RADIOLOGICAL ASSESSMENT OF THE VASCULAR COMPLICATIONS OF COVID-19 IN CORRELATION WITH D-DIMER LEVEL

Mohamed M. Abdel Aziz, Mohamed Yosry and Ahmed Elshimy

ABSTRACT:

Background: The COVID-19 pandemic causes primarily respiratory disease as well as non-respiratory complications such as thromboembolic complications with D-dimer elevation, which lead to multisystem organ dysfunction and respiratory failure.

Aim of the work: To determine the value of radiological assessment of vascular complications in COVID-19 infections and its relation to D-dimer levels as important tools for early diagnosis and proper management of these patients.

Patients & Methods: The study included 100 patients diagnosed as COVID-19 positive with embolic manifestations depending on their symptoms, signs, and laboratory assessment, which included D-dimer levels. They underwent radiological assessment of their vascular complications, including CT, MRI, and CT angiography.

Results: Among 100 COVID-positive patients with thromboembolic symptoms, 55 had evidence of pulmonary embolism, 13 had strokes, 4 had mesenteric arterial occlusion and 28 patients had no radiological evidence of vascular manifestations. D-dimer levels were increased (0.50 mcg/mL or greater) in 70 percent of positive COVID patients, including 89% of those with pulmonary embolism, 84% of those with stroke, 75% of mesenteric thrombosis cases, and in 7 patients (25% of those with symptoms suggestive of vascular thrombosis without radiological imaging of thromboembolic manifestations), with a sensitivity of 88.6%, specificity of 75%, positive predictive value of 90.9%, and negative predictive value of 70%.

Conclusion: This study confirmed that D-dimer elevation in COVID-positive patients is highly suggestive of thromboembolic complications, especially pulmonary, cranial, and abdominal embolisms, and that confirmation by proper radiological evaluation is mandatory for the diagnosis of these findings and proper management of their complications.

Keywords: COVID 19, vascular complications, D-dimer.

INTRODUCTION:

Since the emergence of the worldwide pandemic coronavirus disease (COVID-19), which causes respiratory tract infection as well as multisystem affection, venous thromboembolism has been identified as one of the disease’s most serious complications[1&2]. The COVID-19-related thromboembolic complications were a significant factor in these patients' admission to intensive care [3].
A variety of potential risk factors for venous thromboembolism exist in COVID-19 patients, especially those who are severely and critically ill. These include infection, immobilization, respiratory failure, mechanical ventilation, and central venous catheter use \[4\]. Furthermore, the virus was discovered to affect coagulation factors, resulting in a cascade of coagulation profile alteration with elevation of the D-dimer, which in turn led to multisystem organ dysfunction and increased respiratory failure \[5\]. Moreover, several theories for thromboembolic mechanisms associated with COVID-19 exit, include direct effect through several illnesses, severe inflammatory response, or hypoxia \[6\].

The outcomes of these thromboembolic events include mainly acute pulmonary embolism (PE); however, other coagulopathies such as deep-vein thrombosis (DVT), ischemic stroke, myocardial infarction, or systemic arterial embolism have also been reported \[3\]. These complications are usually associated with poorer prognoses and high mortality rates \[7\], with increased risk when severe lymphopenia and elevations of D-dimer greater than 2.0 mg/ml are also noted \[2\].

For diagnosis, the chest x-ray is considered the primary modality for assessment of COVID-19 \[8\]. However, chest computed tomography (CT) plays an important role in the diagnosis of COVID pneumonia and eliminating alternate diagnoses or added pathologies, particularly for acute pulmonary embolism. However, in patients with severe clinical features of COVID-19 or elevated D-dimer who may have associated acute pulmonary emboli, the use of contrast-enhanced CT (pulmonary CT angiography) rather than routine non-contrast CT may be considered for these patients \[9\&10\].

AIM OF THE WORK:

So, the aim of this study was to determine the value of radiological assessment of vascular complications in COVID-19 infections and its relation to D-dimer levels as important tools for early diagnosis and proper management of these patients.

PATIENTS & METHODS:

Patients:

This pilot study was designed as a cross-control blinded study. A total of 100 patients diagnosed as COVID-19 positive by PCR testing, presented with embolic manifestations depending on their symptoms, signs, and laboratory assessment and were referred to the Radiology Department of our institute during a period of nine months (from January to September 2022) were included in the study. Unstable or critically ill patients and those with a history of renal impairment, allergy, or hypersensitivity to contrast material were excluded.

Patients were informed about the study design, and a written consent for their participation was obtained. The research protocol was approved by the Radiology Department Scientific Board and fulfilled the ethical guidelines of the institute.

Clinical and laboratory evaluation:

A revision of the history and initial assessment data of all patients was done, including their ages, sex, body weights, and heights, with calculation of body mass index (BMI). Also, their clinical symptoms and signs, such as respiratory and heart rates, blood pressure, embolic manifestations, and others, were documented. In addition, all available laboratory data, particularly hematologic data, including D-dimer levels and renal functions, were reviewed.

Radiologic interventions:

Patients were arranged in groups according to their clinical presentations and examined by either a 128 slice multi-detector computed tomography (MDCT) scanner with
contrast or by magnetic resonance imaging (MRI).

MDCT scanning (GE Optima CT 660 SE 128, Germany) was done in the supine position after fasting for about 4–6 h before the study. The scans were taken from the thorax inlet (the root of the neck, including the proximal aspect of the common carotid and subclavian arteries) to 2 cm below the diaphragm (at the level of the portal vein inferiorly) in a craniocaudal direction in a patient suspected to have a pulmonary embolism, or taken from the lung bases to the level of the symphysis pubis in a patient suspected of having a visceral embolism.

MRI brain stroke protocol using 1.5T scanner (Philips Medical Systems, Acheivea, Netherlands), in cases of suspected stroke, was done. The scans were taken from the skull vault to the skull base in a craniocaudal direction.

A contrast agent (nonionic) was injected into their ante-cubital veins, omnipaque 350 mg Iodine/ml (Iohexol, GE Health Care Ireland, Cork, Ireland), in a dose of 1.5–3 mL/kg followed by a saline chase of 15-20 mL, with an injection rate of 1.5–3 mL/s injected by a dual mechanical power injector. In the case of MRI brain, however, contrast is usually unnecessary.

The region of interest (ROI) is placed at the pulmonary artery in case of suspected pulmonary embolism or the descending aorta in case of visceral embolism, with a trigger threshold set at 150 HU. Repetitive low-dose monitoring examinations (100 kV, 50 mAs, and 0.5 s scanning time) were performed 10 s after contrast medium injection began. When the trigger threshold is reached, the scan starts immediately after the breath-holding command, if possible. The patient was kept under observation for 15–30 minutes after the procedure until recovery from sedation.

The acquired axial images were reconstructed in the sagittal and coronal planes. Furthermore, a variety of high-quality 2D reformatted and 3D reconstructed images were generated. Data were reviewed to obtain all clinically relevant information using a combination of three-dimensional maximum intensity projections (MIP) and multiplanar reconstruction (MPR).

Image analysis was performed in an independent way by two radiologists with at least five years of MDCT or MR imaging experience. If a non-clear finding or observer variability was present, a revision of this variable was done by the two radiologists (in a conjoint form) until an agreement on the finding was reached and no inter-observer variability was present.

**Statistical analysis:**

Study results were analyzed by the Statistical Program for Social Science (SPSS) version 24. Quantitative variables were described in the form of range, mean, and standard deviation, while qualitative variables were described as numbers and percent’s and compared using the Chi-square (X2) test. The diagnostic parameters sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of D-dimer levels for the detection of vascular complications in COVID-19 were also calculated.

**Ethics Approval and Consent to Participate:**

This study was approved by the Research Ethics Committee of the Faculty of Medicine, Ain Shams University in Egypt on 29/12/2021; Reference Number of approval: FWA000017585. FMASU R217/2021

**RESULTS:**

Among the 100 COVID-positive patients with thromboembolic symptoms included in our study, 73 were males and 27 were females. These patients were presented mainly with clinical symptoms and signs of chest pain and dyspnea in cases suspected of
pulmonary embolism (75 patients), motor or sensory loss and weakness in cases of suspected stroke (19 patients), and abdominal pain in cases suspected to have mesenteric vascular occlusions (6 patients), as shown in Table 1.

According to their imaging and radiological basis, 55 out of 75 patients (73.3%) had evidence of pulmonary embolism, 13 out of 19 had stroke (68.4%), 4 out of 6 had mesenteric arterial occlusion (66.9%), and the remaining 28 had no radiological evidence of vascular thromboembolic manifestations (table 2).

Furthermore, among 55 patients with pulmonary embolism, 29 had main right or left pulmonary artery embolism (52.7%) and 23 had peripheral pulmonary embolism (47.3%). In addition, of 13 patients with MRI-diagnosed stroke, 9 had basal ganglionic infarction (69.2%), 3 had middle cerebral artery (MCA) thrombosis (23.1%), and one had superior sagittal thrombosis (7.7%). On the other hand, 3 out of 4 mesenteric vascular occlusion patients were found to have main superior mesenteric and celiac trunk thrombosis (75%), and the fourth patient showed portal vein thrombosis (25%). (Figure 1, 2, 3)

D-dimer levels were increased (0.50 mcg/mL or greater) in 70 percent of our positive COVID patients, including 49 of 55 (89%) patients with pulmonary embolism, 11 of 13 (84%) patients with stroke, 3 of 4 (75%) patients with mesenteric thrombosis, and 7 of 28 (25%) patients with symptoms suggestive of vascular thrombosis without radiological imaging of thromboembolic manifestations (table 3).

**Figure 1**: MDCT pulmonary angiography with contrast and thin axial and coronal cuts of known case of COVID19 with bilateral pulmonary embolism, (1a, 1b and 1c) show multiple filling defects in both main pulmonary branches, MDCT chest pulmonary window (1d) in the same case shows mainly peripheral oriented ground glass density and small consolidation patch.
Figure (2): MDCT mesenteric angiography with contrast and thin axial and sagittal cuts of known case of COVID19 with mesenteric artery embolism, (2a, 2b, 2c and 2d) show filling defects in mesenteric artery, MDCT chest pulmonary window (2e) in the same case shows mainly peripheral oriented extensive ground glass density.
Figure (3): MDCT cerebral angiography MIP and 3D with contrast of known case of COVID19 with left middle cerebral artery embolism, (3a, 3b), axial T2WI (3c) shows area of cortical and subcortical area of infarction in the territory of left MCA with small hemorrhagic area, MDCT chest pulmonary window (4d) in the same case shows mainly peripheral oriented ground glass density.

On studying the relation of D-dimer to the occurrence of embolic disease in these patients, false-positive cases (high D dimer with no evidence of embolism) were found in 7 cases, false-negative cases (low D dimer with evidence of embolism) in 9 cases, true positive cases (high D dimer with evidence of embolism) in 63 cases, and true negative cases (low D dimer with no evidence of embolism) in 21 cases, representing a sensitivity of 87.5% (63 from 72), specificity of 75% (21 from 28), positive predictive value of 90% and negative predictive value of 70%, giving an accuracy for the test of 84% (table 4).
Table 1: Demographic, clinical and laboratory parameters of our 100 COVID 19 positive patients.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>COVID 19 positive patients</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD (Range)</td>
<td></td>
</tr>
<tr>
<td>Age (Yrs)</td>
<td>52.4 ± 8.35 (30 – 66)</td>
<td></td>
</tr>
<tr>
<td>Sex (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>78.44 ± 14.19 (58 – 115)</td>
<td></td>
</tr>
<tr>
<td>Height(cm)</td>
<td>166.55 ± 7.82 (150 – 188)</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>28.16 ± 4.90 (20.1 – 39.8)</td>
<td></td>
</tr>
<tr>
<td>Smoking (n)</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Hypertension (n)</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Diabetes (n)</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>S &amp; S of PE (n)</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>S &amp; S of Stroke (n)</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>S &amp; S of MVO (n)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>High D-dimer (≥0.50 mcg/mL)</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

S & S = symptoms & signs, PE= pulmonary embolism, MVO= mesenteric vascular occlusion

Table 2: Radiological findings of vascular complications in different groups suspected of embolism in our 100 COVID 19 positive patients.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cases with suspected PE</th>
<th>Cases with suspected stroke</th>
<th>Cases with suspected MVO</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive findings of embolism</td>
<td>55</td>
<td>13</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>Negative findings of embolism</td>
<td>20</td>
<td>6</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>19</td>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

The chi-square statistic is 0.2715. The p-value is .873056. The result is not significant at p < .05.

Table 3: Incidence of high D-dimer levels in different groups with and without radiological evidence of embolism in our 100 COVID 19 positive patients.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cases with PE</th>
<th>Cases with stroke</th>
<th>Cases with MVO</th>
<th>Cases without embolism</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High D-dimer</td>
<td>49</td>
<td>11</td>
<td>3</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Normal D-dimer</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>21</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>13</td>
<td>4</td>
<td>28</td>
<td>100</td>
</tr>
</tbody>
</table>

The chi-square statistic is 37.9154. The p-value is < 0.00001. The result is significant at p < .01. (Highly significant)
MoheM. M. Abdel Aziz, et al.,

Table 4: Relation of D-dimer level to occurrence of vascular embolism in our 100 COVID 19 positive patients.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cases with vascular embolism</th>
<th>Cases without vascular embolism</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High D-dimer</td>
<td>63</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Normal D-dimer</td>
<td>9</td>
<td>21</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>28</td>
<td>100</td>
</tr>
</tbody>
</table>

DISCUSSION:

Thromboembolic complications have emerged as significant sequelae since the beginning of the COVID-19 pandemic, resulting in significant morbidity and mortality in these patients. So, early detection of these problems, either clinically or by laboratory and radiological procedures, was considered mandatory to save lives and prevent further morbidities from these complications [6&11].

In the present study, of 100 COVID-19-proven patients with different manifestations of thromboembolic events, radiological evidence of pulmonary embolism was detected in 55% of them. In addition, 73.3% of suspected PE cases (having chest pain and dyspnea) were proved by CT angiography examination. The incidence of PE in patients with coronavirus disease (COVID-19) who underwent pulmonary CT angiography was reported to be between 23% and 30% [9&12]. Also, Poyiadji et al. (2020) reported a similar rate of 22% [13], while Klok et al. found a 31% cumulative incidence of thrombotic events in ICU patients with COVID-19 infections [3].

The higher incidence of PE in our cases may be attributed to many factors. First, we chose COVID-19 patients who presented with manifestations suggestive of thromboembolic events and not all infected patients. Second, our cases were mostly obese or overweight (BMI ranged from 20.1 to 39.8 with a mean of 28.16 ± 4.90 kg/m2), which has been linked to an increased risk of PE in previous studies [13]. Thirdly, the presence of a high incidence of smoking (40%) in our cases is a risk factor for the development of thromboembolic events [14], in addition to the controversial roles of high incidences of hypertension and diabetes (72% and 32%, respectively) [15]. Lastly, the possible late presentations and lack of resources for diagnosis and management may have a role in this high incidence of embolic complications in our patients.

The location of the embolus on CT scan among our 55 patients with pulmonary embolism was found in the main right or left pulmonary artery in 29 patients (52.7%), while 23 patients showed peripheral pulmonary embolism (47.3%). Leonard-Lorant et al. (2020) found only 22% of the embolization in main pulmonary artery cases, while 34% occurred in the lobar artery, 28% in the segmental artery, and 16% in the subsegmental artery [12].

In our 100 COVID-19 positive patients, 13% had radiological evidence of cerebral infarction by MRI, accounting for 68.4% of those 19 patients with motor or sensory loss and weakness (suspected stroke). These thromboembolic events included basal ganglionic infarction (69.2%), middle cerebral artery (MCA) thrombosis (23.1%), and superior sagittal thrombosis in the remaining 7.7%. Qureshi et al. (2021) found acute ischemic stroke in 1.3% of their patients, especially in those with other cardiovascular risk factors such as hypertension, diabetes, hyperlipidemia, atrial fibrillation, and congestive heart failure [16]. The higher incidence of stroke in our patients may be attributed to the presence of many risk factors, such as smoking, hypertension, and diabetes, as mentioned before.

On the other hand, 3 of 4 mesenteric vascular occlusion patients (representing 4%
of our 100 COVID patients) were found to have main superior mesenteric and celiac trunk thrombosis (75%), and the fourth patient had portal vein thrombosis (25%). Although the true prevalence of GI symptoms among COVID-19 positive patients is unknown, with estimates ranging from less than 10% to 70% [17], acute mesenteric ischemia is rare and usually fatal, with an overall incidence of less than 1%, which is consistent with our findings.

As the prothrombotic nature of severe acute respiratory syndrome caused by coronavirus disease in the 2019 pandemic has been well established, infection with this virus has been increasingly associated with coagulopathy and thrombotic complications such as PE and others, which are associated with a higher progressive increase in D-dimer levels [58&18]. Patients with elevated levels of D-dimer and fibrin degradation products had a higher risk of death, according to Tang et al. in 2020[19].

In the present study, D-dimer levels were increased (0.50 mcg/mL or greater) in 70% of positive COVID patients, who included 89% of pulmonary embolism cases, 84% of stroke cases, and 75% of patients with mesenteric thrombosis. However, only 25% of patients with symptoms suggestive of vascular thrombosis without radiological imaging of thromboembolic manifestations have higher levels of D-dimer. The D-dimer test had a sensitivity of 87.5%, specificity of 75%, a positive predictive value (PPV) of 90% and a negative predictive value (NPV) of 70%, giving an accuracy of 84% for predicting the occurrence of thromboembolic events.

In previous studies, patients with higher levels of D-dimer were found to be at a higher risk of developing PE [58&13] which supports our results. Even so, an association between the severity of the disease and the levels of D-dimer was postulated by many others [19,20&21]. So, anticoagulant treatment has been found to be associated with decreasing mortality in severe COVID-19-infected patients [22].

Poyiadji et al. (2020) found a D-dimer test sensitivity of 78% and specificity of 81% for the development of PE [13]. In the study done by Cui et al. [23], the prevalence of venous thromboembolism (VTE) was 25%, with a sensitivity, specificity, and negative predictive value of the D-dimer cut-off value of 1.5 μg/mL of 85, 88.5, and 94.7%, respectively, which supported our findings. More recently, Lin et al. (2023) found that the standard D-Dimer threshold of 500 ng/mL had a sensitivity of 97.8%, a specificity of 40.9%, and a negative predictive value of 99.8% for the diagnosis of PE [24].

Lastly, although our study proved the importance of D-dimer in detecting thromboembolic events in COVID cases, some limitations in this study were present, as follow-up of the test during the course of the thromboembolism was not done (as it was a cross-sectional study), and in addition, we limited our test to patients who presented with manifestations suggestive of vascular events and not all cases from the start of the disease. So, further studies are needed to document the baseline of the test at the start of the COVID infection and its progress when complications start, which may be more predictive in detecting the early occurrence of thromboembolic manifestations in this infection.

**Conclusion:**

In conclusion, this study emphasized the importance of proper radiological detection of vascular thromboembolic complications in COVID-19 infections, such as pulmonary, cranial, and abdominal embolus, especially in patients with elevated D-dimer levels, as a prompt tool for early diagnosis, and thus proper management of these patients.

**Consent for publication:**

All patients approved and gave written informed consent for their participation in the study.
Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

We have no competing interests to declare.

Funding:

This study had no funding from any resource.

Acknowledgements:

The authors thank all the study participants for their patience and support.

List of Abbreviations

CT: Computed tomography
DVT: Deep-vein thrombosis
MCA: Middle cerebral artery
MDCT: Multi-detector computed tomography.
MRI: Magnetic resonance imaging
MVO: Mesenteric vascular occlusion
NPV: Negative predictive value
PE: Pulmonary embolism
PPV: Positive predictive value
VTE: Venous thromboembolism

REFERENCES


Mohamed M. Abdel Aziz, et al.,

The radiological assessment of vasculature complications of coronavirus and its relationship with D-dimer level

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Background: Coronavirus infection leads to respiratory symptoms as the main feature, in addition to non-respiratory complications, such as thrombotic complications, leading to multi-organ failure and respiratory failure.

Objective: To determine the value of radiological assessment of vasculature complications in coronavirus infection and its correlation with D-dimer levels as an important tool for early diagnosis and adequate management of these patients.

Patients and Study Methods: The study included 100 coronavirus-positive patients, based on their symptoms and laboratory tests, which included D-dimer levels. They underwent radiological assessment of vasculature complications, including computed tomography, magnetic resonance imaging, and angiography.

Results: Among the 100 coronavirus-positive patients suffering from thrombotic complications, 55 patients showed pulmonary embolism, 13 patients had cerebral embolism, and 4 patients had abdominal vessel embolism. No evidence of vasculature complications was found in 28 patients. D-dimer levels were increased in 70% of coronavirus-positive patients, including 89% of patients with pulmonary embolism, 84% of patients with cerebral embolism, and 75% of patients with abdominal vessel embolism. The sensitivity was 88.6%, specificity 75%, and positive predictive value 90.9%, and negative predictive value 70%.

Conclusion: This study confirmed that increased D-dimer levels in coronavirus-infected patients reflect severe thrombotic complications, especially pulmonary and cerebral embolism and abdominal vessel embolism, and that the radiological assessment is essential for diagnosis and adequate management of these complications.