Evaluation of acute pulmonary embolism by sixty-four slice multidetector CT angiography: Correlation between obstruction index, right ventricular dysfunction and clinical presentation

Noha M. Attia a,*, Gehan S. Seifeldein a, Ali A. Hasan b, Abdelkarim Hasan a

a Radiology Department, Faculty of Medicine, Assiut University, Egypt
b Chest Department, Faculty of Medicine, Assiut University, Egypt

Received 22 August 2014; accepted 21 October 2014
Available online 17 November 2014

KEYWORDS
- Pulmonary embolism
- Multidetector CT
- Obstructive index
- Right ventricular dysfunction

Abstract  Introduction: MDCT pulmonary angiography is the method of choice for the detection of pulmonary embolism (PE). The severity of PE as estimated by the obstruction index (OI) and right ventricular dysfunction (RVD) can be evaluated with MDCT.

Objective: To investigate the correlation between the OI, RVD and clinical presentation in patients with acute PE.

Methods: Among 70 patients with suspected PE, 35 patients proved to have PE with MDCT. The CT OI and the RV/LV diameter (RVD-ratio) using the four-chamber view of the heart were calculated for PE patients. The cut-off for the OI to detect RVD was constructed using ROC curve.

Results: Dyspnea and RVD (RVD-ratio > 1) were significantly more common in patients with central pulmonary emboli. The mean OI (35% ± 19%) was significantly higher in patients with dyspnea, tachycardia and obesity. A positive correlation was found between the OI and both the CT pulmonary artery diameter (r = 0.66, p < 0.001) and the RVD-ratio (r = 0.628, p < 0.001). The mean OI was significantly higher in patients with RVD (p < 0.001). A CT OI > 43% identified more than 90% of patients with RVD (area under the curve on ROC analysis: 0.825; p < 0.001).

Conclusion: The mean OI correlated linearly with PA diameter and RVD-ratio. OI > 43% proved to be an independent predictor of RVD.

© 2014 The Egyptian Society of Radiology and Nuclear Medicine. Production and hosting by Elsevier B.V. Open access under CC BY-NC-ND license.

1. Introduction

Acute pulmonary embolism (PE) is a common and potentially fatal disease with mortality ranging from 2% to 7%, even when treated with anticoagulation (1). Rapid risk assessment...
is essential in selecting the appropriate treatment strategy in patients with acute PE because high-risk patients may benefit from thrombolysis or embolectomy in addition to anticoagulation. Echocardiography has emerged as an important prognostic tool for risk stratification, with right ventricular dysfunction (RVD) serving as an independent predictor of short-term mortality (2). Disadvantages of echocardiography include limited availability, incremental cost, and an occasional poor imaging quality of the right ventricle (RV).

The advent of multidetector computed tomography (MDCT) pulmonary angiography, particularly 16- and 64-slice made volumetric acquisition of images of the entire chest in a single breath-hold with isotropic resolution possible. This capability enables multiplanar viewing and assessment of pulmonary vessels to subsegmental levels. All these advantages made MDCT angiography the most commonly used procedure for the diagnosis of PE (3).

Because the MDCT pulmonary angiography in the cranio-caudal direction includes the heart, evaluation of the RV extends the prognostic role of MDCT. RV enlargement signifies a complicated hospital course. The best studied parameter to evaluate RV enlargement is the RV/LV diameter ratio, as first suggested by Reid and Murchison (4).

It is important to show the relationship between the CT obstruction index (OI) and other parameters (e.g., those recently used in stratification of patient risk, such as the right ventricular dilatation). The presence of RVD may indicate a high likelihood of recurrent and possibly fatal PE, despite an adequate anticoagulation therapy. The degree of pulmonary vascular obstruction is considered the most important factor determining the right ventricular impairment in patients with PE (5).

The aim of our study was thus to evaluate the correlation between the OI, RVD and clinical presentation in patients with acute PE.

2. Patients and methods

2.1. Patients

The study included 70 consecutive patients (36 females and 34 males). Their ages ranged from 18–77 years. The patients came to the Assiut University Hospital in the period from May 2012 to September 2013 with clinical suspicion of pulmonary embolism. The ethics committee approval was obtained and all enrolled patients completed a written consent form. All 70 patients were grouped according to Well’s score into low, moderate or high clinical probability. Then they underwent MDCT pulmonary angiography and 35 had proven pulmonary emboli and were eligible for our study. The remaining patients who proved negative for pulmonary embolism or those with inconclusive examination were excluded from the study.

2.2. Methods

MDCT pulmonary angiography was performed using 64-slice MDCT (Aquilion 64; Toshiba Medical Systems Corporation, Otawara, Japan) at Radiology Department. The clot burden in the pulmonary vascular tree was quantified using the established and validated Qanadli score and the obstruction index was calculated. The RVD ratio and the main pulmonary artery diameter were determined.

2.2.1. Pulmonary angiography

MDCT pulmonary angiography was carried out at 120 kV, 100 mAs, with 0.75 mm collimation and pitch of 1.22. Images were reconstructed with a thickness of 1 mm, reconstruction interval of 0.7 mm. The area from the supra-aortic trunks to the base of the lungs was studied from cranial to caudal direction.

All patients were placed in supine position and 80 ml of non-ionic iodated contrast medium (Ultravist 370) was injected via an antecubital vein at a rate of 4 ml/s. 20 ml of normal saline was injected at the same rate before and after contrast administration to check the IV line for saline extravasation and as a wash-out bolus respectively. A double-syringe pump (Ulrich Medical, Ulm/Germany) was used for injection of the contrast medium and normal saline. The scanning delay time was determined using the bolus-tracking technique in the lumen of the pulmonary trunk. The threshold value was selected at 120 HU. The total scanning time was approximately 4–5 s.

Images were reviewed independently by two radiologists on a Vitrea workstation then the clot burden score and obstruction indices were calculated for all patients without the knowledge of their clinical assessment or diagnostic exam results.

The diagnostic criteria for acute PE include, first, complete arterial occlusion with failure to opacify the entire lumen and the artery may be enlarged in comparison with the pulmonary arteries of the same order of branching; second, a central arterial filling defect surrounded by IV contrast material; and third, a peripheral intraluminal filling defect that makes an acute angle with an arterial wall (6).

2.2.2. Clot burden score

Qanadli et al. (5) evaluated a specific index for quantifying arterial obstruction with a helical CT in acute pulmonary embolism and showed that their proposed score was reproducible and correlated highly to the pulmonary angiography index. In this study, we used the same scoring system based on the site of obstruction and the degree of occlusion of the pulmonary arteries.

2.2.2.1. Site of obstruction.

The presence of thrombus in a segmental artery received a point value of 1. Emboli in the most proximal arterial level received a total score equal to the number of segmental arteries arising distally, according to the predetermined anatomic subdivisions described previously (maximum score of 3 for the upper lobe arteries, 2 for the middle lobe and the lingual arteries, 5 for the lower lobe arteries, 7 for the intermediate arteries, and 10 for the main pulmonary artery). A single filling defect extending into more than one anatomic location was scored for each location up to, but not exceeding, the maximum designated for each region. The maximum possible score for involvement was 20 points (7).

2.2.2.2. Degree of obstruction.

In addition to assessing the level of obstruction, and to provide additional information about the perfusion distal to the thrombus, we multiplied all scores related to the level of obstruction by a weighting factor...
when the thrombus was partially occlusive; \( \times 2 \) when the thrombus was totally occlusive), depending on the degree of vascular obstruction caused by embolism. Each obstruction therefore received a score depending on the vessel involved multiplied by the weighting factor. The value of the most proximal thrombus in the pulmonary arterial tree scored a maximum of 6 (\( 3 \times 2 \)) for the upper lobe arteries, 4 (\( 2 \times 2 \)) for the middle lobe and the lingual arteries, 10 (\( 5 \times 2 \)) for the lower lobe arteries, 14 (\( 7 \times 2 \)) for the intermediate arteries, and 20 (\( 10 \times 2 \)) for the main pulmonary artery; thus, the maximum CT obstruction score for any patient could not exceed 40.

The percentage of the vascular obstruction was calculated by dividing the patient score on the maximum total score (40) and multiplying the result by 100 (5).

### 2.2.3. RVD ratio measurement

Right and left ventricular dimensions (RVD and LVD) were measured on the reconstructed 4-chamber view by identifying the maximal distance between the ventricular endocardium and the interventricular septum, perpendicular to the long axis. RVD was diagnosed if the right to left ventricular diameter ratio was > 1 (7).

### 2.3. Statistical analysis

SPSS was used for statistical analysis of the results, which are presented as means ± standard deviation and overall percentages. The variables under study were compared using the chi-square test for categorical variables and an independent t-test for numeric variables. A value of \( p < 0.05 \) was considered statistically significant. ROC curve was constructed to establish the best cut-off for the OI.

### 3. Results

After performing MDCT pulmonary angiography for 70 patients, 35 proved positive and were included in the study. 17 (48.6%) were males and 18 (51.4%) were females. The mean age was 50.3 years. The patient characteristics are shown in Table 1. The mean clot burden score was 14.7 ± 7.9. The number of patients with RVD was 13.

The site of the emboli was named according to the most proximal location. It was central in 16 patients (45%) (Figs. 5 and 6), lobar in 10 patients (28%) (Fig. 6), segmental in 6 patients (17%) and subsegmental in 3 patients (8%) (Fig. 7). The relationship between the clinical presentation, risk factors and the site of emboli is shown in Table 2. Dyspnea was significantly more common in patients with central pulmonary emboli but was inversely related to patients with segmental

### Table 1 Characteristics of the studied patients.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>17 (48.6%)</td>
</tr>
<tr>
<td>Female</td>
<td>18 (51.4%)</td>
</tr>
<tr>
<td>Age “years”</td>
<td>50.3 ± 15.9</td>
</tr>
<tr>
<td>Risk factors</td>
<td></td>
</tr>
<tr>
<td>Recent surgery/immobility</td>
<td>26 (81.25%)</td>
</tr>
<tr>
<td>Cancer</td>
<td>2 (5.71%)</td>
</tr>
<tr>
<td>Trauma</td>
<td>3 (8.57%)</td>
</tr>
<tr>
<td>Obesity</td>
<td>4 (11.42%)</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>2 (5.71%)</td>
</tr>
<tr>
<td>Concomitant DVT</td>
<td>19 (54.28%)</td>
</tr>
<tr>
<td>COPD</td>
<td>4 (11.42%)</td>
</tr>
<tr>
<td>Clinical presentation</td>
<td></td>
</tr>
<tr>
<td>Dyspnea</td>
<td>26 (74.28%)</td>
</tr>
<tr>
<td>Chest pain</td>
<td>22 (62.85%)</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>8 (22.85%)</td>
</tr>
<tr>
<td>Tachycardia (( \geq 100 ) beats/min)</td>
<td>19 (54.28%)</td>
</tr>
<tr>
<td>Wells score</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>3 (8.57%)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>19 (54.29%)</td>
</tr>
<tr>
<td>High</td>
<td>13 (37.14%)</td>
</tr>
<tr>
<td>RVD on MDCT</td>
<td>13 (37.14%)</td>
</tr>
</tbody>
</table>

(x 1 when the thrombus was partially occlusive; \( \times 2 \) when the thrombus was totally occlusive), depending on the degree of vascular obstruction caused by embolism. Each obstruction therefore received a score depending on the vessel involved multiplied by the weighting factor. The value of the most proximal thrombus in the pulmonary arterial tree scored a maximum of 6 (\( 3 \times 2 \)) for the upper lobe arteries, 4 (\( 2 \times 2 \)) for the middle lobe and the lingual arteries, 10 (\( 5 \times 2 \)) for the lower lobe arteries, 14 (\( 7 \times 2 \)) for the intermediate arteries, and 20 (\( 10 \times 2 \)) for the main pulmonary artery; thus, the maximum CT obstruction score for any patient could not exceed 40. The percentage of the vascular obstruction was calculated by dividing the patient score on the maximum total score (40) and multiplying the result by 100 (5).

### Table 2 Clinical presentation according to the site of emboli.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Central 16 (45%)</th>
<th>Lobar 10 (28%)</th>
<th>Segmental 6 (17%)</th>
<th>Subsegmental 3 (8%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p value</td>
<td>OR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>5.19 (0.79–33.93)</td>
<td>.01</td>
<td>0.62 (0.45–0.83)</td>
<td>0.02</td>
</tr>
<tr>
<td>Chest pain</td>
<td>0.99 (0.47–2.07)</td>
<td>Ns</td>
<td>0.87 (0.31–2.57)</td>
<td>Ns</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>1.12 (0.5–2.53)</td>
<td>Ns</td>
<td>1.45 (0.48–4.34)</td>
<td>Ns</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>3.65 (1.26–10.58)</td>
<td>0.004</td>
<td>0.84 (0.29–2.39)</td>
<td>Ns</td>
</tr>
<tr>
<td>COPD</td>
<td>0.52 (0.09–2.93)</td>
<td>Ns</td>
<td>3.32 (1.4–7.87)</td>
<td>Ns</td>
</tr>
<tr>
<td>Immobility/recent surgery</td>
<td>2.56 (0.97–7.33)</td>
<td>0.04</td>
<td>0.89 (0.31–2.57)</td>
<td>Ns</td>
</tr>
<tr>
<td>Trauma</td>
<td>2.14 (2.83)</td>
<td>Ns</td>
<td>1.19 (2.22–6.45)</td>
<td>Ns</td>
</tr>
<tr>
<td>Concomitant DVT</td>
<td>2.52 (1.01–6.31)</td>
<td>0.03</td>
<td>0.56 (0.91–1.65)</td>
<td>Ns</td>
</tr>
<tr>
<td>Obesity</td>
<td>1.78 (0.88–3.61)</td>
<td>Ns</td>
<td>0.86 (0.15–5.13)</td>
<td>Ns</td>
</tr>
<tr>
<td>Cancer</td>
<td>1.94 (1.39–2.7)</td>
<td>Ns</td>
<td>2.67 (1.57–4.73)</td>
<td>Ns</td>
</tr>
<tr>
<td>RVD</td>
<td>0.46 (0.23–0.94)</td>
<td>0.03</td>
<td>1.38 (0.43–4.42)</td>
<td>Ns</td>
</tr>
</tbody>
</table>

Chi-square test. Abbreviations: OR = Odd’s ratio, Ns = non-significant.
and subsegmental emboli. Concomitant DVT, recent surgery or immobilization and tachycardia were also more common in patients with central pulmonary emboli but showed no significant relation to distally located emboli.

The mean obstructive index was 35% ± 19%. It was significantly higher in patients with dyspnea (40.86% ± 20.68% vs. 25% ± 10.6%, \( p < 0.03 \)), tachycardia (44.5% ± 21.43% vs. 26.5% ± 11.25%, \( p < 0.006 \)) and obesity (57.5% ± 36.17% vs. 34.11% ± 15.72%, \( p < 0.02 \)). No significant difference was found between the mean OI values in patients with or without hemoptysis, cancer, chest pain, surgery or immobilization, COPD, concomitant DVT and trauma (\( p > 0.05 \)).

Among the 35 patients included in the study, 13 of them (37%) had RVD (ratio of RV to LV diameter in 4-chamber view, >1) (Figs. 5 and 6). A statistically significant relationship was found between the presence of RVD and central pulmonary emboli (OR, 0.46; 95% CI, 0.23–0.94; \( p < 0.03 \)).

The mean OI was also significantly higher in patients with RVD (51.38 ± 22.3 vs 28.06 ± 11.57, \( p < 0.001 \)). A positive correlation was found between the obstruction index and CT pulmonary artery diameter (\( r = 0.66, p < 0.001 \)). Similarly a strong correlation was found between the OI and the RV/LV ratio (\( r = 0.628, p < 0.001 \)) (Figs. 1–3).

ROC curve was constructed as shown in Fig. 4 to establish the best cut-off for the OI which was 43% with 77% sensitivity and 13% specificity. Ten patients (77%) out of 13 with RVD had an OI greater than or equal to 43%. Only 3 patients with RVD had an OI of <43%.

4. Discussion

The introduction of MDCT pulmonary angiography has considerably changed the approach to PE and is currently the diagnostic method of choice as it is available, rapid, sensitive and allows adequate visualization of the pulmonary arteries and clots up to at least the segmental level beside addition to its ability to exclude alternative diagnoses. In addition decision-making in suspected PE has changed with recent improvements in the technology available (8).
A substantial proportion (40%) of normotensive patients with PE present with signs of RVD. These patients had latent hemodynamic impairment and have a 10% risk of developing shock and a 5% rate of in-hospital mortality. Since MDCT is the first-line technique to diagnose PE, assessing RVD by this technique would facilitate risk stratification in all patients (9).

Risk stratification is important in patients with acute PE to identify those at low, intermediate or high risk for adverse outcomes. Low-risk patients are candidates for an early discharge or even home treatment, whereas intermediate or high risk patients should be admitted to the hospital and considered for an upgrade in treatment (10).

The degree of pulmonary vascular obstruction is better determined by calculating the clot burden. Now MDCT is the method of choice in calculating the clot burden score as the technique is an accurate method of diagnosing PE and determining an OI provides an objective and reproducible score that is useful for interdisciplinary communication between clinicians and radiologists. Calculating the clot burden score is important in determination of the degree of vascular obstruction which helps in stratification of patient risk and identification of those who would benefit from more aggressive treatment. Also, the clot burden score enables the effects of treatment to be monitored non-invasively by subsequent imaging studies (5).

There are various systems described in the literature to assess the pulmonary tree and calculate clot burden scores (5,8,11–13). In this study we used the Qanadli score, to calculate the OI after MDCT pulmonary angiography as it was considered the easiest to calculate in imaging terms since the

---

**Fig. 5** A 60 year old female patient presented with dyspnea, chest pain and tachycardia. The patient suffered from ankle fracture 2 weeks earlier in addition to her overweight. MSCT pulmonary angiography revealed (A and B) bilateral main PE causing partial obstruction with \( \text{OI} = 50\% \) (C and D), RV/LV diameter ratio = 47/46 mm (E) and pulmonary artery diameter = 35.4 mm (F).
weighting system makes it more objective, resulting in less interobserver variability. In addition, Qanadli score can differentiate between complete and partial obstruction by the proximal clot which adds relevant information about the residual perfusion of the lung unlike modified Miller score where the presence of non obstructive clots in the main pulmonary arteries corresponds to a percentage of obstruction of 100%, which is not necessarily consistent with clinical severity. Moreover, Walsh scoring system is more complex to calculate and, consequently, has rarely been used in clinical practice.

In this study central PE was found in 45% of the patients which is similar to that obtained by Nazarog˘lu et al.(6). However the mean OI in our study was 35% which is higher than that reported by Qanadli et al. (5). This was probably caused by the referral of most of the patients from emergency, chest and cardiology departments which led to the inclusion of many high risk patients.

Dyspnea was the commonest symptom which was present in 74% of our patients while tachycardia was the commonest sign which was present in 54%. PE causes dyspnea through the increase in ventilation that is required to compensate for the enlarged dead space that resulted from embolism. In addition, dyspnea in PE can also be attributed to V/Q mismatch, hypoxemia, mediator-induced bronchoconstriction and pleuritic chest pain especially if associated with infarction (14). The results of our work were consistent with those of The PIOPED, 1990 study who reported that dyspnea, tachypnea and tachycardia were the most common symptoms of PE (15).

In our study dyspnea was significantly more common in patients with central pulmonary emboli but was inversely related to patients with segmental and subsegmental emboli. This may be explained by the great hemodynamic and respiratory impairment in patients with central pulmonary artery obstruction while patients with peripheral pulmonary emboli had less impairment due to the great capacity of the pulmonary circulation (16). So we found that the mean OI was higher in patients with dyspnea and tachycardia but showed no relation to hemoptysis and chest pain which were common in patients with peripheral pulmonary emboli.

In PE patients, obstruction of the pulmonary vascular tree is the main factor in increased pulmonary vascular resistance, resulting in pulmonary hypertension and subsequent RVD. In this study we found that RVD is more common in patients with central PE which coincides with the results of several studies which reported a better correlation between mean pulmonary artery pressure, RVD and the severity of obstruction.

In this work there was a linear correlation between the OI and RVD ratio as assessed by MDCT pulmonary angiography. The mean OI was higher in patients with RVD, than patients without. This was also reported in the study of Rodrigues et al. (17) who found a linear correlation between QS and RVD parameters on CT angiography.

The cut-off point for the OI that predicted the presence of RVD (with a significant sensitivity and specificity) in our study was 43% which means that most patients with OI above 43% had RVD. These results were comparable to those reported in

Fig. 6 A 42 year old female patient presented with dyspnea, cough, hemoptysis, and tachycardia. MSCT pulmonary angiography revealed right main PE (A) and left lingular and lower lobar PE (B) causing complete obstruction with OI = 85%, RV/LV diameter ratio = 39/37 mm (C) and pulmonary artery diameter = 30.4 mm (D).
many literatures and found that the best cut-off point of a CT OI with a great sensitivity and specificity lies between 40% and 49% and values at these levels or greater will identify more than 90% of patients with right ventricular dilatation. Alternately, a CT obstruction index of <40% would be unlikely in the presence of a pulmonary embolism with acute right ventricular dysfunction (5,11,18). So in coinciding with other reports (19), the results of our study further support the use of MDCT pulmonary angiography as a single test for both diagnosis and risk stratification in patients presented with acute PE.

4.1. Limitations

Our study has certain limitations. Firstly, potential limitation of our present study is that MDCT acquisition was not ECG gated. Non–ECG-gated CT is inevitably inaccurate for measuring ventricular chamber size, because the images are acquired in different phases of the cardiac cycle. However, the use of ECG-gated CT protocols over routine chest CT has been shown to result in only limited incremental diagnostic improvements (20). Secondly, a criticism about patient selection was present as most of the selected patients had intermediate or high probability for PE. Thirdly, patients with coexisting heart or lung disease were not excluded where structural changes in the heart or the lung could affect the pulmonary pressures and cardiac chamber dimensions obtained on CT angiography.

5. Conclusions

Our study showed that the assessment of pulmonary clot burden using an objective and reproducible MDCT score has a considerable clinical and imaging impact, enabling accurate diagnosis, risk stratification and the selection of patients for more aggressive treatment. There is a strong association between OI, clinical presentation and RVD.

Conflict of interest

There is no conflict of interest.

References


