The Relationship between Computed Tomography Pulmonary Angiography Findings and Right Ventricular Dysfunction in Patients with Pulmonary Embolism

Erdal İn1, Teyfik Turgut1, Mehmet Kalkan1, Müge Otlu Karadağ2, Mustafa Necati Dağlı1
1Department of Chest Diseases, Fırat University Faculty of Medicine, Elazığ, Turkey
2Clinic of Chest Diseases, Bingöl State Hospital, Bingöl, Turkey
3Department of Cardiology, Fırat University Faculty of Medicine, Elazığ, Turkey

OBJECTIVES: In this study, we aimed to localize thrombus and to evaluate the relationship between the site of thrombus and right ventricular dysfunction (RVD) in patients with pulmonary embolism (PE) diagnosed with computed tomography pulmonary angiography (CTPA).

MATERIAL AND METHODS: CTPA and echocardiography (ECHO) findings of 59 patients (35 male, 24 female) with PE diagnosed on CTPA were analysed retrospectively. The site of thrombus on CTPA was documented. Patients were divided into 2 groups according to ECHO findings as patients without RVD (group 1) and with RVD (group 2).

RESULTS: The most frequent sites of thrombus formation were the right main pulmonary artery (33.8%) and right lower lobar artery (30.5%). It was observed that thrombus formation was significantly higher in the right system than that of the left (63.8% and 36.2%, respectively; p<0.01). ECHO findings revealed that 16 of the 59 patients had RVD. The number of patients who had thrombus in the right main pulmonary artery was significantly higher in group 2 (p<0.001). Pulmonary trunk diameter measured by CT was significantly lower in group 1 (28 mm±3.61) in comparison to that in group 2 (37 mm±5.88) (p<0.01). Systolic pulmonary artery pressure was significantly positively correlated with pulmonary trunk and right ventricular diameter (p<0.001). Sensitivity, specificity and positive predictive value of CTPA in detecting RVD were 87.5% (14/16), 95.3% (41/43) and 87.5% (14/16), respectively.

CONCLUSION: It was observed that the probability of RVD was higher in patients with thrombus in right main pulmonary artery. There was a strong relationship between the pulmonary trunk and right ventricular diameter measured by CT and RVD observed on ECHO. It was suggested that CTPA is a reliable imaging method for detecting RVD in patients with PE.

KEY WORDS: Pulmonary embolism, echocardiography, tomography

INTRODUCTION
Pulmonary embolism (PE) is a serious life-threatening cardiopulmonary disease that results from complete or partial obstruction of the pulmonary artery. PE is associated with substantial mortality and morbidity as the third leading cause of cardiovascular system-related diseases after myocardial infarction and stroke. Therefore, findings obtained from clinical, laboratory and radiological examination performed for diagnosis must be precisely evaluated in patients with suspected of PE [1-3].

In the recent years, notable progression has been achieved in the evaluation of patients that present with suspicious PE by means of clinical evaluation, opportunity of pretesting, Doppler ultrasound (US), ventilation/perfusion (V/P) scintigraphy, and spiral computed tomography pulmonary angiography (CTPA) [4]. Owing to technological advances, new generation multi-detector computed tomography (CT) devices that enable reliable visualization of small clots located in the sub-segmental or further peripheral regions have been developed. This method, which requires holding breath for a short time (10 seconds or shorter), has a slice interval of less than 5 mm, and advanced spatial resolution provided by thin slices allows precise analysis of pulmonary artery up to the fifth branching [5]. The use of CTPA in the diagnosis of PE has dramatically increased in the recent years as the result of considerable advances in CT technologies. CTPA has substituted V/P scintigraphy and catheter pulmonary angiography in routine clinical practice as a primary method for visualization of pulmonary vascular configurations in case of suspicious PE and has become the “gold standard” in the diagnosis of PE in clinical practice since the beginning of the use of new generation multi-detector CT devices [6,7].

Echocardiography (ECHO) is a cheap method that can be easily performed in many centres, even in patients with impaired hemodynamic performance. ECHO is not recommended to be performed as a routine imaging method in the diagnosis of
PE, but it is known to be the most beneficial method used for risk classification and prognosis estimation after the diagnosis of PE is made. Demonstration of right ventricular dysfunction (RVD) by ECHO is of great importance in both determining prognosis and therapy choice in PE cases [8-10].

The present study aimed to determine the site of thrombus observed on CTPA and to identify the relation between thrombus localization and RVD in PE patients, as well as to evaluate the role of CTPA in detecting RVD.

MATERIAL AND METHODS

The present study comprised the patients that have been hospitalized and treated with a diagnosis of PE between January 2012 and January 2013 at Fırat University Hospital, Department of Chest Diseases. In order to create a homogeneous group, only the patients diagnosed with PE via CTPA method were included in this retrospective analysis. Patients that had been diagnosed by other diagnostic methods such as V/P scintigraphy, those who were hospitalized in other clinics for concomitant diseases, and those with inadequate data in hospital records were excluded from the study.

CTPA and ECHO findings of 59 patients that fulfilled the above-mentioned criteria were retrospectively analysed. Main, lobar, segmental and sub-segmental arteries of each lung were examined in detail on CT. Thrombus was considered in case of an intraluminal filling defect with well-defined margins in contrast enhanced examinations. Embolus in the pulmonary trunk, main pulmonary artery and lobar arteries were classified as “central” (Figure 1), whereas lobular, segmental and sub-segmental embolus were classified as “peripheral” (Figure 2). Sites of thrombus formation identified on CTPA were recorded. RVD was considered on CTPA images in the presence of at least one of the following; displacement of interventricular septum (IVS) towards left, reflux of contrast medium into the inferior vena cava or right ventricle (RV) diameter/left ventricle (LV) diameter ratio>1 on axial CTPA images [11].

Review of patient files revealed that echocardiographic images had been obtained from all cases in semi-supine position, apical four chambers, parasternal short-long axis and subcostal positions. On ECHO, RVD was considered in the presence of at least one of right ventricular hypokinesia, systolic paradoxical septal motion or right ventricular dilatation (end-diastolic diameter >30 mm) [12]. The patients were divided into two groups according to ECHO findings: without RVD (Group 1) and with RVD (Group 2).

Statistical Analysis

Statistical analysis of this retrospective study was done using IBM SPSS Statistics 21 (Statistical Product and Service Solutions, version 21.0, license no: d91314f638c364094170) statistical program. Results are given as mean ± standard deviation. Radiological and functional findings of the cases were evaluated using $\chi^2$ (Chi-square) test. The relation of ECHO findings with pulmonary artery and right ventricular diameter was analysed by Pearson correlation test, whereas the difference between the groups was analysed by student-t test. P<0.05 was considered statistically significant.

RESULTS

Of the 59 patients included in the study, 35 (59.3%) were male and 24 (40.7%) were female. The mean age of the cases was 65.25±17.74 years. The most prevalent chest X-ray findings were parenchymal infiltration (22 cases, 37.3%) and pleural effusion (21 cases, 35.6%). No pathology was detected in 20 (33.9%) patients. CT pathologies other than thrombus, in the order of frequency, were parenchymal infiltration (22 cases, 37.3%) and pleural effusion (21 cases, 35.6%). No pathology was detected in 20 (33.9%) patients. CT pathologies other than thrombus, in the order of frequency, were parenchymal infiltration (30 cases, 50.8%), pleural effusion (27 cases, 45.8%) and atelectasis (23 cases, 39%). Different from the chest x-ray,

*İn et al. CT Angiography and ECHO in Pulmonary Embolism*
any pathology other than embolus was not detected in 12 patients (20.3%). Chest x-ray and CT findings of the patients are presented in Table 1.

When computed tomography images were examined in detail, thrombus was observed in the right main pulmonary artery in 20 (33.8%), in the left main artery in 10 (16.9%), in the right inferior lobar artery in 18 (30.5%), in the left inferior lobar artery in 5 (8.5%), in the right superior lobar artery in 7 (11.9%), in the left superior lobar artery in 10 (16.9), in the segmental/sub-segmental arteries of the right superior lobe in 4 (6.8%), in the segmental/sub-segmental arteries of the left superior lobe in 1 (1.7%), in the segmental/sub-segmental arteries of the right inferior lobe in 11 (18.6%), and in the segmental/sub-segmental arteries of the left inferior lobe in 14 (23.7%) patients. No thrombus was observed in the pulmonary trunk of any of the patients. Of the thrombi, 64 (68%) were central (main and lobar arteries) and 30 (32%) were peripheral (segmental and sub-segmental arteries). In addition, the number of thrombi was the highest in the right main pulmonary artery (20 thrombi, 33.8%) and in the right inferior lobar artery (18 thrombi, 30.5%). Comparing the total number of thrombi in the right system (60 thrombi, 63.8%) with the total number of thrombi in the left system (34 thrombi, 36.2%), it was observed that the number of thrombi was statistically significantly higher in the right system (p<0.01). Whilst there was bilateral thrombi in 21 (35.6%) patients, it was only in the right pulmonary system in 27 (45.8%) and in the left pulmonary system in 11 (18.6%) patients. Thrombus localizations on CTPA are demonstrated in Table 2.

When the patients were divided into two groups according to ECHO findings as without (Group 1) and with (Group 2) right ventricular dysfunction, it was observed that 43 patients were in Group 1 and 16 patients were in Group 2. There was no significant difference between the groups in terms of age, gender, and chest x-ray and CT findings. With regard to the site of thrombus, patients with thrombus formation in the right main pulmonary artery were statistically significantly more prevalent in Group 2 (p<0.001). There was a statistically significant positive correlation between systolic pulmonary artery pressure (sPAP) determined on ECHO and right ventricular diameter measured on CT (p<0.001, r: 0.837) (Figure 3). There was also a statistically significant positive correlation between sPAP and pulmonary trunk diameter measured on CT (p<0.001, r: 0.633) (Figure 4). Pulmonary trunk diameter measured on CT was statistically significantly lower in Group 1 (28 mm±3.61) as compared to Group 2 (37 mm±5.88) (p<0.01). RVD was determined on CTPA in 14 of 16 patients that had RVD also on ECHO. Signs of RVD were absent on CTPA in only 2 patients. Moreover, RVD was absent also on CTPA in 41 of 43 patients that had no RVD on ECHO. As compared with ECHO, the sensitivity, specificity and positive predictive value of CT in detecting RVD were 87.5% (14/16), 95.3% (41/43) and 87.5% (14/16), respectively.

**DISCUSSION**

In the recent years, multi-detector CT devices, which allow visualization of sub-segmental and further peripheral thrombi, are being widely used in the diagnosis of PE. The sensitivity, specificity, positive predictive value and negative predictive value of this new generation CT examination, which minimizes the artefacts caused by breathing and beating of the heart, are 90%, 90%, 93%, and 94%, respectively [5].

With regard to the site of thrombus; de Monye et al. [13] conducted a study in 487 cases and found embolus by 7.7% in pulmonary trunk, 14.6% in the right and left pulmonary arteries, 28.5% in the lobar arteries, 26.9% in the segmental arteries, and 22.3% in the sub-segmental arteries. In another study, the prevalence of PE was reported to be 58% in segmental and larger arteries and 42% in sub-segmental and smaller arteries [14]. In a study from Turkey, embolus was detected in the pulmonary trunk in 5 (2.4%), in the right and left main pulmonary arteries in 25 (12.3%), in the right and left lobar arteries in 117 (57%), at segmental level in both pulmonary arteries in 32 (15.6%) and at sub-segmental level in both pulmonary arteries in 26 (12.7%), patients. The most frequent site of embolism was right inferior lobar artery [15]. In another study from Turkey that evaluated 164 cases, bilateral emboli was detected in 116 (70.7%) and unilateral

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**Table 1. Chest X-ray and Thoracic CT findings of the patients**

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Chest X-ray</th>
<th>Thoracic CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parenchymal infiltration, n (%)</td>
<td>22 (33.9)</td>
<td>30 (50.8)</td>
</tr>
<tr>
<td>Pleural effusion, n (%)</td>
<td>21 (35.6)</td>
<td>27 (45.8)</td>
</tr>
<tr>
<td>Atelectasis, n (%)</td>
<td>13 (22)</td>
<td>23 (39)</td>
</tr>
<tr>
<td>Diaphragm elevation, n (%)</td>
<td>14 (23.7)</td>
<td>8 (13.6)</td>
</tr>
<tr>
<td>Volume loss, n (%)</td>
<td>5 (8.5)</td>
<td>8 (13.6)</td>
</tr>
<tr>
<td>Oligemia, n (%)</td>
<td>3 (5.1)</td>
<td>5 (8.5)</td>
</tr>
<tr>
<td>No Pathology, n (%)</td>
<td>20 (33.9)</td>
<td>12 (20.3)</td>
</tr>
</tbody>
</table>

CT: computed tomography

**Table 2. Sites of thrombus observed on CTPA**

<table>
<thead>
<tr>
<th>Site of thrombus</th>
<th>Total number of thrombi (n:94)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central, n (%)</td>
<td>64 (68)</td>
</tr>
<tr>
<td>Right main pulmonary artery, n (%)</td>
<td>20 (33.8)</td>
</tr>
<tr>
<td>Left main pulmonary artery, n (%)</td>
<td>10 (16.9)</td>
</tr>
<tr>
<td>Right inferior lobar artery, n (%)</td>
<td>18 (30.5)</td>
</tr>
<tr>
<td>Left inferior lobar artery, n (%)</td>
<td>5 (8.5)</td>
</tr>
<tr>
<td>Right superior lobar artery, n (%)</td>
<td>7 (11.9)</td>
</tr>
<tr>
<td>Left superior lobar artery, n (%)</td>
<td>4 (6.8)</td>
</tr>
<tr>
<td>Peripheral, n (%)</td>
<td>30 (32)</td>
</tr>
<tr>
<td>Right superior lobe segment/sub-segment, n (%)</td>
<td>4 (6.8)</td>
</tr>
<tr>
<td>Left superior lobe segment/sub-segment, n (%)</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>Right inferior lobe segment/sub-segment, n (%)</td>
<td>11 (18.6)</td>
</tr>
<tr>
<td>Left inferior lobe segment/sub-segment, n (%)</td>
<td>14 (23.7)</td>
</tr>
</tbody>
</table>

CTPA: computed tomography pulmonary angiography
emboli was detected in 48 (29.3%) patients. It was observed that, 29 (60.5%) of unilateral emboli were in the right pulmonary arterial system, whereas 19 (39.5%) were in the left pulmonary arterial system [16]. In the present study, 64 (68%) of thrombi were central and 30 (32%) were peripheral. Moreover, it was observed that thrombi was bilateral in 21 (35.6%) patients, whereas it was only in the right pulmonary system in 27 (45.8%) and in the left pulmonary system in 11 (18.6%) patients. The most frequent sites of thrombi were the right main pulmonary artery (33.8%) and the right inferior lobar artery (30.5%). As compared with the left system (34 thrombi, 36.2%), total number of thrombi was statistically significantly higher in the right system (60 thrombi, 63.8%). In all studies including the present study, thrombi were more prevalent in the right system. We think this might result from the facts that right pulmonary arterial system is more commonly supplied by the main pulmonary system in comparison to the left system, as well as from diverse anatomical structures of the right and left pulmonary arterial branching.

Various studies reported that acute PE cases with RVD have a poorer prognosis as compared to those without RVD, even if they have normal systemic arterial pressure [17,18]. Recognition of RVD in PE cases is beneficial for risk classification, as well as for applying thrombolytic agents, vasoreactive agents, or more aggressive treatments such as inferior vena cava filter [19]. In a study, in which 103 hemodynamically stable PE patients were evaluated by ECHO in terms of RVD and pulmonary hypertension (PHT), Golpe et al.[12] detected RVD in 24.5% and isolated PHT in 19.6% of the patients. They found that CTPA and ECHO findings were strongly correlated in determining RVD. Furthermore, the same study determined a correlation between the degree of vascular obstruction detected by CTPA and sPAP detected by ECHO in all patients (p<0.04, r: 0.298). In a study that comprised 25 patients diagnosed with PE based on CT findings, 23 patients underwent ECHO and 2 patients underwent pulmonary angiography for the assessment of right cardiac functions, and RVD was considered in the presence of right ventricular dilatation or deviation of the IVS towards left on CT. Accordingly, compared with ECHO or pulmonary angiography, the sensitivity, specificity and positive predictive value of CT in detecting RVD were found to be 78%, 100% and 100%, respectively [20]. In a study that evaluated 14 patients diagnosed with massive PE by CTPA, RVD was detected by ECHO in 12 of the patients, 11 of whom had right ventricular dilatation or deviation of the IVS to the left side according to CT findings. The sensitivity and specificity of CT in determining RVD were found to be 91.6% and 100%, respectively [19]. Özsu et al.[21] evaluated CTPA, ECHO and cardiac biomarker findings of 108 normotensive PE patients that had been diagnosed based on CT, and found a statistically significant correlation between CTPA and ECHO in terms of measuring right ventricular diameter (r=0.408, p<0.001). In addition, the same study compared RV/LV ratios measured by CTPA and ECHO, and again found a statistically significant correlation between two methods (r=0.499, p<0.001). Likewise, as compared with ECHO, the present study found that sensitivity, specificity and positive predictive value of CT in detecting RVD, were 87.5%, 95.3% and 87.5% respectively. Moreover, a statistically significant correlation was found between sPAP measured by ECHO and pulmonary trunk and right ventricle diameters measured by CT. Diameter of the pulmonary trunk measured by CT was found to be correlated with RVD presence and it was observed that the presence of a thrombus in the right main pulmonary artery enhanced the probability of RVD.

In the present study, data of the patients with PE were obtained by retrospectively reviewing the patient files in hospital computer system. Exclusion of the patients with inadequate data was the most important limitation of the present study. The other limitation was not including the patients diagnosed based on methods other than CTPA and those hospitalized in the other clinics for concomitant diseases.

In conclusion, based on this retrospective analysis, CTPA performed in PE patients revealed that thrombi were most frequently localized in the right main pulmonary artery followed by the right inferior lobar artery. It was observed that the probability of RVD was higher in patients with thrombus in the right main pulmonary artery. A strong correlation was
observed between pulmonary trunk and right ventricular diameters measured by CT and RVD detected by ECHO. It was concluded that CTPA is a beneficial and reliable method in detecting RVD.

**Ethics Committee Approval:** There was no need to get ethics committee approval since the study was retrospectively done by using the data on the medical files of the patients.

**Informed Consent:** Since the study have a retrospective design, patient consents were not obtained.

**Peer-review:** Externally peer-reviewed.


**Conflict of Interest:** No conflict of interest was declared by the authors.

**Financial Disclosure:** The authors declared that this study received no financial support.

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