novel COVID-19 lung-lesion segmentation deep network (Inf-Net) was reported to automatically identify abnormal regions from chest CT slices. Experimental results demonstrated that the semi-supervised Inf-Net framework improved learning ability and performance [1].

Numerous deep-learning-based segmentation methods have been proposed to automate the segmentation of both the entire lung and lung lesions (abnormalities). For instance, a dual-branch combination network (DCN) was introduced for COVID-19 diagnosis, which could perform diagnostic classification and lesion segmentation simultaneously. Furthermore, a federated, semi-supervised learning framework was developed for COVID-19 lung-lesion segmentation, which effectively utilized shared model weights compared to fully supervised scenarios with conventional data sharing. Another novel COVID-19 lung-lesion segmentation deep network (Inf-Net) was designed to automatically identify abnormal regions in chest CT slices. Experimental results revealed that the semi-supervised Inf-Net framework improved the learning ability and performance of the model [2].

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Literature Review

Computed tomography (CT) imaging is widely used for the diagnosis, characterization and monitoring of diseases, including COVID-19. Accurate segmentation and quantification of both the whole lung and lung lesions in chest CT images of COVID-19 patients are crucial for evaluating lung abnormalities in a consistent and reliable manner. However, manual segmentation and quantification can be time-consuming and have low inter- and intra-observer agreement, even for experienced radiologists. In this context, automated segmentation methods based on deep learning have gained attention. Numerous deep-learning-based segmentation methods have been proposed for the automated segmentation of both the entire lung and lung lesions. For instance, a dual-branch combination network (DCN) was introduced for COVID-19 diagnosis, which could perform diagnostic classification and lesion segmentation simultaneously. This approach has shown promising results in accurately segmenting lung lesions in COVID-19 patients. Similarly, a federated, semi-supervised learning framework was developed for COVID-19 lung-lesion segmentation. This framework effectively utilized shared model weights, resulting in improved performance compared to fully supervised scenarios with conventional data sharing. Another novel deep network, called Inf-Net, was designed to automatically identify abnormal regions in chest CT slices. The semi-supervised Inf-Net framework was found to improve the learning ability and performance of the model [3].

Deep-learning-based segmentation methods have the potential to significantly improve the accuracy and efficiency of lung segmentation and lesion quantification in CT images. One of the key advantages of deep learning is that it can learn complex features and patterns in data, allowing for accurate segmentation and quantification of lung abnormalities. Furthermore, deep learning-based methods can be used to segment CT images in a fully automated manner, reducing the need for manual intervention and increasing efficiency. However, deep learning-based segmentation methods require large amounts of labeled data for training, which can be challenging to obtain, particularly for COVID-19 imaging data. Additionally, the inconsistent ground truth in COVID-19 imaging data can pose a challenge for deep learning-based methods. Nevertheless, several approaches have been proposed to address these challenges, including semi-supervised and transfer learning methods [4].

Discussion

Deep learning-based segmentation methods hold significant promise for accurate and efficient whole-lung and lung-lesion quantification in CT imaging, particularly in the context of COVID-19. These methods can potentially facilitate the diagnosis, monitoring and prognostication of COVID-19 patients and may have broader applications in the field of medical imaging. However, further research is needed to address the challenges of obtaining labeled data and dealing with inconsistent ground truth in COVID-19 imaging data.

A fully automated deep-learning-based whole-lung and lung-lesion segmentation and quantification method that is specific to non-human primates (NHP) could be developed by training a deep neural network on a large dataset of NHP chest CT scans with annotated lung and lesion regions. The method could begin with pre-processing the NHP chest CT scans, including noise reduction, normalization and resizing, to ensure consistency in image size and quality. The deep neural network could then be trained on this pre-processed dataset, with the goal of accurately segmenting the entire lung and lung lesions. The deep neural network could consist of multiple convolutional layers, with pooling and activation functions to extract relevant features from the input CT images. The final layer could be a segmentation layer, which outputs a binary mask of the lung and lesion regions. The performance of the trained model could be evaluated on a validation dataset and hyperparameters could be tuned to optimize the model's performance [5,6].

Conclusion

Once the model has been trained and validated, it could be used for automated segmentation and quantification of the entire lung and lung lesions in NHP chest CT scans. The method could be applied to a large cohort of NHPs to generate quantitative metrics for lung volume, density and lesion burden. These metrics could be used to monitor disease progression, evaluate the efficacy of treatments and inform preclinical studies. Overall, a fully automated deep-learning-based whole-lung and lung-lesion segmentation and quantification method specific to NHPs could offer significant advantages over manual segmentation methods, including increased efficiency, consistency and accuracy. This approach has the potential to improve our understanding of lung disease in NHPs and inform the development of novel therapies for human respiratory diseases.

Acknowledgement

None.

Conflict of Interest

None.

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