MDCT PULMONARY ANGIOGRAPHY ASSESSMENT OF SEVERITY OF ACUTE PULMONARY EMBOLISM: PULMONARY ARTERY OBSTRUCTION INDEX COMPARED WITH RIGHT VENTRICLE TO LEFT VENTRICULAR DIAMETER RATIO

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ABSTRACT

AIMS AND OBJECTIVES
To investigate the relation between pulmonary artery obstruction index (PAOI) and right ventricle to left ventricle diameter ratio in patients with acute pulmonary embolism.

MATERIALS AND METHODS
The study population comprised of patients with definite diagnosis of pulmonary thromboembolism based on their CTPA. PAOI was calculated from the size of embolus and the location of thrombus on CT images according to a study by Qanadli et al and compared with the right to left ventricular diameter ratio.

Quantitative variables were expressed in terms of mean, standard deviation with confidence interval of 95%. PAOI was compared with RV/LV ratio using Spearman correlation test, $p<0.005$ was considered statically significant.

RESULTS
Total of 32 patients with pulmonary embolism, mean PAOI was 38.9 ± 17.7%. The mean RV/LV ratio was 1.14 ± 0.37; twenty two patients (69%) had an RV/LV ratio of more than 1; ten patients (31%) had an RV/LV ratio of less than 1. There was a statistically significant correlation between PAOI and RV/LV ratio ($p < 0.0001$; rho=0.75).

The mean PAOI of patients with RV/LV ratio >1 was significantly higher than that of patients with RV/LV ratio <1 (46.2% vs. 18.0%; $p < 0.0001$).

CONCLUSION
Quantification of a clot at CTPA is an important predictor of right heart failure and determines patient's outcome in the setting of pulmonary thromboembolism.

KEYWORDS
Pulmonary Embolism, Multidetector CT, PAOI, RV/LV Ratio.

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INTRODUCTION: Pulmonary Embolism (PE) is the third most common acute cardiovascular disease after myocardial infarction and stroke. Risk stratification for patients with Pulmonary Embolism is essential to establish appropriate treatment strategy in patients with pulmonary embolism because high risk patients may benefit from thrombolysis or embolectomy in addition to anticoagulation.[1,2] It is associated with significant morbidity & mortality. Death occurs in 90% of patients with unrecognised Pulmonary Embolism, whereas treated Pulmonary Embolism accounts for less than 10% of deaths.

Therefore, Rapid and timely diagnosis of this life-threatening disease is important to improve patient outcome as the signs and symptoms as well as ancillary tests are nonspecific.[3,4,5,6]

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 is possible. This capability enables multiplanar viewing and assessment of pulmonary vessels to subsegmental levels. All these advantages made MDCT angiography the most

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commonly used procedure for the diagnosis of pulmonary embolism.[7,8,9]

MDCT pulmonary angiography has considerably changed the approach to Pulmonary Embolism and is currently the diagnostic method of choice.[7,9,10] Authors of several studies have suggested right-sided heart strain and embolic burden at CT as prognostic parameters.[1,2,7,10] Patients with RV dysfunction have a higher mortality rate than those without, even if they are initially haemodynamically stable. Thus, the presence of RV dysfunction is a marker for adverse clinical outcome in patients with acute pulmonary embolism.[3,5,10,11]

AIM: To investigate the relation between pulmonary artery obstruction index (PAOI) and right ventricle to left ventricle diameter ratio in patients with acute pulmonary embolism.

MATERIALS AND METHODS:

PROSPECTIVE STUDY: The study included 72 patients (30 males and 32 females) ages ranged from 20 to 76 years. The patients came to J.L.N. Medical College and Hospitals, Ajmer from July 2015 to December 2015 with clinical suspicion of pulmonary embolism, underwent MDCT Pulmonary angiography and 32 patients having pulmonary emboli were included in the study. The remaining patients who were proven negative for pulmonary embolism or those with inconclusive examination were excluded from the study.

MDCT pulmonary angiography was performed at Radiology Department of J.L.N. Medical College and Hospital. 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.

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 100 to 120 mL of non-ionic iodinated contrast medium (Iohexol) was injected via an antecubital vein at a rate of 3 to 4 mL/s. A 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. 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 seconds.

Images were reviewed at workstation, reconstructed using mediastinal/soft tissue algorithm to reduce the edge-enhancing artefacts that may mimic emboli when bone algorithms are utilised. MPR images are generated along the long axis of vessels.

PAOI and RVD ratio were calculated in all patients without the knowledge of their clinical assessment or diagnostic exam results.

The diagnostic criteria for acute Pulmonary embolism include:

1. 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.
2. Central arterial filling defect surrounded by IV contrast material.
3. Peripheral intraluminal filling defect that makes an acute angle with an arterial wall.

PAOI was calculated from the size of embolus and the location of thrombus on CT images according to a study by Qanadli et al and compared with the right to left ventricular diameter ratio.

PAOI Measurement: The index was defined as the product of N x D.

Where N was the value of the clot site, and D was the degree of obstruction, defined as 1 for partial obstruction and 2 for total obstruction.

To define the N, the arterial tree of each lung was regarded as having 10 segmental arteries (three to the upper lobes, two to the middle lobe and to the lingula, and five to the lower lobes).

The presence of embolus in a segmental artery was scored 1 point.

Emboli in the most proximal arterial level were scored a value equal to the number of segmental arteries arising distally.

The value of the most proximal thrombus in the pulmonary arterial tree scored a maximum of 6 (3 x 2) for the upper lobe arteries, 4 (2 x 2) for the middle lobe and the lingual arteries, 10 (5 x 2) for the lower lobe arteries, 14 (7 x 2) for the intermediate arteries and 20 (10 x 2) for the main pulmonary artery;

Thus, the maximal PAOI was 40. Final PAOI for each patient was expressed as percent (Score/ 40× 100).

RVD ratio measurement: RV/ LV.

The scans were evaluated by measuring the minor axes of the right and left ventricles.

By identifying the maximal distance between the ventricular endocardium and the interventricular septum, perpendicular to the long axis.

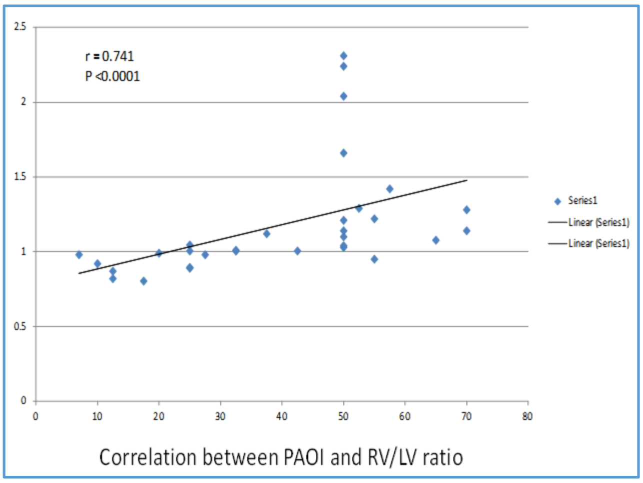
RVD was diagnosed if the right to left ventricular diameter ratio was >1.

Results are expressed as the mean ± standard deviation for data distributed normally.

Correlation between PAOI and RV/LV ratio was evaluated by Spearman correlation test, and receiver operating characteristic (ROC) curve was used to determine an optimal cut-off value for PAOI. A p value < 0.05 was considered significant.

RESULTS: Total of 32 patients with pulmonary embolism. The mean PAOI was 38.9±17.7%. The mean RV/LV ratio was 1.14±0.37.

Twenty two patients (69%) had an RV/LV ratio of more than 1; ten patients (31 %) had an RV/LV ratio of less than 1.

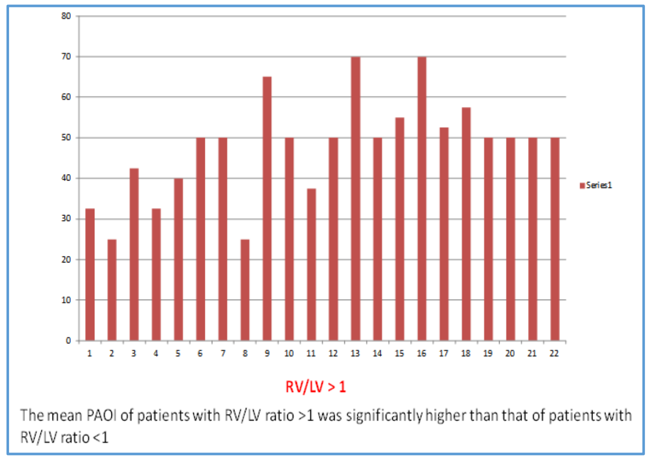


Graph 1

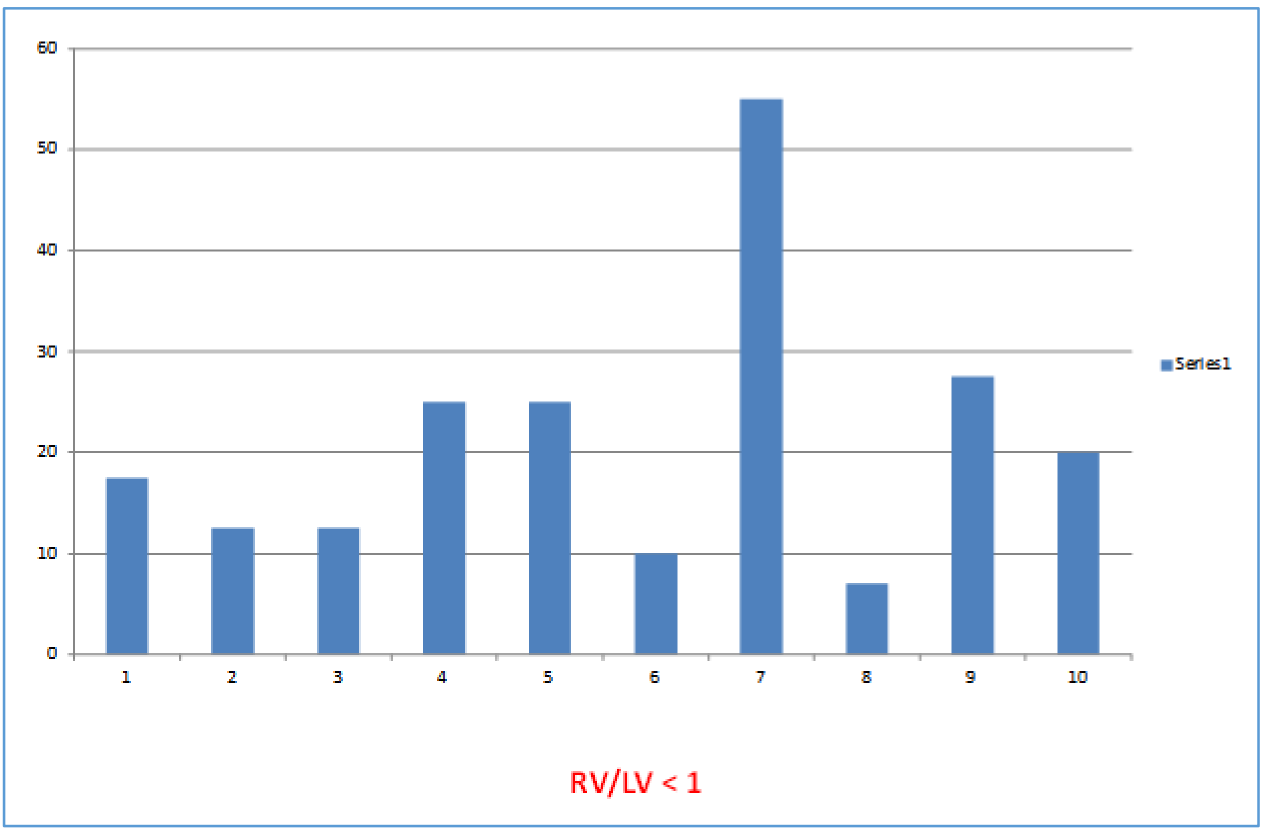
A strong correlation was found between the OI and the RV/LV ratio (r=0.741, p< 0.0001).

The mean PAOI of patients with RV/LV ratio >1 was significantly higher than that of patients with RV/LV ratio <1. (46.27 ± 12.33 vs 18.02 ± 13.76, p<0.0001).

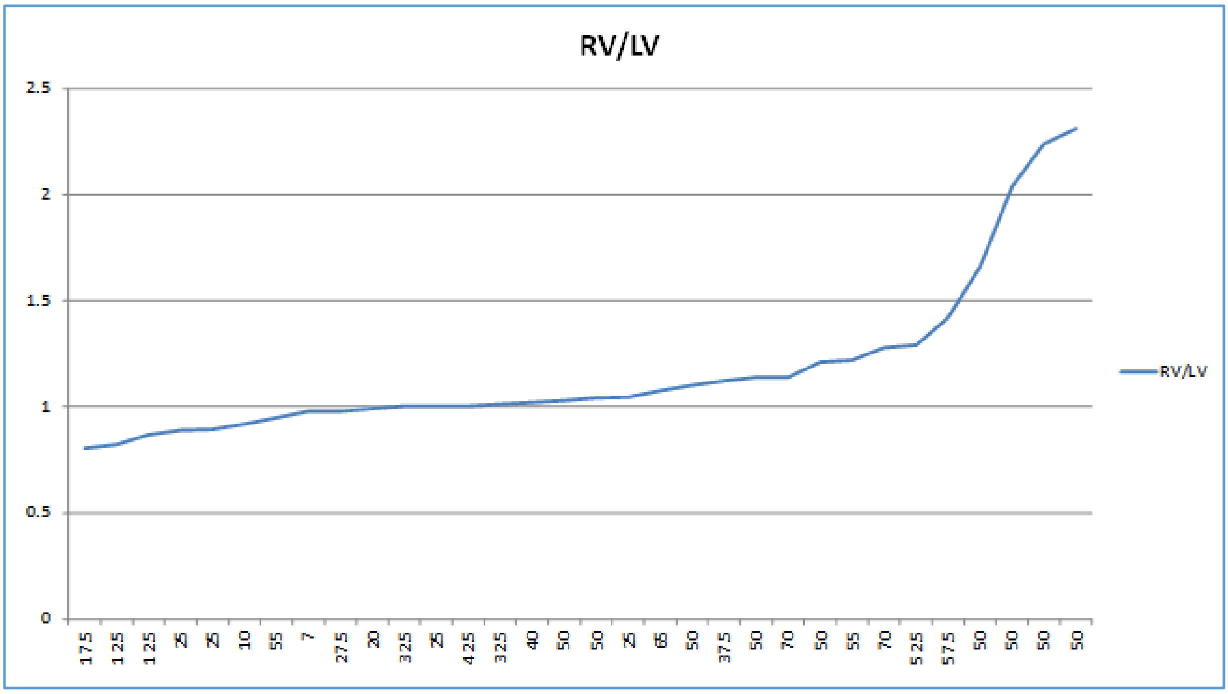
Also, there was no significant difference in PAOI between different age (P > 0.05) and sex (P > 0.05) groups.



Graph 2



Graph 3

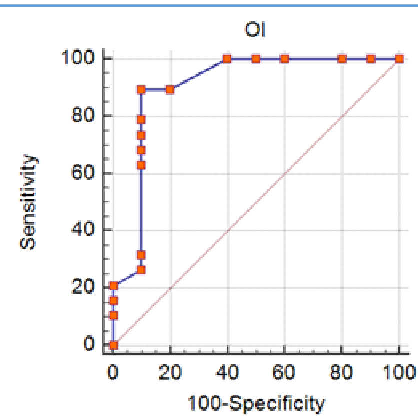


Graph 4

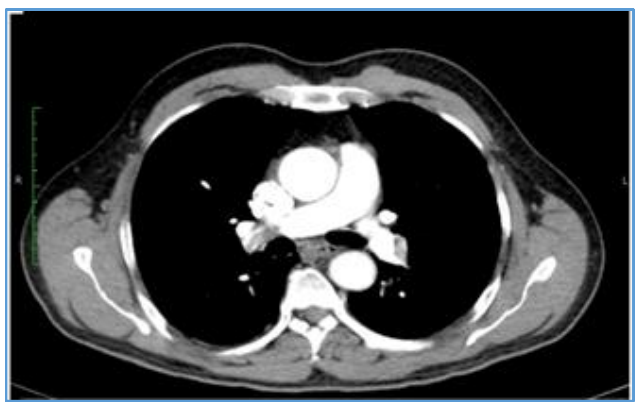
ROC curve was constructed to establish the best cut-off for the OI which was 37.5% with 89.4% sensitivity and 80% specificity.

18 (89.4 %) out of 22 with RVD had an OI greater than or equal to 37.5%.

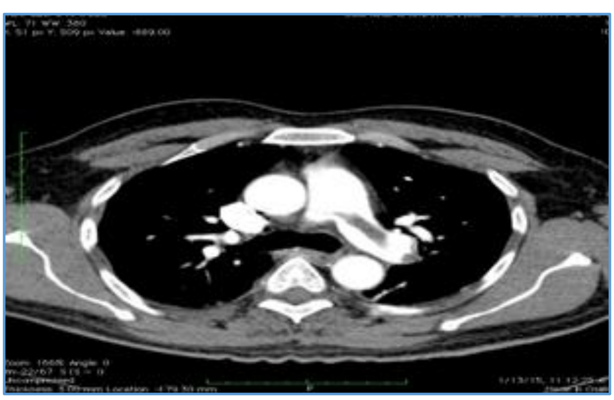
Only 4 patients with RVD had an OI of < 37.5%.



AUC	Sensitivity	Specificity	95% CI	*p* value
0.903	89.4	80	0.73 – 0.98	<0.0001

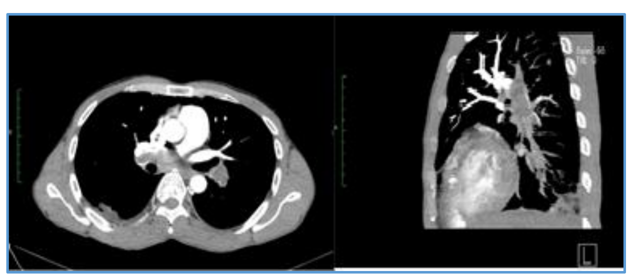


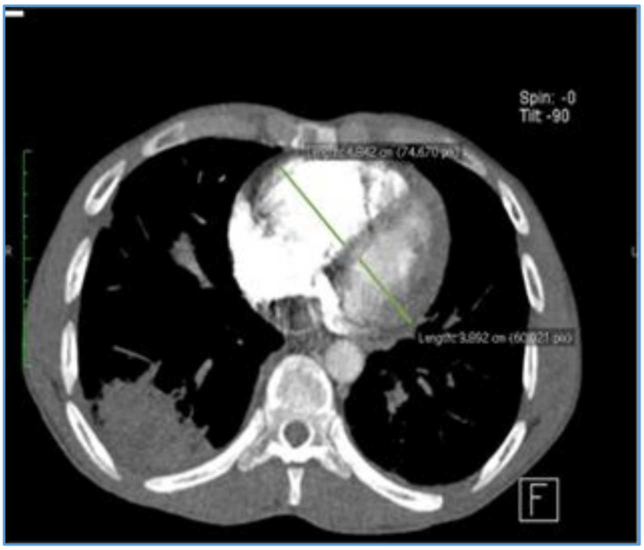
Clot Partially Occluding both Interlobar Arteries. Calculated PAOI was scored as 35%



Axial Pulmonary CT Angiography image showing Clot partially Occluding Left Pulmonary Artery

Total obstruction of interlobar artery with clot.





RV / LV: 1.24

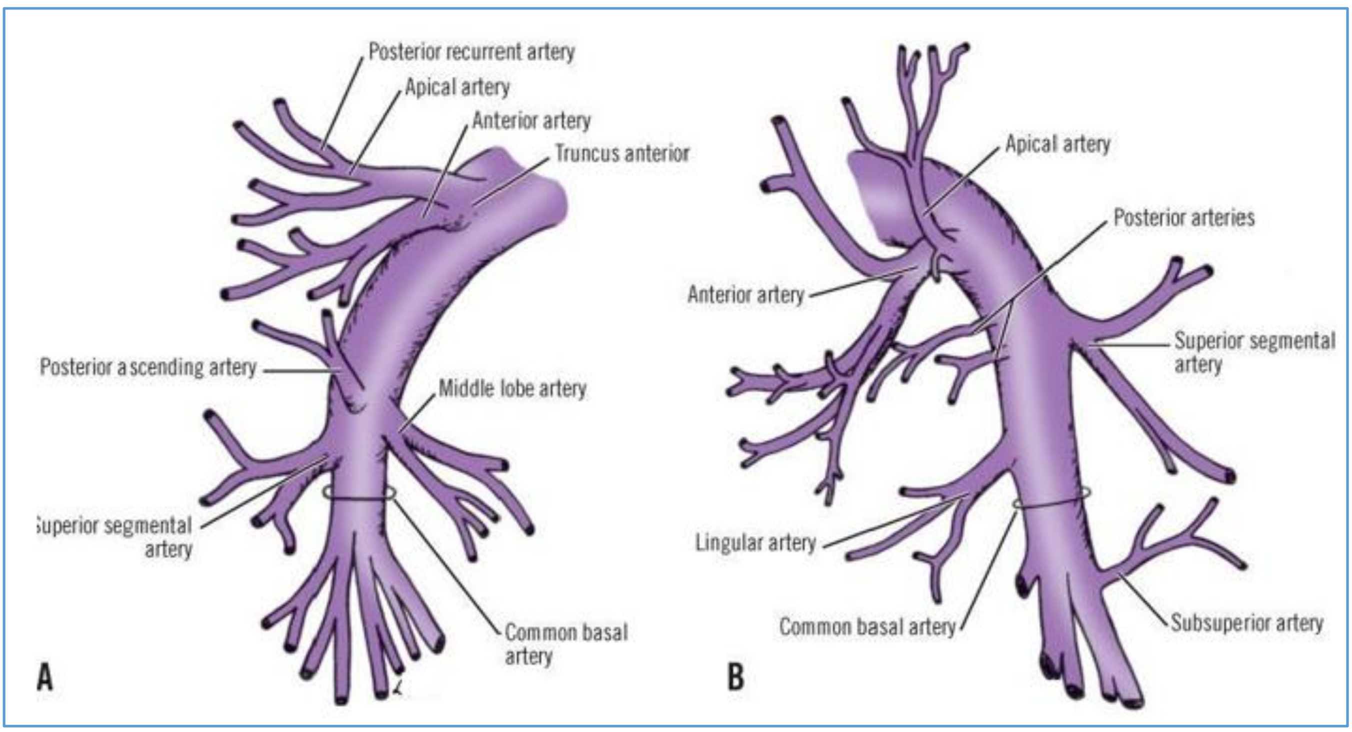
DISCUSSION: Anatomy.

Main Pulmonary Artery: Measures approx 5 cm in length and is entirely enveloped within the pericardium. Arises at the base of the right ventricle & it passes superiorly and posteriorly, initially anterior and then to the left of the ascending aorta. At about the level of the D5, it divides to form the left & right pulmonary arteries.

Left Pulmonary Artery: Shorter of the two branches. Its course runs cephalad & posterior from the main pulmonary artery arching superiorly over the left main bronchus to enter the left hilum.

Right Pulmonary Artery: Arises at a right angle from the main pulmonary trunk, traverses the mediastinum posterior to the SVC and ascending aorta & anterior to the right main bronchus.

The right and left pulmonary arteries should be of approximately equal size, although the left pulmonary artery appears slightly larger in most persons.



Pulmonary Embolism (PE) is a consequence of thrombus, most commonly formed in the deep veins of the pelvis and lower extremities (rarely from veins of the head, neck, upper extremities, right atrium and right ventricle).

Risk Factors for DVT[2,7,12]:

- **Venous Stasis:** Immobilisation, Surgery, Long airplane flights.
- Malignancy.
- **Cardiac Disease (30%):** Myocardial infarction, Permanent pacemaker, Venous catheters.
- Indwelling catheters.
- Abnormality of the wall of the veins (such as thrombophlebitis).
- **Hypercoagulable States:** Pregnancy, Oestrogen use (prostate cancer, Oral Contraceptive pills), Antithrombin C, Protein C & S deficiency.

Pulmonary Embolism often are multiple than solitary & frequently found in the lower lobes, probably due to the greater pulmonary blood flow to the lower lobes.

Clinical Features: Cardinal signs of Pulmonary Embolism are chest pain, dyspnoea, or haemoptysis seen in only 50% of patients.

Imaging Evaluation:

- Direct –CXR, ventilation perfusion (V/Q) scintigraphy, MDCT (CT Pulmonary Angiography) & MRI and pulmonary angiography.
- Indirect - Doppler US, and magnetic resonance venography of the leg veins to look for DVT.

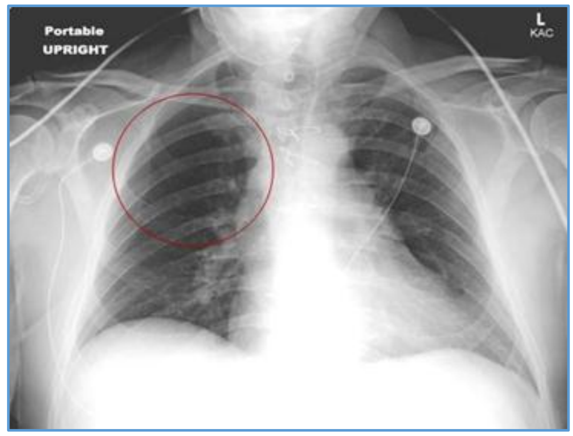
- CXR features are neither sensitive nor specific for the diagnosis of Pulmonary Embolism. CXR remains important in the determination of other alternative diagnoses such as pneumothorax, lobar collapse, Congestive Cardiac Failure, or rib fractures that may cause similar symptoms on presentation.
- Suspected PE further evaluated by Ventilation-Perfusion Scintigraphy
- Finally CTPA (with MDCT) is the definitive diagnostic modality for the evaluation of both acute and chronic Pulmonary Embolism.

Chest X-ray: Normal in up to 40% of patients.

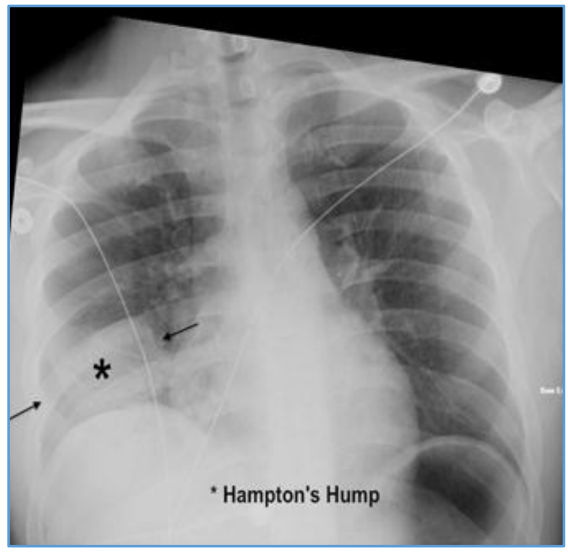
- Common signs of Pulmonary Embolism not associated with infarction are:
- Localised peripheral regional oligaemia (Westermark's sign) secondary to the embolus lodging in a peripheral pulmonary artery.
- Peripheral airspace opacification, which represents pulmonary haemorrhage.
- Linear atelectasis.
- Pleural effusion—often small.
- Enlargement of the central pulmonary arteries seen secondary to chronic repeated embolic disease.

Signs of PE Associated with Infarction:

- Hampton's hump - Wedge-shaped opacity, pleurally based with apex pointing toward the occluded feeding vessel, usually at lateral or posterior costophrenic sulcus +/- air bronchograms.
- Consolidation (which may be multifocal) is seen predominantly in the lower lobes.
- Cavitation (< 5% of cases, due to secondary infection at infarct or due to a septic embolus).
- Haemorrhagic pleural effusion (which may be slow to clear) and may be seen in up to 50% of patients with Pulmonary Embolism.



Westermark's sign



CT Pulmonary Angiography (CTPA): It is rapidly becoming the first-line imaging modality for Pulmonary Embolism.[1,2,10,11]

- It is noninvasive (Compared with pulmonary angiography), easily scheduled, rapidly performed, and highly accurate in the detection of Pulmonary Embolism (CTPA has been almost as reliable as pulmonary angiography in the detection of Pulmonary Embolism up to the segmental level; with MDCT with thinner collimation, this reliability also extends to the subsegmental level).
- Unlike V/Q scans that provide only indirect evidence of pulmonary embolism, MDCT allows direct visualisation of intra-arterial clot. Interobserver reliability of CTPA is good.

Multidetector Computed tomography (MDCT) with its faster data acquisition and thinner sections:

- Whole lung may be examined during a single breath-hold in almost all patients.
- Improved the ability of the technique to resolve peripheral arteries.
- An additional use of spiral CT is its ability to image the deep venous system to detect thrombus: Procedure that is termed as CT venography (CTV).

Findings:

- CTPA directly visualises emboli by observation of a filling defect within the enhanced pulmonary arteries.
- Contrast medium may be seen to flow around or adjacent to the clot (giving a 'tram track' appearance only if the vessel is in the plane of the image section).
- Ancillary features of PE such as an altered perfusion pattern or pleural effusions, or evidence of another cause of the patient's symptoms (e.g. pneumothorax).

The introduction of MDCT pulmonary angiography has considerably changed the approach to PE. It allows adequate visualisation of the pulmonary arteries and clots up to at least the segmental level.

Assessing Right Ventricular Dysfunction (RVD) by this technique would facilitate risk stratification in all patients. Low risk patients are candidates for an early discharge.

Whereas high risk patients should be admitted to the hospital and considered for an upgrade in treatment. The severity of pulmonary vascular obstruction is better determined by calculating the clot burden scores (PAOI).
It helps in stratification of patient risk, 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.[3,7,6,12]

There are various systems described in the literature to assess the pulmonary tree and calculate clot burden scores. Our study used the Qanadli score as it was considered the easiest to calculate.

Qanadli et al. found that a CT obstruction score of 40% or greater correlates well with RV dilatation. However, the mean OI in our study was 38.9% which is higher than that reported by Qanadli et al. 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.

In PE patients, obstruction of the pulmonary vascular tree is the main factor in increased pulmonary vascular resistance, resulting in RVD.

The results of our study were comparable with several studies which reported a better correlation between mean pulmonary artery pressure, RVD and the severity of obstruction. In this work, the mean OI was higher in patients with RVD, than patients without and there was linear correlation between the two. This was also reported in the study of Rodrigues et al.

The cut-off point for the PAOI that predicted the presence of RVD was 37.5% which means that most patients with PAOI above 37.5% had RVD. These results were comparable to those reported in many literatures.

The best cut-off point of a PAOI with a great sensitivity and specificity lies between 37.5% and 50% and values at these levels or greater will identify more than 90% of patients with right ventricular dysfunction.

Alternately, index of <37.5% would be unlikely in the presence of a pulmonary embolism with acute right ventricular dysfunction. So in coinciding with other reports, 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.

LIMITATIONS: Limited subjects.

Control group was not included.

Did not correlate the results of CTA with echocardiographic findings.

Chest CT image acquisition was not ECG gated. Non–ECG-gated CT is inevitably inaccurate 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.

CONCLUSION: Our study showed that the assessment of pulmonary clot burden enables accurate diagnosis, risk stratification and the selection of patients for more aggressive treatment.[1,4.5,10] Our findings were in agreement with those of Wu et al. and suggested that the quantification of a clot at CT pulmonary angiography is an important predictor of right heart failure and hence severity of pulmonary embolism. The prognostic role of RV/LV ratio and obstruction index on spiral CT may also warrant further investigation in patients with pulmonary thromboembolism.

REFERENCES

1. Reid JH, Murchison JT. Acute right ventricular dilatation: a new helical CT sign of massive pulmonary embolism. Clin Radiol 1998;53(9):694–698.
2. Goldhaber SZ. Echocardiography in the management of pulmonary embolism. Ann Intern Med 2002;136(9):691–700.
3. Qanadli SD, El Hajjam M, Vieillard-Baron A, et al. New CT index to quantify arterial obstruction in pulmonary embolism: comparison with angiographic index and echocardiography. AJR Am J Roentgenol 2001;176(6):1415–1420.
4. Subramaniam RM, Mandrekar J, Chang C, et al. Pulmonary embolism outcome: a prospective evaluation of CT pulmonary angiographic clot burden score and ECG score. AJR Am J Roentgenol 2008;190(6):1599–1604.
5. Mastora I, Remy-Jardin M, Masson P, et al. Severity of acute pulmonary embolism: evaluation of a new spiral CT angiographic score in correlation with echocardiographic data. Eur Radiol 2003;13(1):29–35.
6. Nazaroglu H, Ozmen CA, Akay HO 64 slice MDCT pulmonary angiography and CT venography in the diagnosis of thromboembolic disease. AJR Am J Roentgenol 2009;192(3):654–661.
7. Quiroz R, Kucher N, Schoepf UJ, et al. Right ventricular enlargement on chest computed tomography: prognostic role in acute pulmonary embolism. Circulation 2004;109(20):2401–2404.

8. Torbicki A, Perrier A, Konstantinides S, et al. Guidelines on the diagnosis and management of acute pulmonary embolism: task force for the diagnosis and management of acute pulmonary embolism of the European society of cardiology (ESC). Eur Heart J 2008;29(18):2276–2315.
9. Espinosa LA, Kelly AM, Hawley C, et al. Clinical utility of multiplanar reformation in pulmonary CT angiography. AJR Am J Roentgenol 2010;194(1):70–75.
10. Van der Meer RW, Pattynama PM, Strijen MJ, et al. Right ventricular dysfunction and pulmonary obstruction index at helical CT: prediction of clinical outcome during 3-month follow-up in patients with acute pulmonary embolism. Radiology 2005;235(3):798–803.
11. Rodrigues B, Correia H, Figueiredo A, et al. Clot burden score in the evaluation of right ventricular dysfunction in acute pulmonary embolism: quantifying the cause and clarifying the consequences. Rev Port Cardiol 2012;31(11):687–695.
12. Venkatesh SK, Wang SC. Central clot score at computed tomography as a predictor of 30-day mortality after acute pulmonary embolism. Ann Acad Med Singapore 2010;39(6):442–447.