Relationship between clot burden in pulmonary computed tomography angiography and different parameters of right cardiac dysfunction in acute pulmonary embolism

Heba wagih Abdelwahab, Shreif Arafa, Khaled Bondok, Nihal Batouty, Mostafa Bakeer

Abstract

Background: Pulmonary computed tomography angiography (CTA) contains a wealth of information regarding the diagnosis and impact of acute pulmonary embolism (PE). Echocardiography remains the recommended examination to detect signs of right ventricular (RV) dysfunction in patients with shock or hypotension following PE.

Objectives: To detect the relationship between clot volume in pulmonary CTA and different parameters of RV dysfunction assessed by echocardiography and pulmonary CTA in patients with acute PE.

Methods: A cross-sectional study was performed on patients with acute PE from June 2017 to June 2018. Enrolled patients were assessed clinically, radiologically and for cardiac dysfunction. The relationship between clot volume and RV dysfunction was assessed using pulmonary CTA and echocardiography. Data were analysed with SPSS version 16. Correlations were studied using the Spearman and Kruskal–Wallis tests.

Results: There was a significant correlation found between clot volume and parameters of RV dysfunction, assessed by pulmonary CTA, including RV diameter ($p < 0.001$), RV to left ventricular (LV) diameter ratio ($p = 0.01$), pulmonary artery diameter ($p = 0.01$), ratio of main pulmonary artery to ascending aorta diameter ($p = 0.04$), and superior vena cava diameter ($p = 0.01$). On the other hand, there was no significant correlation between clot volume and parameters of RV dysfunction assessed by echocardiography.

Conclusion: In patients with acute PE, the assessment of RV dysfunction using pulmonary CTA showed good correlation with clot burden, unlike the assessment done with echocardiography.

Keywords: acute pulmonary embolism, clot burden, right ventricular dysfunction

Pulmonary computed tomography angiography (CTA) has been established as the first-line imaging modality for the diagnosis of acute pulmonary embolism (PE) in clinical practice. In addition to its role in diagnosis, pulmonary CTA contains a wealth of information, such as characteristics of the clot, which may be used as biomarkers to improve treatment and clinical management.

Risk stratification for patients with acute PE is important to establish the appropriate management. Patients with PE and preserved right ventricular (RV) function are treated with systemic anticoagulation, while haemodynamically unstable patients are considered to be candidates for thrombolytic therapy.

Echocardiography is recommended as the first-line examination in patients with shock or hypotension following PE to detect signs of RV dysfunction. Pulmonary CTA, on the other hand, is a commonly used technique for diagnosis of PE and assessment of RV dysfunction, which would facilitate risk stratification in all patients. This study was planned to detect the relationship between clot volume and different parameters of RV dysfunction assessed by echocardiography and pulmonary CTA in patients with acute PE.

Methods

A cross-sectional study was performed from June 2017 to June 2018. Seventy patients with acute PE admitted to the Chest Medicine Department, Mansoura University, were enrolled in this study. All patients provided written informed consent prior to participation. The study was approved by the institutional review board. Patients with inadequate pulmonary CTA scans (poor imaging) were excluded. Any decision about treatment was at the discretion of the attending physician.

Enrolled patients in this cross-sectional study were assessed clinically and radiologically, as well as for cardiac dysfunction.
The clinical assessment was done using pulmonary embolism severity index score:  class I: ≤ 65 points, very low risk; class II: 66–85 points, low risk; class III: 86–105 points, intermediate risk; class IV: 106–125 points, high risk; class V: > 125 points, very high risk.

Assessment of RV dysfunction

For pulmonary CTA, Philips Ingenuity core 128, the Netherlands, and non-ionic iodinated contrast agent iohexol 350 mgI/ml, Omnipaque, GE Health Care, Ireland, were used. The imaging studies were analysed by a radiologist. PE was assessed on pulmonary CTA images by detecting the presence of an endoluminal central filling defect partially or completely occluding the pulmonary arteries. We used a standard mediastinal window and a semi-automated segmentation program to segment each clot from pulmonary CTA images and measure clot volume (mm³). Clot assessment was done with regard to localisation (central, lobar or distal) and clot volume.

Pulmonary CTA signs were used to assess the function of the right side of the heart, including: the ratio of RV to left ventricular diameter (RV/LV ratio), ratio of main pulmonary artery to ascending aorta diameter (PA/AO ratio), and the superior vena cava diameter. The diameters of the right and left ventricles were measured on the axial CTA image of the heart at their widest point (Fig. 1), and the RV/LV ratio was calculated. The diameters of the main PA and the AO were measured on the transverse image at which the right pulmonary artery is in contiguity with the main pulmonary artery. The PA/AO ratio was calculated from this (Fig. 2).

For echocardiography, a Sonoscape A5 portable echocardiograph was used. Ideally, multiple parameters should be used to determine RV systolic function. Visual examination is the most commonly used method to quantify RV function (RVF) however it was proved that this method is not accurate if used as a single parameter for evaluation of RVF. Therefore the guidelines suggest using at least one of the following parameters to quantify RVF: fractional area change (FAC), tissue Doppler of the free lateral wall (S'), and tricuspid annular plane systolic excursion (TAPSE) with or without RV index of myocardial performance (RIMP). In our study, we used the following parameters to assess right cardiac function:

- Assessment of RV dilatation.
- Pulmonary artery systolic pressure.
- TAPSE, which represents a measure of RV longitudinal function. It is measured by M-mode echocardiography with the cursor optimally aligned along the direction of the tricuspid lateral annulus in the apical four-chamber view, measuring the amount of longitudinal motion of the annulus at peak systole (Fig. 3).
- Tissue Doppler imaging (TDI)-derived tricuspid lateral annular systolic velocity (S'), which correlates well with other measures of global RV systolic function.
- The RV myocardial performance index (MPI) or Tei index, which is an index of global RV performance. The isovolumic contraction time, isovolumic relaxation time and ejection time intervals were measured. This reflects both systolic and diastolic RV function. MPI is defined as the sum of isovolumic contraction time (IVCT) and isovolumic relaxation (IVRT) time, divided by the ejection time (ET) of the RV (Fig. 4).
Statistical analysis

SPSS version 16 was used in the analysis of data. Spearman correlation was used to test the association between clot volume and other continuous variables, while the Kruskal–Wallis test was used to test the association between categorical variables and clot volume. The post hoc Mann–Whitney U-test was applied to indicate which groups had significant associations with clot volume. Linear regression was used to evaluate the contribution of factors found to be significant in bivariate analysis in predicting clot volume.

Results

Seventy patients with acute PE were evaluated and 34 (48.6%) were male. Mean age was 43 ± 15 years. Five patients (14.3%) were haemodynamically unstable at admission. Patient characteristics are shown in Table 1.

Localisation of emboli was central in 40 patients (57.14%), lobar in 18 (25.71%) and distal in 12 patients (17.14%). Saddle emboli were observed in eight patients (11.42%).

The median clot volume measured in all patients was 4 285 mm$^3$ (1 650–11 226) (minimum – maximum). No correlation was found between clot volume and age ($p = 0.24$) or gender ($p = 0.86$). Bivariate analysis using the Kruskal–Wallis test showed that there were significant associations between clot volume and the presence of auto-immune disease ($p = 0.028$) and hypotension ($p = 0.002$).

Table 1. Characteristics of the study population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>34 (48.6)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>36 (51.4)</td>
</tr>
<tr>
<td>Age (mean ± SD) years</td>
<td>43 ± 15</td>
</tr>
<tr>
<td>Risk factors</td>
<td></td>
</tr>
<tr>
<td>Cancer, n (%)</td>
<td>20 (28.5)</td>
</tr>
<tr>
<td>Orthopedic surgery, n (%)</td>
<td>10 (14.28)</td>
</tr>
<tr>
<td>Auto-immune disease, n (%)</td>
<td>18 (25.7)</td>
</tr>
<tr>
<td>Heart failure, n (%)</td>
<td>8 (11.4)</td>
</tr>
<tr>
<td>Postpartum, n (%)</td>
<td>8 (11.4)</td>
</tr>
<tr>
<td>Immobilisation, n (%)</td>
<td>6 (8.5)</td>
</tr>
</tbody>
</table>

Table 2. Correlation between clot volume and different imaging parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>SD</th>
<th>Correlation coefficient (rho)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT angiography</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RV diameter (mm)</td>
<td>33.8603</td>
<td>6.26018</td>
<td>0.417</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>RV/LV</td>
<td>0.9331</td>
<td>0.18969</td>
<td>0.364</td>
<td>0.011</td>
</tr>
<tr>
<td>PA diameter (mm)</td>
<td>28.4651</td>
<td>5.30103</td>
<td>0.297</td>
<td>0.013</td>
</tr>
<tr>
<td>PA/AO</td>
<td>0.9023</td>
<td>0.16398</td>
<td>0.245</td>
<td>0.041</td>
</tr>
<tr>
<td>SVC diameter (mm)</td>
<td>18.3343</td>
<td>4.01406</td>
<td>0.287</td>
<td>0.016</td>
</tr>
<tr>
<td>Echocardiography</td>
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<tr>
<td>TAPSE</td>
<td>1.9355</td>
<td>0.45778</td>
<td>-0.258</td>
<td>0.091</td>
</tr>
<tr>
<td>S wave</td>
<td>9.3790</td>
<td>1.93405</td>
<td>-0.068</td>
<td>0.667</td>
</tr>
<tr>
<td>Tei index</td>
<td>0.3875</td>
<td>0.25753</td>
<td>0.003</td>
<td>0.985</td>
</tr>
<tr>
<td>PASP</td>
<td>34.3471</td>
<td>16.31748</td>
<td>0.239</td>
<td>0.173</td>
</tr>
<tr>
<td>RV diameter</td>
<td>4.6875</td>
<td>0.86922</td>
<td>0.317</td>
<td>0.231</td>
</tr>
</tbody>
</table>

Regarding pulmonary CTA parameters, a significant correlation was found between clot volume and the following parameters of RV dysfunction: RV diameter ($p < 0.001$), RV/LV ratio ($p = 0.01$), PA diameter ($p = 0.01$), PA/AO ratio ($p = 0.04$) and superior vena cava diameter ($p = 0.01$) (Table 2).

On other hand, regarding echocardiography, there was no significant correlation found between clot volume and the following echocardiographic parameters of RV function: TAPSE ($p = 0.091$), S wave ($p = 0.667$), Tei index ($p = 0.985$), pulmonary artery systolic pressure ($p = 0.173$) and RV diameter ($p = 0.231$) (Table 2).

Discussion

PE is associated with a high risk of morbidity and mortality, mainly resulting from RV dysfunction. The effect of PE on RV function can be evaluated by either transthoracic echocardiography or pulmonary CTA. Echocardiography is less costly than the other techniques available and remains the first-line examination technique for the RV. However, RV evaluation through echocardiography remains difficult because of the complex anatomy of the RV, its retrosternal position, and the interposition of the lungs. In addition, studies comparing severity of clot load with RV burden assessed by echocardiography have reported controversial results.

Pulmonary CTA, on the other hand, is the method of choice for the diagnosis of PE. It can also identify signs of RV dysfunction that may have prognostic significance or implications for treatment, for example, need for the institution of thrombolytic therapy versus conventional anticoagulation alone. Therefore there has been interest in inferring measures of RV dysfunction from pulmonary CTA.

The results of our study showed a good correlation between clot burden and signs of RV dysfunction assessed by pulmonary CTA, but did not demonstrate a good correlation with those commonly used signs assessed by echocardiography. Different echocardiographic and CTA parameters of RV dysfunction were used in previous studies to assess its correlation with clot volume. These findings suggest that pulmonary CTA may be a more reliable method for assessing RV dysfunction in patients with PE.
burden. Rodrigues et al. assessed the effect of pulmonary vascular obstruction severity on RV function in patients with acute PE and concluded that no significant correlation was found between clot burden and echocardiographic parameters. These results could support our finding despite the fact that they used quantitative parameters such as fractional area change and pulmonary systolic pressure.

On the hand, another study was performed by Rodrigues et al. to evaluate the correlation between a score of angiographic embolic load (Qanadli score, QS) and the parameters of RV dysfunction. They found that a QS > 18 points proved to be an independent predictor of RV dysfunction in acute PE, where echocardiography showed higher pulmonary artery systolic pressure, and CTA revealed larger RV diameters and higher RV/LV ratio (p = 0.002), and greater superior vena cava, azygos vein and coronary sinus diameters. PA diameter and PA/AO ratio were similar.

In addition, the correlation between clot burden and echocardiographic regional RV dysfunction (RRVD) was studied by Tuzovic et al. RRVD was defined as normal excursion of echocardiographic regional R V dysfunction (RRV D) was studied and coronary sinus diameters. PA diameter and PA/AO ratio outcome during 3-month follow up in patients with acute pulmonary embolism. Radiology 2005; 235: 798–803.


References