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Perfusion lung scans during the pandemic: COVID-19 experience in a large trauma hospital

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ABSTRACT

Purpose: To evaluate the results of perfusion only lung scans and the frequency of necessary addition of the ventilation part of the scans to diagnose acute pulmonary embolism (PE) during Corona Virus Disease of 2019 (COVID 19) pandemic.

Material and methods: We retrospectively reviewed perfusion lung scans' results between April to December 2020. The images were interpreted by two experienced nuclear medicine physicians as daily routine studies. Ventilation images were performed only if deemed necessary for accurate diagnosis of acute PE.

Results: A total of 128 lung perfusion scans in 127 patients were included. The scans were interpreted with certainty using the modified PIOPID criteria in 122 patients (95.3%). The results included low probability for acute PE in 110 patients (85.9%), normal in 6 patients (4.7%) and high probability of acute PE in 6 patients (4.7%). Ventilation imaging were performed in 4 patients with high probability, after negative testing for COVID19. The other 2 high probability results were confirmed clinically and with radiologic imaging. Only 6 scans (4.7%) were interpreted as intermediate perfusion scans, two of which due to inability to differentiate old from new perfusion defects in patients with chronic thromboembolic disease. Thus, the true indeterminate results due to the lack of ventilation scan were encountered in only 4 intermediate probability lung scans (3.1%). Thus, the total number of requested ventilation scans was 8 scans (6.2%) when considering both the high and intermediate probability interpretations. Six scans were performed (2 in the intermediate and 4 in the high probability scans). The two ventilation scans performed in the intermediate probability changed the diagnosis to low probability and the four performed in the high probability confirmed the initial interpretation of high probability scans by perfusion only.

Conclusion: The ventilation part of lung scans is required only in a small number of patients for certain interpretation of the result. Perfusion lung scans are sufficient for evaluation of acute PE with certainty in most patients.

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1. Introduction

A new fast spreading virus resulting in a global pandemic in the span of few weeks was added to the list of viral respiratory disease. The virus originated in Wuhan, China in year 2019 and was identified as the etiology of a severe acute respiratory syndrome coronavirus 2 (SARS 2) on January 7, 2020 (World Health Organization, n.d.-a; World Health Organization, n.d.-b). The World Health Organization declared a global health emergency on January 30, 2020. Subsequently the number of cases increased rapidly as a **Co**rona **Vi**rus **D**isease of 2019 (COVID 19) pandemic evolved throughout 30 countries to a total of 75,761 cases by February 20, 2020 and 2130 reported deaths (Gardner, 2020). Respiratory droplets were soon identified as the main source of spread of the virus which alerted the nuclear medicine community to the possibility of spread of the disease during the use of xenon delivery machine to

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perform the ventilation part of a lung scan. Spread of disease was alerted with the use of Tc-99m diethylene triamine pentaacetate (DTPA) aerosol as well. The Society of Nuclear Medicine and Molecular Imaging (SNMMI) responded promptly to the fast spread of pandemic by releasing a statement on March 19, 2020 to perform ventilation scans only when it is necessary to diagnose pulmonary embolism (PE) (2021).

Surely, this was the most difficult time when many patients are presenting with shortness of breath and there was a desperate need to differentiate those suffering from COVID 19 only, acute PE or both for appropriate management of those patients. Many institutions including our large trauma hospital opted to performing perfusion only lung scans as per the recommendations of the SNMMI statement with ventilation scans performed only when necessary to ensure accurate diagnosis of acute PE.

Our observation was that we rarely needed ventilation scans to confirm or rule out the diagnosis of acute PE during the period of the pandemic. Therefore, we systematically evaluated and reviewed the results of our perfusion first lung scans and how it impacted our interpretations of lung scans and the patients' final diagnosis during the pandemic period.

2. Materials and Methods

After obtaining our institution review board approval, we retrospectively collected data from all consecutive lung scans performed between April and December 2020 during the peak of the pandemic period in the USA. During this period, we performed perfusion lung scans first followed by ventilation scan only if the patient tested negative for COVID 19 and the ventilation part of the study was deemed necessary by the interpreting nuclear medicine physician when segmental or subsegmental perfusion defects were seen on the perfusion scan. Perfusion planar images in the routine 8 projections around the lungs were performed for the patients after administration of 85.1–225.7 MBq (2.3–6.1 mCi) of Technetium 99m macroaggregated albumin (Tc-99m MAA). Three patients had mobile camera scans with 3 static images in the anterior, and two anterior oblique projections acquired for 500K counts. If required, the ventilation scan was performed in COVID 19 test negative patients using xenon 133 (Xe-133) gas, with a dose range of 370–740 MBq (10–20 mCi). Posterior and anterior static images of the lungs were obtained in the breath hold, equilibrium and wash out phases of the study. The scans were interpreted by 2 experienced nuclear medicine physicians as routine standard of care studies on a daily basis using the modified PIOPID criteria (Sostman et al., 2008). The interpreting physician was able to view the patients' clinical information and the findings from other imaging studies prior to interpretation of the perfusion scan and prior to making the determination for the need for a ventilation scan. If required, ventilation studies were performed on a different day following the perfusion scan and ensuring a COVID negative status with a recent test.

We retrospectively collected consecutive patients' demographic data, clinical indications, results of the perfusion scans, and the number of ventilation scans needed to make a certain diagnosis of acute PE. We also collected the results of the ventilation scans and if the addition of the ventilation scan has changed the initial interpretation of the perfusion only scan.

2.1. Statistical analysis

Descriptive statistics was used to analyze the collected data and evaluate the results. This included calculation of means, medians and percentages.

3. Results

A total of 128 lung perfusion scans in 127 patients were performed at our institution, including 68 female and 59 male patients with average age of 61 yr. Perfusion scans were performed for 99 inpatients, 25 outpatients and 3 emergency room patients. The indications were variable and are summarized in Table 1. The interpretation results included low probability for acute PE in 110 perfusion scans (85.9%), normal in 6 scans (4.7%), intermediate probability in 6 scans (4.7) and high probability of acute PE in 6 scans (4.7%) (Fig. 1). The scans were interpreted with certainty in 122 perfusion only scans out of 128 total perfusion scans (95.3%). These included the scans interpreted as normal (6), low (110) and high probability (6) perfusion scans. The interpreting nuclear medicine physician was uncertain of the presence of acute PE in six scans interpreted as intermediate probability (4.7%). Two of these scans were followed by ventilation scans which changed the interpretation to low probability. Two other patients had history of chronic thromboembolic phenomenon where the addition of a ventilation scan would not help in differentiating acute from chronic perfusion defects so a ventilation scan was not performed. The last two of the intermediate probability interpretations did not have ventilation scans performed per the discretion of the clinical team. Out of the six patients with high probability of acute PE, four patients, underwent a ventilation scan following the perfusion scan and confirmed the high probability for acute PE (Fig. 2). One patient had a clear change of his perfusion lung scan in one-month interval which confirm the incidence of acute PE (Fig. 3). The remaining patient with high probability interpretation was confirmed with pulmonary CTA and clinical suspicion. Thus, a total 8 (6.2%) ventilation lung scans were needed/requested by the nuclear medicine physician (four in the intermediate probability and 4 in the high probability scans) but 6 (4.7%) were performed (four in high probability scans and 2 in intermediate probability scans) after the perfusion scan at our institution during the period of the pandemic. The ventilation scan would have helped to increase the certainty of the interpreting physician in two patients with intermediate probability perfusion lung scans, but they were not performed.

4. Discussion

The results of our study indicate that ventilation scans are needed in a small percentage (6.2%) of all lung scans to confirm the diagnosis of acute PE. Despite the fact that a change of our imaging protocol to perfusion only lung scans and ventilation when needed was a necessary change during the pandemic, it was also an eye opener to a possible permanent and more practical approach to lung imaging for acute PE in the field of nuclear medicine. This can become a permanent change in lung imaging and would be beneficial and welcomed in the field to facilitate easier and faster diagnosis of acute PE. It would also be less demanding for the patients who are frequently short of breath and have difficulty in complying with the ventilation part of the study. Additionally, it may also be welcomed in many institutions to decrease the demand on performing pulmonary computed tomographic angiography (CTA) for imaging of acute PE to substitute it with more physiologic and rapid perfusion only lung scan in most patients with suspected acute PE.

Table 1
Indications for obtaining a lung scan during the pandemic interval at our institution.

Indication for Lung Scan	Number of perfusion scans (%)
Shortness of Breath	46 (35.9%)
Chest Pain	6 (4.6%)
Tachycardia	10 (7.8%)
Deep Vein Thrombosis	5 (3.9%)
Pulmonary Hypertension	13 (10.1%)
Hypoxia	10 (7.8%)
Chronic Thromboembolic Phenomenon (CTEP)	16 (12.5%)
Respiratory Failure	5 (3.9%)
Elevated D-Dimer	5 (3.9%)
Miscellaneous	12 (9.4%)
Total	**128**

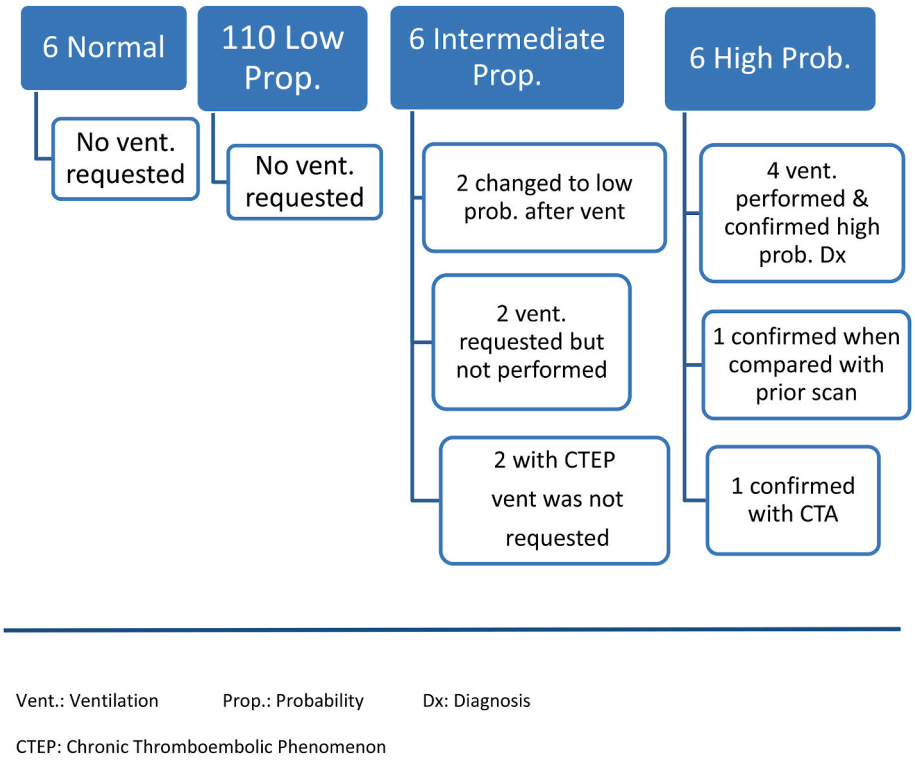

Fig. 1. The distribution of interpretation results of perfusion part of the lung scans with subsequent ventilation scans in our study population during COVID-19 pandemic.

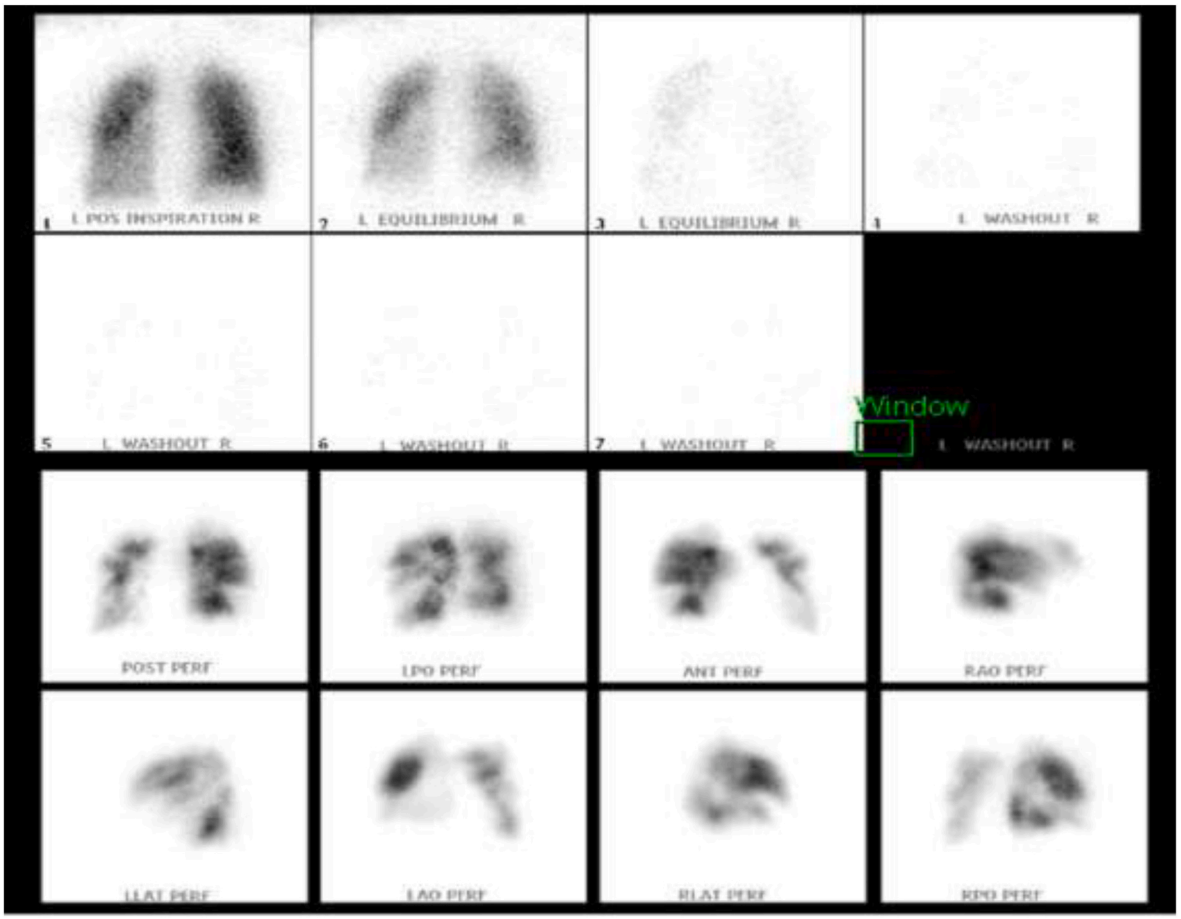

Fig. 2. High probability perfusion lung scan for acute PE, with ventilation performed after the perfusion, to confirm the diagnosis after proof of COVID negative test.

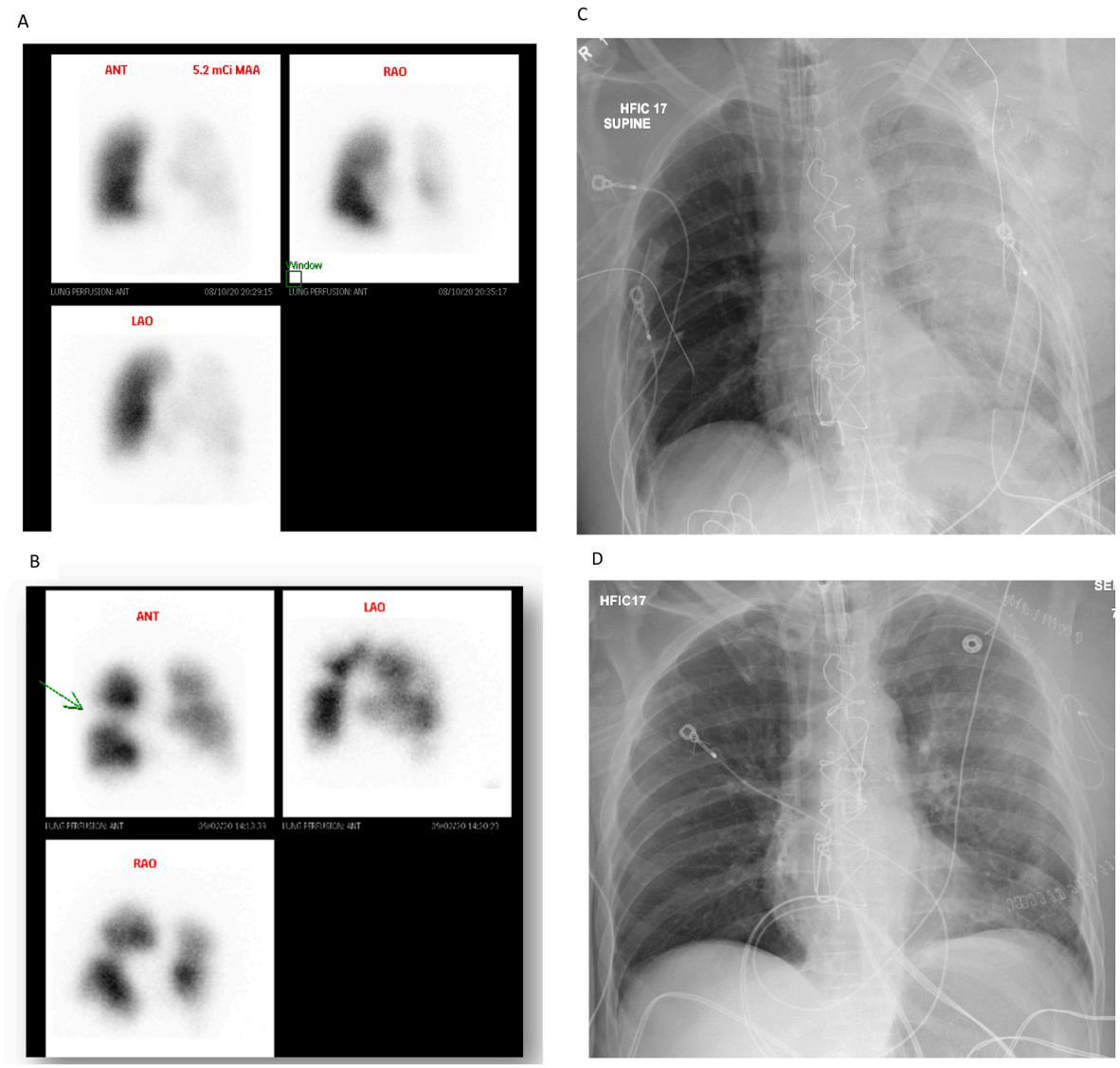

Fig. 3. Mobile camera perfusion scan with intermediate probability result (A) and subsequent high probability result (B) one month later with new perfusion defects involving the right middle lobe and superior segment of the right lower lobe. Corresponding chest x-ray with the first admission (C) and with the second admission (D). Ventilation scan was not performed during both admissions.

It would also reduce unnecessary room contamination with leaked xenon gas and reduce radiation exposure to the patients and personnel.

Perfusion lung imaging before ventilation imaging is routinely used when Tc-99m labelled radiotracers are used for the ventilation images e. g. Tc-99m DTPA aerosol or Tc-99m Technegas (Konstantinides et al., 2014; Parker et al., 1996). Kipper et al., described minimal Compton scatter from the Tc-99m MAA if performed immediately prior to Xe-133 ventilation scan. He concluded negligible effect on the ventilation image quality and the interpretation of the study (Kipper and Alazraki, 1982). Additionally, Lu et al., previously described an improved image quality using scatter correction algorithms when Xe-133 ventilation imaging is performed immediately after perfusion imaging with Tc-99m MAA (1997). Thus, perfusion first or perfusion only lung scans are a well-accepted practice in the field of nuclear medicine and possibly can be adopted as a routine standard of care for evaluation of acute PE.

As the pandemic continues to circulate and new mutations of the virus emerge, new routine practice of rapid testing for possible COVID 19 positive patients prior to using the Xe-133 ventilation machine are needed. Patients with COVID positive test and a need for a ventilation scan after perfusion may be triaged to pulmonary CTA or consider the use of perfusion SPECT CT imaging for further evaluation of acute PE (Kan et al., 2015; Bajc et al., 2009). Our results showed only six patients' scans were interpreted as intermediate probability (4.7%) and only four of them required ventilation studies, but the ventilation part was performed in only two of them (Kember et al., 1997; Quinn et al., 1991; Calvo et al., 2005). Clinical findings and/or pulmonary CTA were used in the remaining 4 patients to make the final diagnosis (Quinn et al., 1991; Cueto et al., 2001; Powell et al., 2003; Robinson, 1996). In the high probability scans, the segmental pattern of the perfusion defects was convincing of the presence of acute PE (Fig. 1) but the ventilation scan was performed for confirmation of the diagnosis (Lensing et al., 1992; Roy et al., 2005). Although CTA is the usual first line study to evaluate for PE at our institution, a perfusion only scan has the added value of detecting both small peripheral and large PE, lack of contrast use and ability to evaluate large patients.

Interestingly, the incidence of intermediate and high probability interpretation was lower in our study (4.7%) compared to the previously reported in the literature of 10.5% intermediate and 28.8% high probability in Calve-Romeo et al. study (2005) and 16% high probability in Bocher et al., 1993. This could be due to the pandemic effect on clinical practice with an increasing cautious not to miss acute PE as an etiology of shortness of breath when many of the hospital admissions are mainly

due to shortness of breath secondary to COVID 19.

Limitations of our study is the retrospective nature of the study with less control on the variables of the study. However, our study is a good reflection of the daily routine performance of perfusion only lung scans during the pandemic time. We consider it as an unexpected opportunity for evaluation of perfusion first lung scintigraphy on a daily routine basis. Another limitation is the lack of assessment of interobserver or intra-observer agreement for the interpretation of the scans which is an inherent deficiency in the retrospective nature of this study.

However, we consider the large number of patients evaluated in this study during the pandemic is a strength of our study. Additionally, the fact that we continued to perform lung scintigraphy during the pandemic was an important contribution to patient management during this unprecedent time. We have also contributed to the care of many COVID 19 patients who are at increased risk of acute PE and deep vein thrombosis with the perfusion only scans (Bompard et al., 2020; Poissy et al., 2020; Suh et al., 2021; Filippi et al., 2021).

5. Conclusions

In conclusion, our study demonstrated that the perfusion part of lung scans is sufficient for evaluation of acute PE with certainty in most patients. The ventilation part of lung scans is required only in a small number of patients for certain diagnosis of acute PE.

Declaration of competing interest

None of the authors has any conflict of interest with the contents of this manuscript.

References

Bajc, M., Neilly, J. B., Miniati, M., Schuemichen, C., Meignan, M., & Jonson, B. (2009). EANM guidelines for ventilation/perfusion scintigraphy: Part 1. Pulmonary imaging with ventilation/perfusion single photon emission tomography. *European Journal of Nuclear Medicine and Molecular Imaging, 36*(8), 1356–1370.

Bocher, M., Shibley, N., & Chisin, R. (1993). The use of Xenon-133 ventilation scan performed immediately after Tc-99m MAA perfusion scan. *Clinical Nuclear Medicine, 18*(2), 157–158.

Bompard, F., Monnier, H., Saab, I., Tordjman, M., Abdoul, H., Fournier, L., Sanchez, O., Lorut, C., Chassagnon, G., & Revel, M.-P. (2020). Pulmonary embolism in patients with covid-19 pneumonia. *European Respiratory Journal, 56*(1), Article 2001365.

Calvo-Romero, J. M., Lima-Rodríguez, E. M., Bureo-Dacal, P., & Pérez-Miranda, M. (2005). Predictors of an intermediate ventilation/perfusion lung scan in patients with suspected acute pulmonary embolism. *European Journal of Emergency Medicine, 12*(3), 129–131.

Cueto, S. M., Cavanaugh, S. H., Benenson, R. S., & Redclift, M. S. (2001). Computed tomography scan versus ventilation-perfusion lung scan in the detection of pulmonary embolism. *Journal of Emergency Medicine, 21*(2), 155–164.

Filippi, L., Sartori, M., Facci, M., Trentin, M., Armani, A., Guadagnin, M. L., & Prandoni, P. (2021). Pulmonary embolism in patients with COVID-19 pneumonia: When we have to search for it? *Thrombosis Research, 206*, 29–32.

Gardner, L. (2020, January 23). *Mapping covid-19*. JHU CSSE. https://systems.jhu.edu/research/public-health/ncov/.

Kan, Y., Yuan, L., Meeks, J. K., Li, C., Liu, W., & Yang, J. (2015). The accuracy of V/Q SPECT in the diagnosis of pulmonary embolism: A meta-analysis. *Acta Radiologica, 56*(5), 565–572.

Kember, P. G., Euinton, H. A., & Morcos, S. K. (1997). Clinicians' interpretation of the indeterminate ventilation-perfusion scan report. *British Journal of Radiology, 70*(839), 1109–1111.

Kipper, M. S., & Alazraki, N. (1982). The feasibility of performing 133XE ventilation imaging following the perfusion study. *Radiology, 144*(3), 581–586.

Konstantinides, S. V., Torbicki, A., Agnelli, G., Danchin, N., Fitzmaurice, D., Galiè, N., Gibbs, J. S., Huisman, M. V., Humbert, M., Kucher, N., Lang, I., Lankeit, M., Lekakis, J., Maack, C., Mayer, E., Meneveau, N., Perrier, A., Pruszczyk, P., Rasmussen, L. H., … Spyropoulos, A. C. (2014). 2014 ESC guidelines on the diagnosis and management of Acute Pulmonary embolism. *European Heart Journal, 35*(43), 3033–3069.

Lensing, A. W., van Beek, E. J., Demers, C., Tiel-van Buul, M. M., Yakemchuk, V., Van Dongen, A., Coates, G., Ginsberg, J. S., Hirsh, J., & ten Cate, J. W. (1992). Ventilation-perfusion lung scanning and the diagnosis of pulmonary embolism: Improvement of observer agreement by the use of a lung segment reference chart. *Thrombosis & Haemostasis, 68*(3), 245–249.

Lu, H., Farison, J. B., & Dennis, M. J. (1997). Enhancement of Xe-133 ventilation lung scan image acquired after Tc-99m perfusion scan. *Biomedical Sciences Instrumentation, 33*, 118–125.

Parker, J. A., Coleman, R. E., Siegel, B. A., Sostman, H. D., McKusick, K. A., & Royal, H. D. (1996). Acute pulmonary embolism: Sensitivity and specificity of ventilation-perfusion scintigraphy in PIOPED II study. *Journal of Nuclear Medicine, 37*(11), 1906–1910.

Poissy, J., Goutay, J., Caplan, M., Parmentier, E., Duburcq, T., Lassalle, F., Jeanpierre, E., Rauch, A., Labreuche, J., Susen, S., & Lille Icu Haemostasis Covid-19 Group. (2020). Pulmonary embolism in patients with COVID-19: Awareness of an increased prevalence. *Circulation, 142*(2), 184–186.

Powell, T., & Müller, N. L. (2003). Imaging of acute pulmonary thromboembolism: Should spiral computed tomography replace the ventilation-perfusion scan? *Clinics in Chest Medicine, 24*(1), 29–v.

Quinn, R. J., & Butler, S. P. (1991). A decision analysis approach to the treatment of patients with suspected pulmonary emboli and an intermediate probability lung scan. *Journal of Nuclear Medicine, 32*(11), 2050–2056.

Robinson, P. J. (1996). Ventilation-perfusion lung scanning and spiral computed tomography of the lungs: Competing or complementary modalities? *European Journal of Nuclear Medicine, 23*(11), 1547–1553.

Roy, P. M., Colombet, I., Durieux, P., Chatellier, G., Sors, H., & Meyer, G. (2005). Systematic review and meta-analysis of strategies for the diagnosis of suspected pulmonary embolism. *BMJ, 331*(7511), 259.

SNMMI statement. (2021, September 22). Covid-19 and ventilation/perfusion (V/Q) lung studies. *SNMMI*. https://www.snmmi.org/NewsPublications/NewsDetail.aspx?ItemNumber=36714.

Sostman, H. D., Stein, P. D., Gottschalk, A., Matta, F., Hull, R., & Goodman, L. (2008). Acute pulmonary embolism: Sensitivity and specificity of ventilation-perfusion scintigraphy in PIOPED II study. *Radiology, 246*(3), 941–946.

Suh, Y. J., Hong, H., Ohana, M., Bompard, F., Revel, M.-P., Valle, C., Gervaise, A., Poissy, J., Susen, S., Hékimian, G., Artifoni, M., Periard, D., Contou, D., Delaloye, J., Sanchez, B., Fang, C., Garzillo, G., Robbie, H., & Yoon, S. H. (2021). Pulmonary embolism and deep vein thrombosis in covid-19: A systematic review and meta-analysis. *Radiology, 298*(2), 70–80.

World Health Organization. (n.d.-a). Pneumonia of unknown cause – China. WHO website, https://www.who.int/emergencies/disease-outbreak-news/item/2020-DON229.

World Health Organization. (n.d.-b). Unity studies: Early investigation protocols. WHO website, https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/early-investigations.