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.

Journal of Radiation Research and Applied Sciences 15 (2022) 293–298

Contents lists available at ScienceDirect

Journal of Radiation Research and Applied Sciences

journal homepage: www.journals.elsevier.com/journal-of-radiation-research-and-applied-sciences

The prevalence of pulmonary embolism among COVID-19 patients underwent CT pulmonary angiography

Samih Kajoak [a], Hamid Osman [a,*], Hanan Elnour [a], Amin Elzaki [a], Ahmad Joman Alghamdi [a], Mona Elhaj [a], Ahmad Alotaibi [a], Khaled Alboqami [a], Fahad Alturaiki [a], Ali Alsulaimani [a], Kholoud Alsulimany [b], Mayeen Udinn Khandaker [c], Sultan Alamri [a], Yasser Alzamil [d]

[a] Department of Radiological Sciences, College of Applied Medical Sciences, Taif University, P.O. Box: 11099, 21944, Taif, Saudi Arabia
[b] King Faisal Medical Complex, Taif, Saudi Arabia
[c] Centre for Applied Physics and Radiation Technologies, School of Engineering and Technology, Sunway University, Bandar Sunway, 47500, Malaysia
[d] Department of Diagnostic Radiology, College of Applied Medical Sciences, University of Hail, Saudi Arabia

ARTICLE INFO

Keywords:
Pulmonary embolism
CT Pulmonary angiography
COVID-19
Picture archiving and communication system
SPSS

ABSTRACT

Background: Pulmonary embolism (PE) is a common and fatal complication of COVID-19 infection. COVID-19's main clinical manifestations are not only pneumonia but also coagulation disorders. This study evaluates the prevalence of pulmonary embolism at CT pulmonary angiography (CTA) for positive coronavirus patients as well as the factors associated with PE severity.

Materials and methods: This is a retrospective cross-sectional study that was conducted at King Faisal Medical Complex (KFMC) in Taif city of Saudi Arabia from June 2020 to June 2021. Data was collected from the picture archiving and communication system (PACs) for a total of 445 positive patients who underwent CT pulmonary angiography and analyzed using SPSS.

Results: The mean age and gender of the male were 57.3 ± 15.8 years and 64.5%, respectively. The prevalence of pulmonary embolism at CTA among patients with COVID-19 was found to be 8.1%. Bilateral segmental and bilateral subsegmental pulmonary embolism were found to be the most common sites for PE (16.7% for each). Furthermore, shortness of breath (SOB) was found to be the most common reported symptom among the respondents. Lastly, shortness of breath, chest pain, loss of taste or smell, D-dimer, and cardiac troponin were found to be significantly associated with PE (P-value = < 0.001, <0.001, 0.001, <0.001 and 0.037 respectively).

Conclusion: Present results show that the prevalence of pulmonary embolism among COVID19 patients with CT Pulmonary Angiography at KFMC is relatively low (8.1%) and most of the patients were from the ICU department. Early detection and treatment of COVID-19 patients with PE and APE complications are critical for lowering the mortality rate.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a highly contagious disease caused by the SARS-CoV-2 virus that affects the respiratory system of the human body. Soon after the detection of the first case in Wuhan, China on the December 31, 2019, it has been spread quickly around the world and became a global pandemic (About the virus, 2022). On March 2, 2020, in Saudi Arabia, the first case was announced by the ministry of health, and as of July 31, 2022, the total number of confirmed cases was 810 K with about 9 K deaths.

The statistics show that Covid-19 patients had mild symptoms including fever, cough, fatigue, loss of taste/smell, and rhinorrhea (Lovato et al., 2020). In addition, some patients may develop respiratory failure. Although the underlying reason for respiratory deterioration

Peer review under responsibility of The Egyptian Society of Radiation Sciences and Applications.
* Corresponding author.
E-mail addresses: S.kajoak@tu.edu.sa (S. Kajoak), ha.osman@tu.edu.sa (H. Osman), hanour@tu.edu.sa (H. Elnour), a.zaki@tu.edu.sa (A. Elzaki), dr.ahmadjomanalghamdi@gmail.com (A.J. Alghamdi), mesheekh@tu.edu.sa (M. Elhaj), ahmad.j.511@hotmail.com (A. Alotaibi), kms91139@gmail.com (K. Alboqami), fahad.ttt777@gmail.com (F. Alturaiki), loly-alameen@hotmail.com (A. Alsulaimani), kalsulimany@moh.gov.sa, kholoudalsulimany@yahoo.com (K. Alsulimany), mu_khandaker@yahoo.com (M.U. Khandaker), S.alamri@tu.edu.sa (S. Alamri), y.alzamil@uoh.edu.sa (Y. Alzamil).

https://doi.org/10.1016/j.jrras.2022.08.002
Received 12 June 2022; Received in revised form 3 August 2022; Accepted 10 August 2022
Available online 17 August 2022

varies from person to person, the development of acute respiratory distress syndrome (ARDS), progression of viral pneumonia, and pulmonary emboli are considered major contributing factors. The diagnosis of ARDS, pneumonia and PE in COVID-19 patients is challenging with significant therapeutic implications. Consequently, several international guidelines recommend the use of low-dose non-enhanced CT (LDCT) for assessing the severity of COVID-19 pneumonia (Rubin et al., 2020; Vogel-Claussen et al., 2020). Therefore, PE can be ruled out as a cause of sudden respiratory deterioration. Moreover, the patients who suffer from severe pneumonia, show deficiency in some signs and symptoms that are needed to initiate diagnostic evaluation for PE. This kind of COVID-19 patients shows elevated levels of d-dimer (Yu et al., 2020).

Pulmonary embolism occurs when a blood clot (thrombus) causes a blockage in the main pulmonary artery or its bifurcation, this clot arises from deep leg veins in 95% of cases. PE affects about 300,000–600,000 humans every year and an estimated 100,000 deaths per year in the USA (Beckman et al., 2010), due to the inconsistency of signs and symptoms, resulting in the misdiagnosis by doctors. COVID-19 infections usually cause the coagulation system to be activated. This is known as COVID-19 hypercoagulability, and it results in many complications to the relevant COVID-19 patients followed by high mortality and morbidity rates (Connors & Levy, 2020).

Computed tomography pulmonary angiography (CTPA) provides many advantages over other modalities in diagnosing PE because it is fast, noninvasive, widely available, and includes direct visualization of the embolus cross-sections in multiple planes. Therefore, it is considered the best modality to diagnose patients with PE. Normal pulmonary vessels appear as a bright white when the contrast agent is injected unlike PE appears as a contrast filling defect (Albert et al., 2008) (Hamid, 2021). There is a lack of publication from our community according to literature available for authors, regarding the prevalence of PE, consequently the present study aims to investigate the prevalence of PE among COVID-19 patients who have undergone CTPA examinations and the factors associated with the severity of PE.

2. Materials and methods

This is a retrospective cross-sectional study to investigate the prevalence of PE in COVID-19 patients who have been examined by CT pulmonary angiography and the factors associated with the severity of PE. The study was conducted at King Faisal Medical Complex in Taif, from June 2020 to June 2021. The inclusion criteria of COVID-19 patients include males and females of age greater than 21 years. All data were collected from the picture archiving and communication system (PACS) for all patients who were tested positive for COVID-19 and underwent CT pulmonary angiography.

The search term “pulmonary embolism” was used to identify CT pulmonary angiography examinations performed from December 2020 to September 2021. The electronic medical record for the patients was reviewed to identify those who were confirmed to have COVID-19 infection by reverse transcription polymerase chain reaction (rt-PCR) testing of nasopharyngeal or oropharyngeal swab samples. Only the patients who tested positive for COVID-19 with rt-PCR were included in the study sample. Note that the King Faisal Medical Complex is the only designated center for the treatment of COVID-19 patients in Taif city and it is equipped with two CT machines dedicated to diagnosing COVID-19 patients only during the pandemic. The CTPA examination is performed as a protocol for any patient admitted to the hospital who had tested COVID-19 positive. It has been found that most patients are admitted to the hospital in the early stage of the COVID-19 symptom. The study was ethically approved by the administration of research and studies in the directorate of health affair-Taif city, Saudi Arabia.

CT Protocol: All examinations protocol were performed at the aforementioned King Faisal Medical Complex. Either 64 or 256 slices were obtained by computed tomography scanners (Siemens/GE) during the inspiration phase. The patient was supine and arms above the head and injected with 40–70 ml omnipaque (iohexol injection) contrast media (according to the patient’s weight) together with 20 ml of normal saline, the flow rate was 5 mL/s. The scan direction was caudocranial from the diaphragm to apices (slice thickness 0.6 mm).

3. Statistical analysis

The results are summarized as mean ± SD in the relevant tables shown in later sections. Data were analyzed by applying the standard Statistical Package for the Social Sciences (SPSS) version 23. The P-value of <0.001 was considered significant.

4. Results

In this study, a total of 445 participants were included. The mean age of respondents was 57.3 ± 15.8 years (range 21–112), most of them were males (64.5%) and 158 (35.5%) were females. Present results revealed that BI ground-glass opacity (BI GGO) was the most common reported CT finding among the participants (76.6%) followed by normal CT finding (11.9%), then pleural effusion shown by (11%) of respondents. Moreover, the CT findings demonstrated that only 6.5%, 5.2%, and 3.4% of participants showed bilateral pleural effusion, multifocal pneumonia, and ground-glass opacities (GGO) respectively **(Table 1).**

4.1. The prevalence of PE in COVID-19 patients experienced CTPA examinations

This study found that the prevalence of pulmonary embolism at CT pulmonary angiography was 8.1% among the patients with COVID-19 symptoms who were admitted to the King Faisal Medical Complex (KFMC) in Taif city of Saudi Arabia (see Fig. 1).

Pulmonary Embolism sites: Present results showed that bilateral segmental (16.7%) and bilateral subsegmental (16.7%) were equally the most common sites for Pulmonary Embolism among the respondents followed by bilateral segmental and subsegmental (13.9%), left lower segmental (8.3%), left lower subsegmental (8.3%), and right segmental (8.3%). On the other side, left segmental and left subsegmental were reported at (11%) collectively **(Table 2) (Figs. 2–5).**

Symptoms among the study population: Present results showed that shortness of breath (SOB) is the most common documented symptom among the respondents (66.5%). Almost the same proportion of participants (65.4%) experienced chest pain followed by the symptoms of loss of taste or smell (63.1%). Additionally, we found that cough,

Table 1
CT Findings under this retrospective study.

CT Findings	Frequency	Percent
1. Normal	53	11.9%
2. Gall bladder stone	12	2.7%
3. Pleural effusion	49	11%
4. Bilateral Pleural effusion	29	6.5%
5. Ground-glass Opacities	15	3.4%
6. Pulmonary Embolism	36	8.1%
7. Bilateral Ground-glass Opacities	341	76.6%
8. Cardiomegaly	12	2.7%
9. Bilateral subsegmental	1	0.2%
10. Renal cyst	12	2.7%
11. Fatty liver	5	1.1%
12. Nodule Breast	1	0.2%
13. Hilar calcified	1	0.2%
14. Hypoxia	2	0.4%
15. Dilated Aorta	5	1.1%
16. Paving opacities	15	3.4%
17. Hepatomegaly	8	1.8%
18. Spleen calcification	1	0.2%
19. Hiatus hernia	4	0.9%
20. Multifocal Pneumonia	23	5.2%

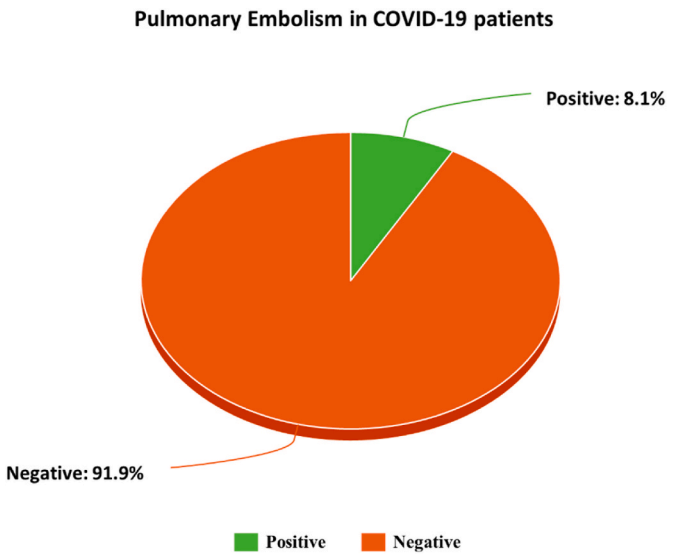

Fig. 1. The Prevalence of Pulmonary Embolism among the study population (n = 445).

Table 2
Pulmonary Embolism site (n = 36).

Pulmonary Embolism Site	Frequency	Percent
Bilateral Segmental	6	16.7%
Bilateral Segmental and Subsegmental	5	13.9%
Bilateral Subsegmental	6	16.7%
Left Lower Segmental	3	8.3%
Left Lower Subsegmental	3	8.3%
Bilateral Middle Subsegmental	1	2.8%
Left Segmental	2	5.5%
Left Subsegmental	2	5.5%
Left Upper Segmental	1	2.8%
Right Lower Segmental	1	2.8%
Right Lower Subsegmental - Segmental	1	2.8%
Right Segmental	3	8.3%
Right Segmental - Subsegmental	1	2.8%
Upper Segmental	1	2.8%
Total	36	100%

fever and headache were reported by nearly forty percent (40%) of the participants. Only 15.5% of respondents suffered from sore throats (Fig. 6). The prevalence of PE in COVID-19 patients in different studies is shown in Fig. 7.

Laboratory investigations: Based on the laboratory investigations, it has been found that the average level of D-dimer was 2.3 ± 3.2 uq/mL (range 0.2–18.6), the average level of Lactate dehydrogenase was 380.9 ± 177.4 U/L (range 148–1192) and the average level of Cardiac Troponin was 32 ± 107.6 pq/mL (range 3–801.8).

4.2. Association between demographic and clinical characteristics with pulmonary embolism

Present results have shown a non-significant association between demographic variables (age and gender) and pulmonary embolism among the study population. However, there was a positive significant association between pulmonary embolism and shortness of breath, chest pain and loss of taste or smell (P values = < 0.001, <0.001 and 0.001 respectively). Based on the laboratory test results, the D-dimer and Cardiac troponin levels revealed a significant association with pulmonary embolism (P values = < 0.001 and 0.037 respectively) as shown in Table 3. The pulmonary Embolism site compared to other studies is shown in Table 4.

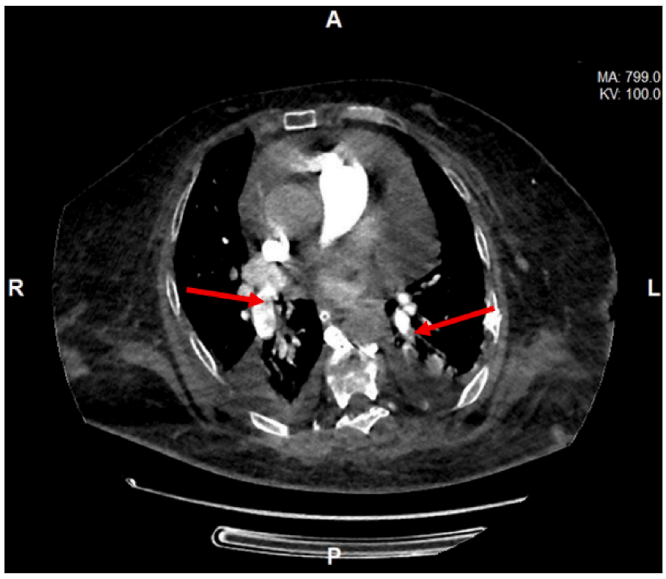

Fig. 2. CTPA of 60 years old female with covid demonstrates PE in the right middle and left lower segmental branches (red arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

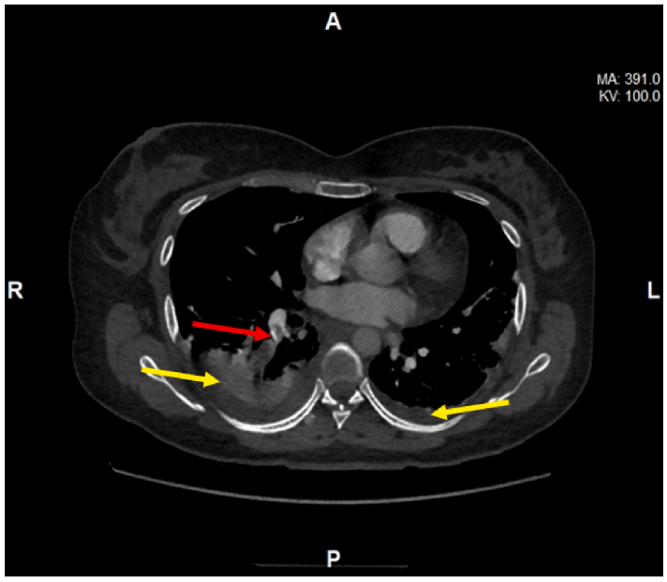

Fig. 3. CTPA of 38 years old female with Covid-19 demonstrates PE in the right descending pulmonary artery (red arrow) and mild bilateral pleural effusion (yellow arrows). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

5. Discussion

This is a retrospective cross-sectional study that assessed the prevalence of pulmonary embolism in patients who tested positive for coronavirus disease and were examined by CT pulmonary angiography at King Faisal Medical Complex (KFMC) in Taif city of Saudi Arabia. COVID-19 may predispose patients to thrombotic complications as a result of excessive inflammation, platelet activation, endothelial dysfunction, and stasis (Bikdeli et al., 2020). The impact of thrombotic complications is increasingly recognized as an important component of this disease, and a subset of patients who develop severe respiratory distress syndrome, sepsis, septic shock, and pulmonary embolism

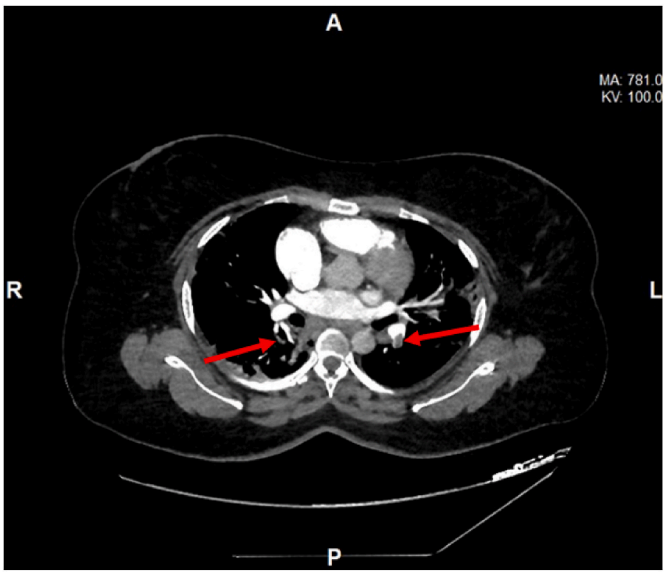

Fig. 4. CTPA of 37 years old female with Covid-19 demonstrates PE in the left lower and right lower segmental pulmonary artery (red arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

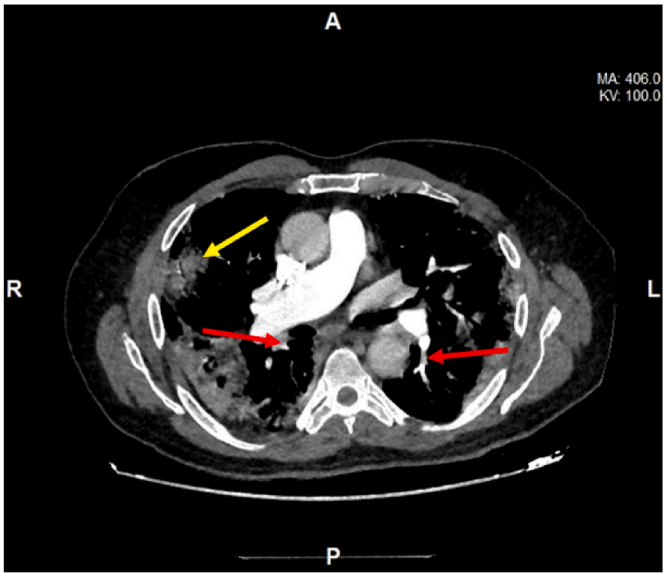

Fig. 5. CTPA of 69 years old male with Covid-19 demonstrates PE in the bilateral lower segmental branches (red arrow) and Ground Glass Opacification (yellow arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

requires more likely mechanical ventilation and critical care unit for recovery than the patients who do not have a pulmonary embolism (Awulachew et al., 2020).

A review of the literature shows that several studies from around the world have assessed the prevalence of PE in COVID19 patients only recently, beginning with a single case and small-series reports (Danzi et al., 2020; Fabre et al., 2020; Rotzinger et al., 2020; Ullah et al., 2020; Xie et al., 2020). In the current study, we found that the prevalence of PE at CT Pulmonary Angiography was 8.1% among patients with COVID-19. This prevalence was lower than in some other studies conducted in Saudi Arabia, with rates between 12% and 32% (Abohamr et al., 2021; Badr et al., 2021; Bukhari et al., 2021). Other studies in Italy, New York, Spain, and the UK revealed a very high prevalence of PE

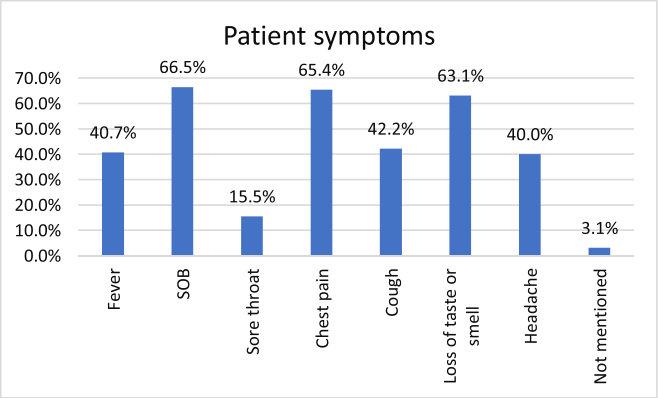

Fig. 6. Symptoms among the study population (n = 445).

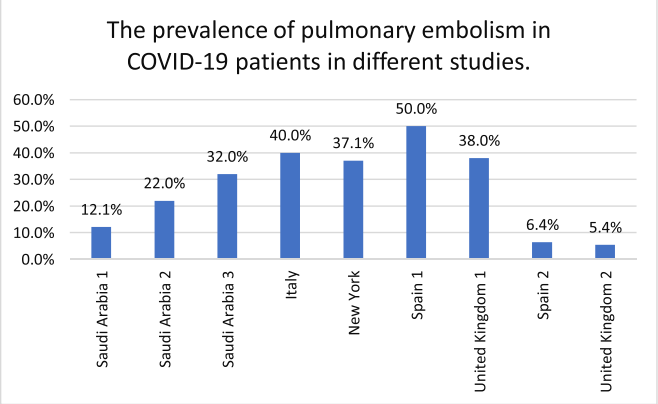

Fig. 7. The prevalence of pulmonary embolism in COVID-19 patients in different studies.

Table 3
Association between demographic and clinical characteristics with PE.

Variable		APE N = 36	Non-PE N = 409	P value
Demographic data:				
Age (years) (mean ± SD)		56.1 (16.3)	57.4 (15.7)	0.633
Gender, n (%)	Male	22 (61.1%)	265 (64.8%)	0.658
	Female	14 (38.9%)	144 (35.2%)	
Department	ICU	34 (94.4%)	401 (98%)	0.162
	Emergency	2 (5.6%)	8 (2%)	
Clinical presentation: n (%)				
Fever		20 (55.6%)	161 (39.4%)	0.058
SOB		35 (97.2%)	261 (63.8%)	**< 0.001**
Sore throat		3 (8.3%)	66 (16.1%)	0.215
Chest pain		35 (97.2%)	256 (62.6%)	**< 0.001**
Cough		20 (55.6%)	168 (41.1%)	0.092
Loss of taste or smell		32 (88.9%)	249 (60.9%)	**0.001**
Headache		18 (50%)	160 (39.1%)	0.201
Not mentioned		0 (0)	14 (3.4%)	0.259
Laboratory tests: median (in quartile range 25% - 75%)				
D-dimer test ug/ml		3.5 (1.1–7.1)	1.0 (0.7–1.9)	**< 0.001**
Lactate Dehydrogenase U/L		342 (267.5–420)	385.5 (278–522)	0.637
Cardiac troponin pg/ml		13.2 (8.5–52.5)	8.6 (6.1–12.2)	**0.037**

among COVID-19 patients, 40%, 37.1%, 50%, and 38% respectively (Alonso-Fernández et al., 2020; Kaminetzky et al., 2020; Masselli et al., 2021; Ooi et al., 2020). However, earlier studies in Spain and UK demonstrated a lower rate of PE prevalence 6.4% and 5.4% respectively among COVID 19 patients (Mestre-Gómez et al., 2020; Whyte et al.,

Table 4
Pulmonary Embolism site compared to other studies.

Pulmonary Embolism Sites	Our Findings	Spain	Saudi Arabia
Bilateral	50%	60%	72.7%
Segmental	30.5%	53%	27.3%
Subsegmental	13.9%	7%	None
Unilateral (Segmental - Subsegmental)	5.6%	None	None

2020, pp. 95–99) (see Fig. 7). This may indicate that the differences between these studies are due to variations in the clinical condition of the sample population, which is explained in a systemic review from the Netherlands which concluded that the frequency of PE in patients with COVID-19 is highest in the ICU, followed by general wards and the emergency department (Kwee et al., 2021, pp. 1–19). It has been found that the results of the systemic review are similar to our results, most PE patients 34 (94.4%) were from the intensive care unit and 2 (5.6%) were from the emergency department. Moreover, the effect of vaccines should be considered while calculating the reduction of prevalence and incidence of PE. It is assumed that some of the above-mentioned studies were conducted before the development and successful administration of COVID-19 vaccines. In addition, the observed frequency of PE also depends on the selection criteria for CT Pulmonary Angiography.

The current study revealed that Bilateral segmental and Bilateral subsegmental were the most common sites for PE in the current participants. A case-control study in Saudi Arabia has reported similar results to ours, namely that unilateral acute PE was seen in 3/11 cases, while bilateral distribution was seen in 8/11 cases. There were no emboli at the central level among 11 cases of acute PE, but there were three cases of PE at the lobar level, three cases at the segmental level, and five cases at the lobar, segmental, and subsegmental levels (Darwish et al., 2021, pp. 1–5). Another study in Spain supported this finding (Alonso-Fernández et al., 2020) (Table 4).

Several studies have reported that D-dimer levels are significantly associated with pulmonary embolism in COVID-19 patients (Alonso--Fernández et al., 2020; Darwish et al., 2021, pp. 1–5; Masselli et al., 2021). The D-dimer level appears to be an important parameter in the management of COVID-19 patients, allowing both the severity of the disease (Zhou et al., 2020) and the suspicion of acute pulmonary embolism (APE). Given that an increase in D-dimer levels has been linked to COVID-19, it would be interesting to see if there is a cut-off D-dimer level at which CTPA could be recommended to look for APE in COVID-19 patients based on large-scale studies (Leonard-Lorant et al., 2020). Moreover, we found other associated factors with PE such as shortness of breath, chest pain, loss of taste or smell, and cardiac troponin level. Also, another study in Saudi Arabia (Abohamr et al., 2021) showed a significant association between PE in COVID-19 patients and cardiac troponin levels, which is in agreement with the present study. This indicates that more studies are needed to have a better understanding of the pathophysiology of PE among COVID-19 patients.

6. Conclusion

This study shows that the prevalence of pulmonary embolism among COVID-19 patients diagnosed by CT Pulmonary Angiography at King Faisal Medical Complex in Taif city of Saudi Arabia is relatively low (8.1%) and most of the patients were from the ICU department. Preventive measures should be considered for hospitalized patients who have shortness of breath, chest pain, loss of taste or smell, and elevated D-dimer and cardiac troponin levels. Early detection and treatment of COVID-19 patients with PE and APE complications are critically needed for lowering the mortality rate. More studies are needed to assess the risk factors and thrombosis mechanisms associated with the COVID-19 symptoms.

7. Limitations

Due to the retrospective study design, it was not possible to establish a causal relationship between COVID-19 and pulmonary embolism. Furthermore, the present study utilized the data that was obtained only from King Faisal Medical Complex in Taif, which is recognized as the COVID-19 Center in Taif city of Saudi Arabia. Data obtained from several designated hospitals may provide more accurate results by removing any possible bias with many known/unknown local/regional factors.

Acknowledgements

The authors deeply acknowledge Taif University for supporting this research through Taif University Researchers Supporting project number (TURSP-2020/287), Taif University, Taif, Saudi Arabia.

References

Abohamr, S. I., Aldossari, M. A., Amer, H. A., Saadeddin, H. M., Abdelhamid, S. W., Bhat, F. A., & Abdul Aziz Elsheikh, E. (2021). The incidence of acute pulmonary embolism with COVID-19 pneumonia in Saudi Arabia: A retrospective single-center study. *Journal of the Saudi Heart Association, 33*(2), 128–134. https://doi.org/10.37616/2212-5043.1253

Albert, R. K., Spiro, S. G., & Jett, J. R. (2008). Clinical respiratory medicine. *Clinical Respiratory Medicine, 61*, 763–781.

Alonso-Fernández, A., Toledo-Pons, N., Cosío, B. G., Millán, A., Calvo, N., Ramón, L., de Mendoza, S. H., Morell-García, D., Bauça-Rossello, J. M., Núñez, B., Pons, J., Palmer, J. A., Martín, L., Peñaranda, M., Pou, J. A., Sauleda, J., & Sala-Llinas, E. (2020). Prevalence of pulmonary embolism in patients with COVID-19 pneumonia and high D-dimer values: A prospective study. *PLoS One, 15*(8), Article e0238216. https://doi.org/10.1371/journal.pone.0238216

Awulachew, E., Diriba, K., Anja, A., Getu, E., & Belayneh, F. (2020). Computed tomography (CT) imaging features of patients with COVID-19: Systematic review and meta-analysis. *Radiology Research and Practice*, 1–8. https://doi.org/10.1155/2020/1023506, 2020.

Badr, O. I., Alwafi, H., Elrefaey, W. A., Naser, A. Y., Shabrawishi, M., Alsairafi, Z., & Alsaleh, F. M. (2021). Incidence and outcomes of pulmonary embolism among hospitalized COVID-19 patients. *International Journal of Environmental Research and Public Health, 18*(14), 7645. https://doi.org/10.3390/ijerph18147645

Beckman, M., Hooper, W., Critchley, S., & Ortel, T. (2010). Venous thromboembolism. *American Journal of Preventive Medicine, 38*(4), S495–S501. https://doi.org/10.1016/j.amepre.2009.12.017

Bikdeli, B., Madhavan, M.v., Jimenez, D., Chuich, T., Dreyfus, I., Driggin, E., et al. (2020). COVID-19 and thrombotic or thromboembolic disease: Implications for prevention, antithrombotic therapy, and follow-up. *Journal of the American College of Cardiology, 75*(23), 2950–2973. https://doi.org/10.1016/j.jacc.2020.04.031

Bukhari, Z. M., Alqarni, M. S., Abukhodair, A. W., Alzahrani, A. S., Alzahrani, A., Alsrhani, H., Alasadi, F., Alotaibi, A. M., & Althobaiti, M. (2021). COVID-19-Related pulmonary embolism: Incidence, characteristics, and risk factors. *Cureus*. https://doi.org/10.7759/cureus.19738

Connors, J., & Levy, J. (2020). Thromboinflammation and the hypercoagulability of COVID-19. *Journal of Thrombosis and Haemostasis, 18*(7), 1559–1561. https://doi.org/10.1111/jth.14849

Danzi, G., Loffi, M., Galeazzi, G., & Gherbesi, E. (2020). Acute pulmonary embolism and COVID-19 pneumonia: A random association. *European Heart Journal, 41*(19). https://doi.org/10.1093/eurheartj/ehaa254, 1858-1858.

Darwish, H. S., Habash, M. Y., & Habash, W. Y. (2021). *COVID-19 viral pneumonia complicated with acute pulmonary embolism: A descriptive study*. Radiology Research and Practice. https://doi.org/10.1155/2021/6649086, 2021.

Fabre, O., Rebet, O., Carjaliu, I., Radutoiu, M., Gautier, L., & Hysi, I. (2020). Severe acute proximal pulmonary embolism and COVID-19: A word of caution. *The Annals of Thoracic Surgery, 110*(5), e409–e411. https://doi.org/10.1016/j.athoracsur.2020.04.005

Hamid, H. O. (2021). Role of computed tomography angiography in detecting pulmonary embolism and the prevalence of it. *Medical Science, 25*(109), 716–722.

Kaminetzky, M., Moore, W., Fansiwala, K., Babb, J. S., Kaminetzky, D., Horwitz, L. I., McGuinness, G., Knoll, A., & Ko, J. P. (2020). Pulmonary embolism on CTPA in COVID-19 patients. *Radiology. Cardiothoracic Imaging*. https://doi.org/10.1148/ryct.2020200308 [online] 2(4).

Kwee, R. M., Adams, H. J. A., & Kwee, T. C. (2021). *Pulmonary embolism in patients with COVID-19 and value of D-dimer assessment: A meta-analysis*. European Radiology. https://doi.org/10.1007/s00330-021-08003-8 [online] pp.

Leonard-Lorant, I., Delabranche, X., Severac, F., Helms, J., Pauzet, C., Collange, O., Schneider, F., Labani, A., Bilbault, P., Moliere, S., Leyendecker, P., Roy, C., & Ohana, M. (2020). Acute pulmonary embolism in COVID-19 patients on CT angiography and relationship to D-dimer levels. *Radiology*. , Article 201561. https://doi.org/10.1148/radiol.2020201561

Lovato, A., de Filippis, C., & Marioni, G. (2020). Upper airway symptoms in coronavirus disease 2019 (COVID-19). *American Journal of Otolaryngology, 41*(3), Article 102474. https://doi.org/10.1016/j.amjoto.2020.102474

Masselli, G., Almberger, M., Tortora, A., Capoccia, L., Dolciami, M., D'Aprile, M. R., Valentini, C., Avventurieri, G., Bracci, S., & Ricci, P. (2021). Role of CT angiography in detecting acute pulmonary embolism associated with COVID-19 pneumonia. *La radiologia medica, 126*(12), 1553–1560. https://doi.org/10.1007/s11547-021-01415-y

Mestre-Gómez, B., Lorente-Ramos, R. M., Rogado, J., Franco-Moreno, A., Obispo, B., Salazar-Chiriboga, D., Saez-Vaquero, T., Torres-Macho, J., Abad-Motos, A., Cortina-Camarero, C., Such-Diaz, A., Ruiz-Velasco, E., Churruca-Sarasqueta, J., & Muñoz-Rivas, N. (2020). Incidence of pulmonary embolism in non-critically ill COVID-19 patients. Predicting factors for a challenging diagnosis. *Journal of Thrombosis and Thrombolysis, 51*(1), 40–46. https://doi.org/10.1007/s11239-020-02190-9

Ooi, M. W. X., Rajai, A., Patel, R., Gerova, N., Godhamgaonkar, V., & Liong, S. Y. (2020). Pulmonary thromboembolic disease in COVID-19 patients on CT pulmonary angiography – prevalence, pattern of disease and relationship to D-dimer. *European Journal of Radiology, 132*, Article 109336. https://doi.org/10.1016/j.ejrad.2020.109336

Rotzinger, D., Beigelman-Aubry, C., von Garnier, C., & Qanadli, S. (2020). Pulmonary embolism in patients with COVID-19: Time to change the paradigm of computed tomography. *Thrombosis Research, 190*, 58–59. https://doi.org/10.1016/j.thromres.2020.04.011

Rubin, G. D., Ryerson, C. J., Haramati, L. B., Sverzellati, N., Kanne, J. P., Raoof, S., et al. (2020). The role of chest imaging in patient management during the COVID-19 pandemic: A multinational consensus statement from the fleischner society. *Radiology, 296*(1), 172–180. https://doi.org/10.1148/radiol.2020201365

Ullah, W., Saeed, R., Sarwar, U., Patel, R., & Fischman, D. (2020). COVID-19 complicated by acute pulmonary embolism and right-sided heart failure. *Journal of the American College of Cardiology: Case Reports, 2*(9), 1379–1382. https://doi.org/10.1016/j.jaccas.2020.04.008

Vogel-Claussen J, Ley-Zaporozhan J, Agarwal P, Biederer J, Kauczor HU, Ley S, et al. (2020). Recommendations of the Thoracic Imaging Section of the German Radiological Society for clinical application of chest imaging and structured CT reporting in the COVID-19 pandemic. 192(07), pp.633-640. http://doi.org/10.1055/a-1174-8378.

Whyte, M. B., Kelly, P. A., Gonzalez, E., Arya, R., & Roberts, L. N. (2020). *Pulmonary embolism in hospitalised patients with COVID-19*. Thrombosis Research. https://doi.org/10.1016/j.thromres.2020.07.025 [online] 195.

Xie, Y., Wang, X., Yang, P., & Zhang, S. (2020). COVID-19 complicated by acute pulmonary embolism. *Radiology: Cardiothoracic Imaging, 2*(2), Article e200067. https://doi.org/10.1148/ryct.2020200067

Yu, B., Li, X., Chen, J., Ouyang, M., Zhang, H., Zhao, X., et al. (2020). Evaluation of variation in D-dimer levels among COVID-19 and bacterial pneumonia: A retrospective analysis. *Journal of Thrombosis and Thrombolysis, 50*(3), 548–557. https://doi.org/10.1007/s11239-020-02171-y

Zhou, F., Yu, T., Du, R., Fan, G., Liu, Y., Liu, Z., Xiang, J., Wang, Y., Song, B., Gu, X., Guan, L., Wei, Y., Li, H., Wu, X., Xu, J., Tu, S., Zhang, Y., Chen, H., & Cao, B. (2020). Clinical course and risk factors for mortality of adult inpatients with COVID-19 in wuhan, China: A retrospective cohort study. *The Lancet*, (10229), 1054–1062. https://doi.org/10.1016/s0140-6736(20)30566-3 [online] 395.