Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Lack of AI-based method for pneumocystis pneumonia classification in radiological diagnosis of SARS-CoV-2

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To the Editor,

We have read the letter to the Editor entitled "Pneumocystis pneumonia: an important consideration when investigating artificial intelligence-based methods in the radiological diagnosis of COVID-19" with great interest and we thank the authors for their comments and suggestions. However, we would like to add the following information about the differentiation between SARS-CoV-2 and pneumocystis pneumonia diagnosis using AI-based approaches.

First, our study[1] focuses on reviewing the main radiological features of severe acute respiratory syndrome coronavirus (SARS-CoV-2) infection revealed by various imaging modalities as well as the role of artificial intelligence (AI) approaches in the diagnosis of this virus. For this reason, we have paid more attention to the published studies on AI-based methods for SARS-CoV-2 classification.

Indeed, the main works published in the literature have focused only on the binary classification of CXR or CT images (SARS-CoV-2 vs Normal) while other researchers have developed multi-classification approaches of images into SARS-CoV-2, viral pneumonia, and bacterial pneumonia. However, few works have mentioned other rare pneumonia types such as fungal pneumonia, including pneumocystis pneumonia (PCP), on classification.

This may be due to a variety of reasons. As a matter of fact, it is obvious that it is difficult to differentiate between the two infections, especially in the context of an epidemic emergency. PCP is an unusual case of pneumonia caused by fungus. This infection is commonly associated with the acquired immunodeficiency syndrome (AIDS) epidemic especially among patients with lymphocyte counts (CD4) below 200/mm^3.[2] It has also emerged as a concern in patients without Human Immunodeficiency Virus (HIV), particularly immunosuppressed patients (transplant patients).[3]

Concerning the *Pneumocystis jirovecii* and SARS-CoV-2 co-infection, there are only six cases reported in the literature, 4 of which were HIV positive (3 newly diagnosed cases).[4] Pneumocystis pneumonia occurred after SARS-COV-2 infection treated by tocilizumab and glucocorticoids in one case of them.[5] Therefore, this association is not that frequent compared with bacterial coinfection and prescribing trimethoprim-sulfamethoxazole systematically seems to be abusive. However, we should consider this coinfection particularly when there are other clinical characteristics such as elevated lactate dehydrogenase, cystic findings on chest computed tomography or very low lymphocyte count.[6] A routine HIV screening for patients with severe acute respiratory failure secondary to SARS-COV-2 infection may help early detection of associated pneumocystis pneumonia and thus improve the prognosis.

Clinically, the PCP shares some common clinical features with SARS-CoV-2 such as bilateral multifocal ground-glass opacities (GGO), paramediastinal cystic changes.[7] However, it is important to note that the GGO for the SARS-CoV-2 usually affects the peripheries of lung while the GGO for PCP tends to invade the lung peripheries and it is usually associated with cyst formation (20% of cases).[8] GGO for PCP is also associated with fine reticulations (Crazy Paving) although it takes extensive and severe forms for patients with SARS-CoV-2. Most importantly, vascular thromboembolic disease is more associated with SARS-CoV-2 cases. The following table summarizes the main differences between the two infections. (See Table 1.)

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Table 1
The main differences between clinical features of SARS-CoV-2 and PCP

	PCP	SARS-CoV-2
Clinical features	- The GGO is located in the lung peripheries and also associated with Crazy Paving - The subpleural space is spared in half patients with PCP.[9] - A formation of cyst is usually observed - Extensive and severe forms of Crazy Paving is observed - The PCP is characterized by an apical distribution	- The GGO tends to invade the lung peripheries. - The SARS-CoV-2 is more predominant in the basal regions

PCP infection is under considered by the AI community due to several reasons. The first is related to the fact that this infection is less common in clinical routine since it represents a small portion of community-acquired pneumonia. Therefore, only a limited medical image dataset is available.[10] Moreover, an important step to accurately detect pneumocystis pneumonia using AI is the segmentation of the lung and the lesions caused by this infection.However, PCP manifests by multifocal GGO in CT images, which make the segmentation of different lesions a more challenging task.[11]

Rahimzadeh et al. used a modified deep convolutional neural network (CNN) for detecting SARS-CoV-2 and pneumonia using chest Xray (CXR) images. In their study, they included 42 images from 25 cases with pneumocystis pneumonia.[12] Additionally, Punn et al. proposed a multi-class classification of CXR images to SARS-CoV-2, another type of pneumonia, tuberculosis and normal using a random and weighted class loss function approaches based on several deep learning approaches. The dataset used in this study includes different types of pneumoniae such as streptococcus spp. and pneumocystis and the results show an accuracy of 0.95.[13] Another interesting study developed by Öztürk et al.,[14] used a data augmentation approach to overcome the unbalanced dataset between the different classes of infections. In their study, they used a dataset including 101 SARS-CoV-2, 24 normal, 24 pneumocystis pneumonia, 43 SARS and 28 streptococcus CT images. Although the number of images is still limited in this study, the use of data augmentation could be a solution for other studies based on AI to produce a more balanced dataset that includes other less common pneumonia infections such as pneumocystis pneumonia.[15]

Finally, further works are needed to support the use of AI in aiding clinical decision of pneumocystis pneumonia.

References

[1] Benameur N, Mahmoudi R, Zaid S, Arous Y, Hmida B, Bedoui MH. SARS-CoV-2 diagnosis using medical imaging techniques and artificial intelligence: a review. Clin Imaging 2021;76:6–14. https://doi.org/10.1016/j.clinimag.2021.01.019.

[2] Masur H, Ognibene FP, Yarchoan R, et al. CD4 counts as predictors of opportunistic pneumonias in human immunodeficiency virus (HIV) infection. Ann Intern Med 1989;111(3):223–31.

[3] Tasaka S. Recent advances in the diagnosis and management of pneumocystis pneumonia. Tuberc Respir Dis (Seoul) 2020;83(2):132–40.

[4] Rubiano C, Tompkins K, Sellers SA, et al. Pneumocystis and severe acute respiratory syndrome coronavirus 2 coinfection: a case report and review of an emerging diagnostic dilemma. Open Forum Infect Dis 2021;8(1):1–5. https://doi.org/10.1093/ofid/ofaa633.

[5] Cai S, Sun W, Li M, Dong L. A complex COVID-19 case with rheumatoid arthritis treated with tocilizumab. Clin Rheumatol 2020;39:2797–802.

[6] Menon AA, Berg DD, Brea EJ, et al. A case of COVID-19 and *Pneumocystis jirovecii* coinfection. Am J Respir Crit Care Med 2020;202:136–8.

[7] Fisk DT, Meshnick S, Kazanjian P. *Pneumocystis carinii* pneumonia in AIDS patients in the developing world. Clin Infect Dis 2003;36:70–8.

[8] Salehi S, Abedi A, Balakrishnan S, Gholamrezanezhad A. Coronavirus disease 2019 (COVID-19): a systematic review of imaging findings in 919 patients. Am J Roentgenol 2019;2020:1–7.

[9] Papa A, Pozzessere C, Cicone F, et al. Not all that glitters is COVID! Differential diagnosis of FDG-avid interstitial lung disease in low-prevalence regions. Eur J Hybrid Imaging 2020:4(19). https://doi.org/10.1186/s41824-020-00088-6.

[10] Bhat P, Noval M, Doub JB, Heil E. Concurrent COVID-19 and *Pneumocystis jirovecii* pneumonia in a severely immunocompromised 25-year-old patient. Int J Infect Dis 2020;99:119–21.

[11] Menon AA, Berg DD, Brea EJ, et al. A case of COVID-19 and *Pneumocystis jirovecii* coinfection. Am J Respir Crit Care Med 2020;202(1):136–8.

[12] Rahimzadeh M, Attar A. A modified deep convolutional neural network for detecting COVID-19 and pneumonia from chest X-ray images based on the concatenation of Xception and ResNet50V2. Inform Med Unlocked 2020;19:100360.

[13] Punn NS, Agarwal S. Automated diagnosis of COVID-19 with limited posteroanterior chest X-ray images using fine-tuned deep neural networks. Appl Intell 2020. https://doi.org/10.1007/s10489-020-01900-3.

[14] Öztürk Ş, Özkaya U, Barstuğan M. Classification of coronavirus (COVID-19) from X-ray and CT images using shrunken features. Int J Imaging Syst Technol 2020. https://doi.org/10.1002/ima.22469.

[15] Mikołajczyk A, Grochowski M. Data augmentation for improving deep learning in image classification problem. In: International interdisciplinary PhD workshop (IIPhDW), Świnoujście, Poland; 2018. p. 117–22. https://doi.org/10.1109/IIPHDW.2018.8388338.