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American Journal of Emergency Medicine 38 (2020) 2142–2146

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Pulmonary embolism in COVID-19: Clinical characteristics and cardiac implications

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ARTICLE INFO

Article history:
Received 8 June 2020
Received in revised form 14 July 2020
Accepted 16 July 2020

Keywords:
COVID-19
Coronavirus
Coagulopathy
Pulmonary embolism
Venous thromboembolism

ABSTRACT

Background: The thrombogenic potential of Covid-19 is increasingly recognised. We aim to assess the characteristics of COVID-19 patients diagnosed with pulmonary embolism (PE).
Methods: We conducted a single centre, retrospective observational cohort study of COVID-19 patients admitted between 1st March and 30th April 2020 subsequently diagnosed with PE following computed tomography pulmonary angiogram (CTPA). Patient demographics, comorbidities, presenting complaints and inpatient investigations were recorded.
Results: We identified 15 COVID-19 patients diagnosed with PE (median age = 58 years [IQR = 23], 87% male). 2 died (13%), both male patients >70 years. Most common symptoms were dyspnoea (N = 10, 67%) and fever (N = 7, 47%). 12 (80%) reported 7 days or more of non-resolving symptoms prior to admission. 7 (47%) required continuous positive airway pressure (CPAP), 2 (13%) of which were subsequently intubated. All patients had significantly raised D-dimer levels, lactate dehydrogenase (LDH), C-reactive protein (CRP), ferritin and prothrombin times. The distribution of PEs correlated with the pattern of consolidation observed on CTPA in 9 (60%) patients; the majority being peripheral or subsegmental (N = 14, 93%) and only 1 central PE. 10 (67%) had an abnormal resting electrocardiogram (ECG), the commonest finding being sinus tachycardia. 6 (40%) who underwent transthoracic echocardiography (TTE) had structurally and functionally normal right hearts.
Conclusion: Our study suggests that patients who demonstrate acute deterioration, a protracted course of illness with non-resolving symptoms, worsening dyspnoea, persistent oxygen requirements or significantly raised D-dimer levels should be investigated for PE, particularly in the context of COVID-19 infection. TTE and to a lesser degree the ECG are unreliable predictors of PE within this context.

1. Introduction

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first identified in December 2019 in Wuhan, China. It rapidly spread and was declared a worldwide pandemic on 11th March 2020 [1]. COVID-19 is primarily a respiratory disease and the most common symptoms reported are fever and dry cough. Most patients experience mild disease, but a small subset of patients develop severe disease requiring hospital admission. The course of the disease may be further complicated by type 1 respiratory failure (T1RF) requiring invasive mechanical ventilation [2]. This is initially due to a viral pneumonia, followed by a cytokine driven inflammatory response that can cause acute respiratory distress syndrome (ARDS), multi-organ failure and death.

However, it is becoming increasingly recognised that COVID-19 infection can lead to a procoagulant state, causing pulmonary embolism (PE). Life threatening COVID-19 cases are often associated with excessive activation of the coagulation cascade which is evidenced by raised D-dimer protein levels and coagulopathy [3,4].

The use of non-contrast-enhanced computed tomography (CT) has been advocated for the diagnosis of COVID-19 pneumonia, particularly when initial Real-Time Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) screening is negative [5]. This imaging modality is also used to assess the severity and progression of disease [6]. Patients with COVID-19 are naturally predisposed to PE because of active inflammation, hypoxaemia and immobility and CTPA should be performed in patients who deteriorate despite supportive therapy or demonstrate clinical features of PE such as worsening dyspnoea, haemoptysis or pleuritic chest pain [7,8].

We aimed to assess the characteristics of hospitalised COVID-19 patients who were subsequently diagnosed with PE and to establish any potential risk factors based on our observations. Our secondary

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https://doi.org/10.1016/j.ajem.2020.07.054
0735-6757/

aim was to evaluate the diagnostic yield of cardiac investigations with respect to right ventricular dysfunction related to acute PE, such as resting 12-lead ECG and TTE.

2. Methods

We conducted a retrospective analysis of all patients diagnosed with COVID-19 and PE during their hospital admission between 1st March and 30th April 2020. Patient data including demographics, comorbidities, presenting complaints and inpatient investigations were extracted from our local hospital electronic database. RT-PCR assay of nasopharyngeal swabs was used to confirm a diagnosis of COVID-19. In patients where there was a strong clinical suspicion of COVID-19 but negative RT-PCR assay, a radiological diagnosis was made using CT imaging of the chest. Radiological features of COVID-19 included bilateral peripheral subpleural ground-glass opacities, inter/intra-lobular septal thickening, airspace opacification, traction bronchiectasis and organising pneumonia.

Admission D-dimer levels and CTPA dates were also recorded, along with each patient's Wells score prior to investigation. Routine COVID-19 blood workup including full blood count, serum biochemistry, troponin-T, lactate dehydrogenase (LDH), ferritin, C-reactive protein (CRP) and coagulation profile were recorded. The neutrophil:lymphocyte ratio (NLR) was calculated by dividing the absolute neutrophil count by the absolute lymphocyte count [9].

The anatomical location of PE on CTPA was compared to the pattern of lung consolidation and infiltrates. The right ventricular (RV) and left ventricular (LV) diameters were measured to calculate the RV:LV ratio, a surrogate marker of embolic burden on the heart [10].

Our hospital's guideline for venous thromboembolism (VTE) prophylaxis is subcutaneous dalteparin and we assessed if VTE prophylaxis was prescribed and administered appropriately according to risk stratification. Following diagnosis of PE, we recorded the weight-adjusted treatment doses of dalteparin prescribed and whether any alternative treatment such as oral anticoagulation was initiated.

We analysed each patient's cardiac conduction on an admission resting 12-lead ECG and documented sinus tachycardia, new right bundle branch block (RBBB), right axis deviation, S1Q3T3 pattern, atrial arrhythmia or features of right ventricular strain. If TTE was performed the tricuspid annular plane systolic excursion (TAPSE), severity of tricuspid regurgitation (TR) and echocardiographic probability of pulmonary hypertension (low, intermediate and high) were recorded.

3. Statistical analysis

Categorical variables are summarised as frequencies and percentages. Data outside the normal distribution are presented as medians and ranges. All data were analysed with SPSS Version 26 software.

4. Ethics

As a study using clinically collected, non-identifiable data, this work does not fall under the remit of the National Health Service Research Ethics Committees.

5. Results

During the study period, a total of 15 COVID-19 patients were diagnosed with PE during their hospital admission. The median age was 58 years (IQR = 23) and 13 (87%) were male. Patient demographics and comorbidities are summarised in Table 1.

There were 2 (13%) deaths, both of which were male patients aged >70 years (cases 10 and 12). The most common symptom was dyspnoea (N = 10, 67%) followed by fever (N = 7, 47%). 12 (80%) patients reported 7 days or more of non-resolving symptoms prior to admission to hospital. 3 (20%) patients who had initially been discharged after 24 h (all nasopharyngeal swab positive for COVID-19 on RT-PCR) represented and were readmitted because of worsening symptoms. 7 (47%) patients required continuous positive airway pressure (CPAP), 2 of which were subsequently intubated. Of our study group, 7 (47%) patients had positive nasopharyngeal swabs and the remaining 8 (53%) with negative swabs were diagnosed on the basis of pulmonic radiological changes on CT consistent with COVID-19.

Troponin T (<14 ng/L) was elevated in 5 (33%) patients with a median value of 12 ng/L (range 4–45 ng/L). 9 (60%) patients had leucocytosis (4.0–11.0 $\times 10^9$/L) with a median value of 13.2 $\times 10^9$/L (range 11.3–17.7 $\times 10^9$/L) and predominant neutrophilia (2.0–7.5 $\times 10^9$/L), median value of 10.8 $\times 10^9$/L (range 8.1–14.4 $\times 10^9$/L) in addition to high CRP (0–4 mg/L) with a median level of 189 mg/L (range 115–424 mg/L); the remaining 6 patients had a median CRP of 45 mg/L (range 30–86 mg/L).

Only 3 (20%) patients had lymphopenia (1.0–4.0 $\times 10^9$/L) with a median value of 0.86 $\times 10^9$/L (range 0.63–0.95 $\times 10^9$/L) giving NLR > 9. The median prothrombin time (12.0–14.8 s) was 17.0 s (range 15.1–21.7 s), the median LDH level (135–214 U/L) was 317 U/L (range 155–872 U/L) and median ferritin level (15–300 μg/L) was 780 μg/L (range 353–3364 μg/L). Only 1 patient was thrombocytopaenic

Table 1
Patient demographics and characteristics, presenting symptoms and duration of symptoms prior to admission to hospital.

Case number	Age (y)	Sex	Pre-existing medical conditions	Presenting symptoms	Duration of symptoms prior to admission (days)	Readmission
1	44	Female	None	Fever, dry cough	7	No
2	60	Male	None	Fever, dry cough, dyspnoea	14	No
3	54	Female	Hypertension, Obstructive Sleep Apnoea, Asthma, Obesity	Fever, dry cough, dyspnoea	7	No
4	61	Male	Peripheral Vascular disease	Dyspnoea, thigh pain	10	Yes
5	67	Male	Hypertension, Type 2 Diabetes Mellitus	Vomiting, confusion	2	No
6	56	Male	Type 2 Diabetes Mellitus, High Cholesterol, previous Transient Ischaemic Attack, Epilepsy	Fever, dyspnoea	7	No
7	56	Male	None	Fever, dyspnoea	14	No
8	30	Male	Sickle cell trait	Pleuritic chest pain	2	No
9	73	Male	Hypertension, Rheumatoid arthritis	Dyspnoea	14	Yes
10[a]	94	Male	Previous Transient Ischaemic Attack	Lethargy, dyspnoea	7	No
11	75	Male	Chronic Obstructive Pulmonary Disease	Fever, productive cough	7	No
12[a]	72	Male	Previous knee replacement	Dry cough, dyspnoea	14	No
13	58	Male	Hypertension	Pleuritic chest pain, dyspnoea	18	Yes
14	46	Male	None	Fever, dry cough, pleuritic chest pain	17	No
15	49	Male	Previous deep vein thrombosis, asthma	Dry cough, dyspnoea, pleuritic chest pain	5	No

[a] 2 patients who died.

Table 2
An overview of laboratory investigations on admission to hospital.

Case number	WCC, x10^9/L	Neut, x10^9/L	Lymph, x10^9/L	NLR	Plt, x10^9/L	CRP, mg/L	Trop, ng/L	LDH, U/L	Ferritin, μg/L	PT, s	APTT, s	PT: APTT	Na, mmol/L	K, mmol/L	Urea, mmol/L	Cr, μmol/L	Alb, g/L	Bil, μmol/L	ALP, U/L	ALT, U/L
1	9.9	8.5	0.86	9.83	427	78	4	155	444	15.6	36.0	1.18	139	4.2	2.9	47	34	5	47	14
2	11.8	10.8	0.63	17.08	295	323	45	872	2957	16.8	34.1	1.11	134	4.1	4.5	63	29	13	121	43
3	3.7	1.5	1.47	1.02	403	42	7	260	434	15.3	31.1	1.02	139	5.1	4.6	72	37	10	48	21
4	9.4	6.7	1.28	5.23	272	86	–	–	–	17.0	40.5	1.32	138	4.0	7.3	91	32	10	183	55
5	15.4	12.2	1.84	6.64	83	125	–	408	1281	20.3	42.3	1.38	171	3.8	25.1	167	24	26	50	38
6	7.5	4.9	1.97	2.47	310	10	10	266	896	16.2	42.8	1.40	133	4.9	6.5	69	32	2	104	26
7	11.9	4.6	1.68	2.72	543	82	11	591	977	17.2	32.3	1.06	139	5.1	5.1	72	32	12	103	86
8	16.5	13.3	0.95	13.96	378	422	6	329	649	21.7	48.5	1.58	140	4.8	5.0	86	37	21	61	15
9	14.8	11.6	1.44	8.03	290	49	12	261	531	18.3	38.0	1.24	137	4.6	4.1	63	33	4	70	27
10	9.9	7.2	1.1	6.53	485	189	25	304	863	15.1	42.8	1.4	136	5.0	4.9	55	26	9	196	24
11	11.3	8.9	1.3	6.86	396	33	19	518	1093	16.5	35.3	1.15	133	4.8	12.1	71	31	10	190	55
12	9.6	8.1	1	8.07	349	424	15	378	696	19.1	47.4	1.55	143	4.1	6.0	57	24	4	124	12
13	12.1	9.6	1.2	8.00	229	151	19	452	3364	16.5	38.5	1.26	138	3.7	5.1	86	38	18	61	34
14	17.7	14.4	2.02	7.11	383	30	5	248	607	18.0	38.5	1.26	140	3.9	5.4	83	38	11	64	19
15	13.2	10.1	2.09	4.85	191	115	13	164	353	19.7	47.4	1.55	138	4.4	6.1	110	45	27	91	17

WCC = White cell count; Neut = Neutrophil; Lymph = Lymphocyte; NLR = Neutrophil to Lymphocyte Ratio; Plt = Platelet; CRP = C-reactive protein; Trop = Troponin T; LDH = Lactate Dehydrogenase; PT = Prothrombin Time; APTT = Activated Partial Thromboplastin Time; Na = Sodium; K = Potassium; Cr = Creatinine; Alb = Albumin; Bil = Bilirubin; ALP = Alkaline Phosphatase; ALT = Alanine Transferase.

(150–450 × 10^9/L) at 83 × 10^9/L (Table 2). All patients had significantly raised D-dimer levels (range 2188–60,700 ng/mL [normal 270–750 ng/mL]). 12 (80%) patients had high admission D-dimer levels prompting immediate CTPA and rapid diagnosis of PE. The remaining 3 patients (20%) had a prolonged inpatient stay before PE was diagnosed.

All patients had been commenced on appropriate prophylactic doses of dalteparin (5000 units once daily as standard) on admission with one of them requiring twice daily dosage of dalteparin due to high body mass index (BMI) of 36 kg/m^2. 13 (87%) patients were commenced on weight-adjusted treatment doses of dalteparin following a diagnosis of PE. 9 (60%) of these patients were subsequently switched to apixaban 5 mg twice daily. One patient died shortly after a diagnosis of PE (case 10).

Indications for CTPA included persistent or increasing oxygen requirements (N = 9, 60%), pleuritic chest pain (N = 7, 47%) and persistent sinus tachycardia (N = 6, 40%); with a median Wells score of 4.5 (range 3–6).

The distribution of PE appeared to correlate with the pattern of consolidation observed on CTPA in 9 (60%) patients (Table 3). Only 1 (7%)

Table 3
An overview of D-dimer levels, Wells scores, day of admission CTPA was performed, CTPA results and comparison with site of PE.

Case number	D-dimer, ng/mL		Wells scores	Day of admission	Pattern of consolidation	Site of PE	RV: LV ratio	Mechanical ventilation
	Initial	Repeat						
1	2124	3515	5.5	4	Lower lobe consolidation, more marked on right	Right main, lobar and segmental pulmonary arteries	1.0	Yes, CPAP
2	>20,000	–	3	2	Widespread ground-glass changes in periphery and basal patchy consolidation	Lower lobes and right upper lobe	1.0	Yes, CPAP
3	11,366	–	4.5	7	Peripheral ground-glass changes, bibasal consolidation	Lower lobes	1.0	Yes, CPAP
4	60,700	–	3	2	Left lower lobe consolidation	Bilateral segmental branches	0.8	No
5	>20,000	–	3	2	Multifocal peripheral patchy consolidation in right upper lobe with dependent consolidation in lower lobe	Saddle embolus extending into both lower lobe pulmonary arteries and segmental branches	1.1	No
6	>20,000	–	4.5	14	Widespread ground-glass shadowing	Distal right main artery extending into middle and lower segmental vasculature	1.4	Yes, CPAP
7	6704	–	4.5	3	Peripheral ground-glass opacities	Bilateral segmental and subsegmental	1.0	No
8	–	–	4.5	3	Left lower lobe consolidation	Left lower lobe	0.8	No
9	9572	–	4.5	2	Bilateral peripheral and basal ground-glass opacification and consolidation	Right middle and lower lobe	1.0	No
10	6972	–	3	2	Extensive ground-glass changes, predominantly lower lobes	Lobar level of lingula, lower lobe arteries	1.1	Yes, CPAP
11	>20,000	–	3	4	Basal patches of consolidation and ground-glass opacities	Subsegmental and segmental branches in basal and lower lobe distribution	1.0	Intubated and Ventilated
12	3447	–	3	7	Multiple ground-glass opacities in upper lobes and diffuse in right lower lobe	Segmental branch of right lower lobe artery	1.4	Intubated and Ventilated
13	1320	6170	4.5	2	Bilateral peripheral and basal ground-glass opacification	Subsegmental and segmental arteries of right lower and middle lobe	0.9	No
14	2188	–	4.5	1	Patchy consolidation in peripheral aspects of bilateral lower lobes and subpleural aspect of right upper lobe	Subsegmental in lingula and basal left lower and anteroinferior right upper lobe	1.0	No
15	4540	–	6	1	Peripheral ground-glass changes in right middle lobe and lingula	Distal end of right pulmonary artery with multiple PE in right inferior pulmonary artery and its branches	1.1	No

CTPA = computed tomography pulmonary angiogram; PE = Pulmonary Embolism; RV:LV = Right ventricular diameter to left ventricular diameter; CPAP = Continuous Positive Airway Pressure.

patient (case 5) developed a saddle embolus and the rest demonstrated peripheral or subsegmental PEs, all of which were in the lower lobe arterial distribution where ground-glass opacities and patchy consolidations were observed. The median RV:LV ratio measured on CTPA was 1 (range 0.8–1.4) and the highest ratio of 1.4 was recorded in 2 (13%) patients. Both patients required respiratory support at the time of diagnosis, one of which was intubated and subsequently died (case 12).

Table 4 summarises the cardiac investigations. ECG findings were generally non-specific for PE, with 7 (47%) patients having sinus tachycardia and 5 (33%) patients showing changes consistent with a right ventricular strain pattern. Only 1 (7%) patient demonstrated the classical S1Q3T3 pattern associated with PE. 6 (40%) patients had TTE performed after diagnosis of PE with a median time of 23 h (IQR = 16), all of which demonstrated normal TAPSE, trivial TR and no evidence of right heart strain.

6. Discussion

Our case series supports that the development of PE within the context of COVID-19 infection may be a contributory factor to the pathogenesis of T1RF and subsequent need for mechanical ventilation. During the early COVID-19 outbreak, unknown PEs may have been a key factor in disease mortality and multiple early studies have reported an association between deranged coagulation function (raised D-dimer protein levels and clotting times) and increased mortality [3,4].

PE is classically caused by thrombus propagated from a deep leg vein or pelvic vein. We postulate that the pathophysiology of PE in COVID-19 is different. The sites of PE in our patients correlated with the areas of pulmonary consolidation or infiltrates, suggesting that the development of clots may be secondary to an underlying anatomically localised infective or inflammatory process. The pattern of prothrombotic coagulopathy in our patients deviates from that of sepsis where thrombocytopenia is common and from DIC where significantly deranged clotting times are accompanied by a haemorrhagic tendency [11]. A prospective autopsy series of 12 COVID-19 patients found that a third of these deaths were directly attributable to PE. The histopathological features were characterised by lymphocytic infiltration of lung parenchyma and microvascular thromboemboli [12].

The predisposition to VTE in COVID-19 patients may occur in several ways. SARS-CoV-2 invades the body by using angiotensin converting enzyme 2 (ACE2) as a coreceptor. ACE2 degrades angiotensin II and acts as counter-regulatory hormone to the vasoconstrictive and proliferative axis of the renin-angiotensin-aldosterone system (RAAS) pathway. Increased expression of angiotensin II has been found to be thrombogenic through the enhancement of platelet activity and coagulation [13]. Viral activation of the innate immune system also leads to cytokine release. Interleukin-6 (IL-6) is the key pro-inflammatory cytokine implicated in the cytokine release syndrome or "storm" and directly activates the coagulation cascade [14]. Activation of RAAS and increased angiotensin II can directly increase the expression of IL-6, further amplifying its thrombogenic potential [15]. Inflammation induced alveolar injury and hypoxaemia can also lead to a vascular endothelial response that augments thrombus formation [16]. More recently, Zhang et al. detected the presence of antiphospholipid antibodies in a COVID-19 case, which might also serve as an explanation for the thrombogenicity [17].

We observed a male propensity to developing PE. Early studies found an association between increased mortality and male gender [18]. It has been hypothesised that the gender differences in severity of disease may be due to sex-based immunology differences, but may also be affected by comorbidities or health inequalities [18,19]. Our data supports the notion that poor outcomes observed in men may be a direct result of higher incidence of PE. A recent study by Li et al. investigated ACE2 expression across various human tissues and found a positive correlation between ACE2 expression and immune signatures in lung tissues of men, suggesting an exaggerated inflammatory response may be more likely to occur in males than females [20].

Most common ECG changes in acute PE are sinus tachycardia and non-specific T-wave changes, as demonstrated in our case series. Significant embolic burden may manifest as RBBB and ST segment changes which are considered to be poor prognostic markers [21]. Only 10–25% of patients will have a normal ECG [22]. TTE, on the other hand, has a reported sensitivity of 53% and specificity of 83% in demonstrating right heart strain, making it a potential rule-in test for patients with a suspicion of PE [23]. The embolic burden in our cohort was sufficient to cause respiratory distress requiring hospital admission, with a few requiring ventilatory support, but overall, PE did not result in cardiac decompensation. Surrogate markers of cardiac compromise, namely, raised serum troponin, increased RV:LV ratio on CTPA or TTE measurements, right ventricular strain pattern/RBBB on ECG and significant pulmonary hypertension on TTE, were, notably, largely absent in our group of patients. TTE performed after the diagnosis of PE failed to demonstrate evidence of significant right heart volume or pressure overload, with normal TAPSE measurements and only trivial TR, suggesting that cardiac investigations may have a low sensitivity for the diagnosis of PE in COVID-19 patients.

Table 4
Summary of cardiac investigations.

Case number	ECG findings	TTE findings				
		TAPSE, mm	TR severity	LVEF, %	Probability of pulmonary hypertension	PAP, mmHg
1	Sinus tachycardia, right ventricular strain pattern, S1Q3T3	25.5	Trivial	55–60	Low	17
2	Nil	–	–	–	–	–
3	Right ventricular strain pattern	–	–	–	–	–
4	Right ventricular strain pattern	–	–	–	–	–
5	Nil	17.8	Trivial	60–65	Intermediate	–
6	Nil	11.0	Trivial	59	Low	16
7	Sinus tachycardia	–	–	–	–	–
8	Sinus tachycardia	22.0	Trivial	60–65	Low	16
9	Sinus tachycardia, right ventricular strain pattern, right axis deviation	–	–	–	–	–
10	Sinus tachycardia	–	–	–	–	–
11	Nil	–	–	–	–	–
12	Atrial fibrillation	20.0	Trivial	62	Intermediate	44
13	Nil	–	–	–	–	–
14	Sinus tachycardia, right ventricular strain pattern	–	–	–	–	–
15	Right ventricular strain pattern	25.0	Trivial	60–65	–	–

ECG = Electrocardiogram; TTE = Transthoracic echocardiogram; TAPSE = Tricuspid annular plane systolic excursion; TR = Tricuspid regurgitation; LVEF = Left Ventricular Ejection Fraction; PAP = Pulmonary Arterial Pressures.

The diagnosis of PE in this population appears to depend reliably on clinical history (protracted course of non-resolving respiratory symptoms, presence of pleuritic chest pain and haemoptysis), persistent oxygen requirements disproportionate to the severity of pneumonia, a non-resolving T1RF despite mechanical ventilation, deranged prothrombin times and significantly raised D-dimer levels. Based on our study, a D-dimer levels >2000 ng/mL could be used as a threshold for CTPA. In keeping with other studies, we also observed that male gender may be an independent risk factor for PE and poor prognosis [18]. An NLR > 5.5 has been described to be a useful prognosticator for severe forms of COVID-19 infection [9]; two thirds of our cohort showed an NLR > 5.5, suggesting that raised NLR could potentially be used as a predictor for PE. Another marker of severe COVID-19 infection is elevated LDH levels, as demonstrated in 12 (80%) of our patients including the 2 that died. A pooled analysis by Henry et al. found that elevated LDH levels increased the odds of severe COVID-19 infection by 6-fold and mortality odds by >16-fold and therefore, may be a useful indicator of disease severity and a predictor of mortality [24]. We therefore suggest clinicians be vigilant for the aforementioned risk factors and have a low threshold for performing CTPA because early PE diagnosis and treatment influences outcome.

Due to the procoagulant profile of COVID-19 infection, conventional doses for thromboprophylaxis may not be adequate; hence the emergence of multiple local hospital guidelines advocating thromboprophylactic dose adjustments according to weight and D-dimer levels [25,26]. This is supported by the preliminary findings from an observational study of 16 COVID-19 patients that demonstrated normalisation of procoagulant profiles (reflected by the reduction in fibrinogen concentrations and D-dimer protein levels) following enhanced doses of thromboprophylaxis [11]. However, at the time of writing, there remains an urgency for a consensus agreement on enhanced VTE prophylaxis in COVID-19 patients.

7. Limitations

Our study was retrospective in nature and based at a single centre with a small cohort of patients. Therefore, our data should be interpreted cautiously until larger studies are conducted to validate our observations. Furthermore, we only included PE identified by CTPA after clinical suspicion. Incidentally diagnosed PE on CT-imaging other than CTPA was not included in our series. A large case-controlled study would be of interest to allow confirmation of parameters that predict PE in COVID-19 patients and to quantify PE as a risk factor in COVID-19 outcomes.

8. Conclusion

Our study suggests that patients who demonstrate acute clinical deterioration, a protracted course of illness with non-resolving symptoms, worsening dyspnoea, persistent oxygen requirements or significantly raised D-dimer levels (>2000 ng/mL) should be investigated for PE, particularly in the context of COVID-19 infection. Cardiac investigations are of limited help in the immediate diagnosis of PE and therefore the decision for CTPA should be based on clinical suspicion, irrespective of the lack of supporting evidence from ECG or TTE.

Funding

The authors received no specific funding for this work.

Credit author statement

All authors contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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