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# Correlation of clot distribution with morphometric measurements and pleuroparenchymal findings in acute pulmonary embolism: experience with 692 cases☆

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ABSTRACT

**Purpose:** The aim of the study is to determine if clot distribution in acute pulmonary embolism (PE) correlates with morphometric measurements of right heart function, reflux in inferior vena cava (IVC), and pleuroparenchymal findings.
**Materials and methods:** A total of 692 computed tomography pulmonary angiographies with PE were enrolled, and patients were grouped according to clot localization. Parenchymal findings, morphometric measurements of right heart function, and contrast reflux in IVC were noted.
**Results:** Differences were found between groups for most measurements, and central PE was associated with significantly higher right ventricle (RV) and pulmonary artery diameters, ratio of RV diameter to left ventricle (LV) diameter (RV/LV) ≥1, and IVC reflux.
**Conclusions:** Significant association was present among clot distribution in PE, morphometrics, IVC reflux, and pleuroparenchymal findings.



## 1. Introduction

Acute pulmonary embolism (PE) is a common disease with a mortality rate dependent on right ventricular dysfunction [1]. Mortality varies from <5% in clinically stable patients to >30% in hemodynamically unstable patients [2]. Computed tomography pulmonary angiography (CTPA) is the most commonly used first-line diagnostic modality for detection of PE [3–9]. In addition to the demonstration of intraluminal clot, CTPA provides simultaneous data about lung parenchyma and pleural space. Parenchymal findings have been reported to be associated with PE in rates between 25% and 62% [10–13]. The correlation between the severity of PE and pleuroparenchymal findings as well as risk stratification by means of thrombus characteristics, quantification, and indicators of right ventricular dysfunction have been reported in recent studies [14–18].

The aim of this study is to determine if clot distribution in PE correlates with morphometric measurements of right ventricle (RV) function, reflux in inferior vena cava (IVC), and pleuroparenchymal findings.

## 2. Materials and methods

### 2.1. Patient characteristics

This study was approved by the Ethics Committee of our institution. CTPA examinations performed over an 18-month period between June 2013 and November 2014 were retrospectively evaluated. A total of 740 studies with findings of PE were included in the study. Fifteen examinations with technical insufficiencies, two pediatric patients, and 31 patients with chronic thromboembolic pulmonary hypertension were excluded, leaving 692 patients positive for PE. An age and gender matching group of randomly selected 133 patients with CTPAs negative for PE acquired during the same period was also included, bringing the total subjects enrolled in the study to 825. The median age was 63.1 years (range: 18–101 years). Four hundred and eighty-three (58.5%) patients were female, and 342 (41.5%) were male.

### 2.2. Equipment and computed tomography (CT) examination

All examinations were performed on a 256-slice scanner (Somatom Definition Flash, Siemens, Erlangen, Germany) with the following scan parameters: CARE Dose4D for automatic exposure control for tube voltage (kV) and effective tube current (mA), slices acquired with 128 mm×0.6 mm setting in the caudocranial direction, 0.5 pitch, and 0.28-second rotation time. Field of view was adjusted to patient size, 512×512 matrix was used, and mean scan time was 4.2 s. Bolus tracking software was used with ROI cursor placed on RV with a setting of 50 HU and delay time of 3 s, using 0.8 ml/kg contrast (350 mg I/ml) with 5 ml/s

☆ Conflicts of interest: None.

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delivery rate via antecubital line, followed by 20 cc saline injection. The patient was instructed to cease normal breathing for 5 s on command right before starting the scan. Reconstructions included 0.75-mm-thick and 5-mm-thick image sets to evaluate arteries and parenchyma respectively.

### 2.3. Image interpretation

All patient data were examined on a PACS system (Novapacs, Novarad Corporation, USA) by three radiologists with 3, 10, and 15 years of expertise in chest radiology. All patients were reviewed separately by all radiologists and each documented their findings. Their data were then cross-matched and differing findings for clot localization ($n=22$) were reevaluated together and a consensus was reached to resolve discrepancies. The radiologists were free to adjust window level and width and review multiplanar reformations.

Presence of PE was classified under three groups based on the localization of most centrally detected emboli. PE present in the main pulmonary artery (PA), right PA, left PA, right interlobar artery, and lobar arteries formed Group 1 ($n=310$). PE present in segmental and subsegmental branches formed Group 2 ($n=382$). Patients with no evidence of PE on CTPA formed Group 3 ($n=133$) (Fig. 1).

Parenchymal findings recorded on CTPA examinations were based on Fleischner Society terms [19] and included atelectasis, ground glass opacity, consolidation, parenchymal band, nodule, emphysema, bronchiectasis, mosaic attenuation pattern, and wedge-shaped opacity as these are common findings on CT in patients with dyspnea. The presence of pleural effusion was also noted.

Morphometric measurements included RV widest wall-to-wall diameter obtained on axial images, ratio of RV diameter to left ventricle (LV) diameter (RV/LV) measured at its widest wall-to-wall diameter obtained on axial images, and PA wall-to-wall diameter obtained on axial images at the level of its bifurcation (Fig. 2).

Presence of contrast reflux in IVC was recorded based on the method used by Aviram et al. [20] and graded as no reflux, reflux present in the IVC, and reflux in the IVC extending into the hepatic veins (Fig. 3).

### 2.4. Statistical analysis

Descriptive analysis was performed for patients' characteristics. Continuous variables were reported as mean±standard deviation. Proportions were given by numbers and corresponding percentages. Pearson $\chi^2$ test was used to compare proportional differences among PE categories. Analysis of variance test was used for comparison of numeric variables among three groups. Statistical analysis was performed with SPSS software version 17.0 (SPSS Inc., Chicago, IL) and statistical significance was set at $P$ less than .05.

## 3. Results

CTPA was negative for PE in 133 patients (16.1%). One hundred and ten (13.3%) had PE in the main, 200 (24.3%) in lobar, 328 (39.7%) in segmental, and 54 (6.6%) in subsegmental branches.

Mean RV diameter and mean PA diameter was 38.3 mm (14–69) and 28.0 mm (16–51), respectively. RV/LV was equal to or higher than 1 in 352 (42.7%) patients. Four hundred and seventy-three patients (57.3%) had no reflux in IVC, while 144 (17.5%) had in IVC and 208 (25.2%) had in hepatic veins.

Mean RV diameter was measured as 41.1±9.6, 37.3±7.8, and 34.8±6.3 for Groups 1, 2, and 3, respectively. Mean PA diameter was measured as 29.7±5.4, 27.5±4.9, and 25.4±4.3 for Groups 1, 2, and 3,

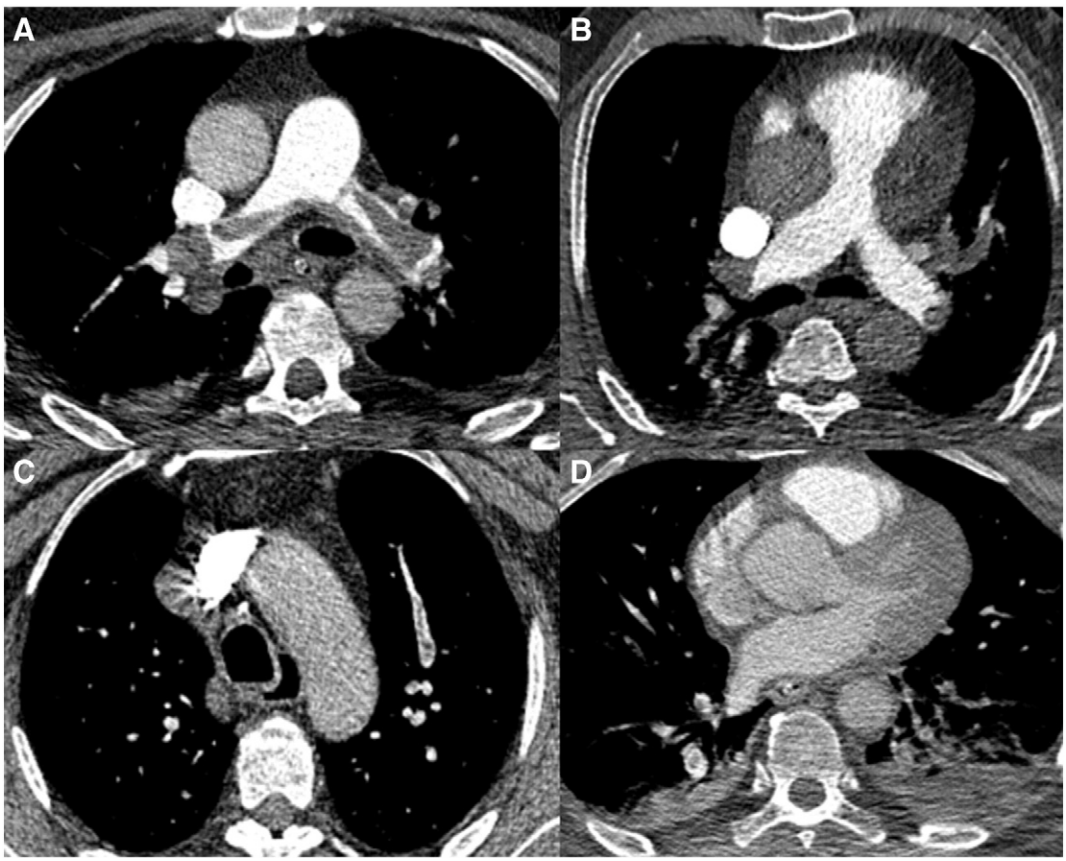


**Fig. 1.** Central PE seen in the main (A) and lobar (B) PAs. Saddle emboli are noted in (A). Segmental PE in upper left lobe branches (C) and subsegmental PE in left lower lobe branches (D). Bilateral pleural effusions and PE in right lower lobe segmental branches are also present in (D).