PULMONARY EMBOLISM: CARDIOVASCULAR AND PARENCHYMAL CHANGES

PULMONER EMBOLİ; KARDİYOVASKÜLER VE PARANKİMAL DEĞİŞİKLİKLER

PULMONARY EMBOLISM

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Öz

Amaç: Pulmoner embolinin şiddetinin kardiyovasküler sistem ve akciğer parankimi üzerine etkisini araştırmak. Gereç ve Yöntem: PE ön tanısı ile BTPA yapılan 180 olguda obstrüksiyon indeks oranı ölçülerek kardiovasküler ve plevroparankimal bulgular retrospektif olarak değerlendirilmiştir. Bulgular: Ana pulmoner arter, sağ pulmoner arter, VKS ortalama çapı, RV kısa çapı ve RV/LV oranının PE bulunan hastalarda PE bulunmayan hastalara göre arttığı (sırasıyla, p<0,001, p=0,004, p=0,007, p=0,01, p=0,001), obstrüksiyon indeksi ile korelasyon gösterdiği saptandı. İnterventrüküler septumun sola doğru konveksitesinin, VKİ ve vena azigoza reflü sıklığının PE' si olan hastalarda bulunmayanlara göre (p<0,001, p=0,001, p=0,001) ve PE bulunup masif embolisi olanlarda submasif olanlara göre artığı (p<0,001, p=0,003, p<0,001) tespit edildi. Kama şeklinde opasite ve damar işareti bulgusu bulunma sıklığının PE olan hastalarda olmayanlara göre artığı (p<0,001, p<0,001), ancak masif pulmoner embolisi olanlarda submasif olanlara göre daha az sıklıkla rastlandığı tespit edildi (p=0,002, p=0,014). Atelaktazi bulunma sıklıklarının PE bulunan hastalar ile bulunmayanlar arasında farklılık içermediği, buzlu cam görünümü, konsolidasyon, oligemi sıklığı ve ortalama skorunun PE bulunan hastalarda arttığı (p=0,02, p<0,001, p=0,001), oligemi skoru ile obstrüksiyon indeksi arasında pozitif korelasyon olduğu saptandı (r=0,202, p=0,027). Plevral efüzyonun PE olan hastalarda genellikle küçük efüzyon şeklinde olduğu, bilateral plevral efüzyon sıklığının hasta grupları içerisinde farklılık göstermediği saptandı. Tartışma: BTPA, pulmoner emboli tanısında, hem embolinin etkilediği vasküler yapıları ve akciğer alanlarını göstermede hem de sağ kalp fonksiyonunun değerlendirilmesinde hızlı ve güvenilir bir yöntemdir.

Anahtar Kelimeler

Anjiografi; Komputerize Tomografi; Tıkanıklık İndeksi; Pulmoner Arter; Pulmoner Emboli

Abstract

Aim: To investigate the effects and the severity of pulmonary embolism on the cardiovascular system and lung parenchyma. Material and Method: Pulmonary artery (PA) obstruction index ratios were calculated, and cardiovascular and pleuroparenchymal changes were retrospectively assessed in 180 patients with a prediagnosis of PE using computerized tomography pulmonary angiography (CTPA). Results: Main PA, right PA, and mean superior vena cava (VCS) diameters, right (RV) and left ventricle (LV) short diameters, and RV/LV ratios in patients with PE were increased (p<0.001, p=0.004, p=0.007, p=0.01, p=0.001, respectively) and correlated with the obstruction index ratio (OIR). Also, the convexity of the interventricular septum, VCI, and vena azygos reflux frequency were increased with PE (p<0.001, p=0.001, p=0.001) and with massive PE (p<0.001, p=0.003, p<0.001). It was determined that the frequency of the presence of wedge-shaped opacities and vein mark findings was increased in patients with PE (p<0.001, p<0.001); however, it was found less frequently in patients with massive PE when compared to the submassive patients (p=0.002, p=0.014). The presence of atelectasis was not different between patients with and without PE; consolidation, ground glass appearance, oligemia frequency, and the average scores were increased in the patients with PE (p=0.02, p<0.001, p=0.001), and there was a positive correlation between the oligemia score and OIR (r=0.202, p=0.027). Pleural effusion was infrequent with PE. Discussion: CTPA is a rapid and reliable method for the determination of the severity of PE, affected vascular structures and lung regions, and for the assessment of right heart function.

Keywords

Angiography; Computed Tomography; Obstruction Index; Pulmonary Artery; Pulmonary Embolism

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Introduction

Pulmonary thromboembolism (PTE) is a preventable disease that has a high recurrence rate, high mortality and morbidity ratios, and frequently occurs as a result of the complication of deep vein thrombosis (DVT) [1]. While the mortality of PTE is approximately 25-30% in untreated cases, it decreases to 2-8% in treated patients [2]. PTE is responsible for approximately 10% of hospital deaths [3]. Depending on the concomitant diseases with PTE, clinical findings can be masked. In recent years, invasive diagnostic applications have given way to non-invasive CT angiographic processes [4, 5]. Via computerized tomography pulmonary angiography (CTPA), the obstruction index ratio (OIR) reveals the thrombus and provides a way to calculate its quantity [6]. As a benefit of knowing the CTPAOIR, the weight of the thrombus can be determined and the treatment plan can be arranged accordingly [7]. Rapid determination of pulmonary artery (PA) obstruction severity in patients with PE may reduce the risks regarding insufficient or unnecessary treatment. Also, there is a correlation between the total thrombus load, obstruction in the arterial bed, and right ventricular dysfunction [8].

The purpose of this study is to assess both vascular and parenchymal differences in acute PTE cases where CTPAOIR is <50% (sub-massive PE) and ≥50% (massive PE).

Material and Method

Among the cases with a suspicion of PE that had CTPA examination, 180 patients (120 patients with PE and 60 patients without PE) were retrospectively included in the study under approval by the Institutional Review Board without patient informed consent. Any cases that included examinations with respiratory artifacts, poor image quality due to insufficient contrast material, or malignancies were excluded from the study.

According to the study protocol, axial images had been obtained after injection of a bolus contrast agent (Iomeprol, Iomeron, Bracco, UK) via pump (Medrad, Bayer Healthcare, NJ, US) 5ml per minute with 80 kilovolt peak (kVp) and automatic bolus tracking technique by 128-slice CT device (Definition AS, Siemens Medical Solutions, Forchheim, Germany). The data were sent to the workstation (Leonardo, Siemens Medical Solutions, Forchheim, Germany) and multiplanar (MIP, MPR) images were evaluated.

The PA, right ventricle (RV), and left ventricle (LV) short axis and VCS diameters were measured from the axial images at largest portions. RV/LV ratio was calculated and evaluated on the following scale: less than 1 is no dysfunction; between 1 and 1.5 is moderate dysfunction; over 1.5 is severe RV dysfunction. The deviation of the interventricular septum was expressed via a 3-point scale (Figure 1).

In the main, right, and left PAs, we examined lobar and segmental branches for intra-luminal filling defect and full or partial vein obstruction grade. Obstruction index (CTPAOI) was calculated by multiplying the total number of segmental arteries with the distal thrombus (n: minimum 1 and maximum 20) by the obstruction grade (d: minimum 0, maximum 2) (CTPAOI = n x d). CTPAOIR was found using the formula CTPAOI x 100/ maximum total score (CTPAOIR = (n x d) x 100/40) [11, 13]. Statistical comparison was performed according to the PE severity (patients with CTPAOIR ≥50% (massive) and <50% (sub-massive).

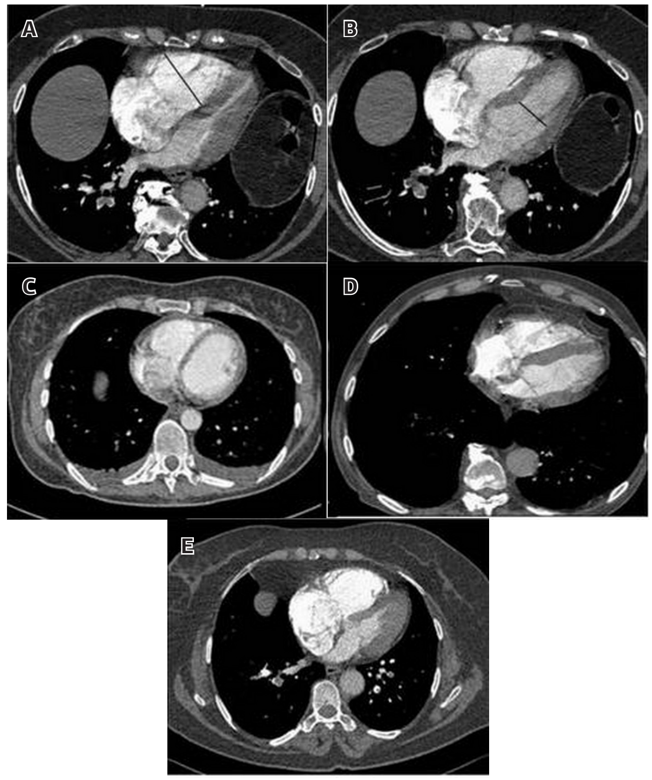

Figure 1. The diameter measurement was done by the short axis of right ventricle (A), The diameter measurement was done by the short axis of left ventricle (B), The interventricular septum score was calculated as 1: normal (C), The interventricular septum score was calculated as 2: flattened septum (D), The interventricular septum score was calculated as 3: convexity through left ventricle (E).

Reflux of the contrast material into the inferior vena cava and vena azygos (Figure 2), presence and size of the pleural effusion, plus the presence, locations, and amounts of parenchymal anomaly (such as atelectasis, ground glass appearance, consolidation, oligemia, opacification in the form of a wedge, nodules, or vein marks) were all recorded.

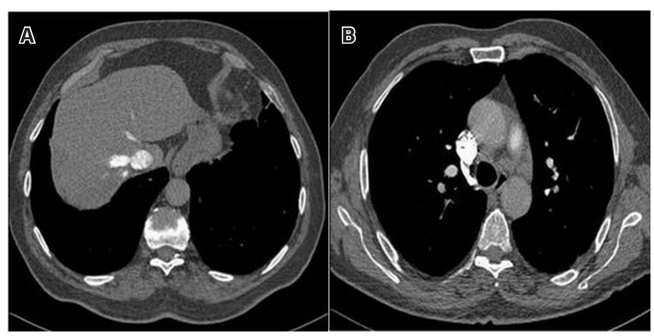

Figure 2. The contrast agent reflux was seen on vana cava inferior (VCI) (A), The contrast agent reflux was seen on vena azygos (B).

A score was given according to atelectasis, ground glass appearance, consolidation, and the affected ratio of the oligemia segment (0: none; 1: <50% segment; 2: ≥50% segment). Scoring was performed as explained in the study of Karabulut and Kıroglu [9]. Pleural effusion diameters were measured from the largest portions.

Statistical analysis

Statistical analyses were done using SPSS (Statistical Package for the Social Sciences) for Windows (version 15.0) program (SPSS Inc., Chicago, IL). Numerical variables were expressed as mean ± standard deviation. As atelectasis, ground glass, consolidation, and oligemia scores showed a heterogeneous distribution in a wide scale, these were expressed as mean ± standard error. Definitive statistics were calculated for the presence and severity of PE and parenchymal findings. Statistical significance level was specified as $p<0.05$.

A t-test was used for the vascular, RV, and LV diameters and determination of the RV/LV ratio. Chi-square test was used for the classification of the RV/LV value (<1, 1-1.5, >1.5) distribution and the comparison of VCI and vena azygos reflux, atelectasis, ground glass appearance, consolidation, oligemia, opacification in the form of a wedge, vein mark, presence of a nodule, and pleural effusion. Mann-Whitney U test was used for the comparison of the scores. Pearson correlation was used for the evaluation of the CTPAOIR and the nominal data.

Results

The study group was composed of 180 patients (82 male, 98 female; age range 19 – 94 years; mean ± standard deviation of 60.7 ± 17.4 years). The average age of patients with PE was 61 ± 16 years with 55 (45.8%) male and 65 (54.2%) female. The average age of patients without PE was 60 ± 18 years with 27 (45%) male and 33 (55%) female. The average age and gender distributions of the patients with and without PE or the patients with OIR ≥50% and <50% were similar and there was no statistically significant difference (p= 0.738, p= 0.916 or p= 0.087, p= 0.209, respectively).

Cardiovascular Findings

Average vascular diameters were increased significantly in patients with PE and were found to be significantly higher in those with OIR ≥50%. However, a slight diameter increase was observed in the left PA, but no statistically significant difference was found between those with and without PE (Table 1).

Average CTPAOIR was 33% ± 17% (range, 5–75). It was found to be 22% ± 11% (range, 5%–45%) in the patients with CTPAOIR <50% and 52% ± 6% (range, 50%–75%) in those with CTPAOIR >50%. There was no statistical correlation between the main PA diameter and the OIR. There was a positive correlation between the right PA, left PA, VCS diameter, and OIR. RV diameter and RV/LV ratio were found to be statistically different at a high significance level, but there was no significant change in LV diameter in patients with PE (Table 2).

Table 1. Correlations between PE and vascular diameters, parenchymal findings

	PE (–) group (n=60)	PE (+) group (n=120)	p-value
Main PA	27.07±4.483	30.33±5.322	<0.001
Right PA	22.22±4.179	24.09±4.067	0.004
Left PA	21.60±3.814	22.54±3.732	0.115
Parenchymal anomaly	53 (88.3%)	119 (99.2%)	0.001
Atelectasis	45 (75%)	110 (91.7%)	0.002
Ground glass appearance	23 (38.3%)	68 (56.7%)	0.02
Consolidation	5 (8.3%)	40 (33.3%)	<0.001
Oligemia	3 (5%)	31 (25.8%)	0.001
Wedge-shaped opacity	1 (1.7%)	33 (27.5%)	<0.001
Nodule	22 (36.7%)	46 (38.3%)	0.828
Vessel mark	0 (0%)	26 (21.7%)	<0.001

a: Chi-square test – Pearson's
PA: Pulmonary artery, PE: Pulmonary emboli

Table 2. Correlation of the strength of PE and vascular diameters, parenchymal findings

	CTPAOIR <%50 (n=77)	CTPAOIR ≥% 50 (n=43)	p-value
Main PA	29.60±5.901	31.61±3.804	0.042
Right PA	23.30±3.997	25.51±3.838	0.004
Left PA	21.83±3.895	23.81±3.073	0.005
Parenchymal anomaly	76 (98.7%)	43 (100%)	0.453
Atelectasis	71 (92.2%)	39 (90.7%)	0.774
Ground glass appearance	44 (57.1%)	24 (55.8%)	0.888
Consolidation	27 (35.1%)	13 (30.2%)	0.590
Oligemia	12 (15.6%)	19 (44.2%)	0.001
Wedge-shaped opacity	28 (36.4%)	5 (11.6%)	0.004
Nodule	31 (40.3%)	15 (34.9%)	0.561
Vessel mark	22 (28.6%)	4 (9.3%)	0.014

a: Chi-square test - Pearson's
PA: Pulmonary artery, PE: Pulmonary emboli, CTPAOIR: Computed tomography pulmonary artery obstruction index ratio

Also, the distribution between those patients with and without PE according to the RV/LV ratio (less than 1, between 1 and 1.5 and more than 1.5) was significantly different (p=0.001). Interventricular septum score distributions and RV/LV ratio were significantly different between patients with OIR <50% and ≥50% (p<0.001).

Inferior vena cava and vena azygos reflux were statistically significantly higher in patients with PE when compared those without PE, as well as in patients with OIR ≥50% when compared those with OIR<50% (p= 0.003). VCS diameter was correlated with OIR.

Parenchymal findings

At least one parenchymal anomaly (Figure 3) was found in 53 of 60 patients without PE (88.3%) and in 119 of 120 patients with PE (99.2%). The presence of a parenchymal anomaly was significantly different between patients with PE and those without it (p=0.001). However, there was no difference in the frequency of a parenchymal anomaly in PE patients with OIR <50% and ≥50%.

Atelectasis, ground glass appearance, consolidation, and nodule presence frequency were not different between patients with OIR <50% and ≥50% (p=0.774). Also, there was no statistical correlation between the severity of the obstruction and the ground glass score. It was determined that the presence of a wedge-shaped opacification was higher in patients with PE when compared to those without PE (p<0.001). No vein marks were observed in patients without PE. Frequency of wedge-shaped opacification and vein marks was significantly lower in patients with CTPAOIR ≥50% when compared to patients with CTPAOIR <50% (p=0.004, p=0.014, respectively) (Table 3).

There was no significant difference between pleural effusion mean dimension and bilateral presence frequencies with PE, but mean scores were slightly increased in patients with OIR <50% (p=0.051). Also, a small difference was observed between patients with OIR <50% and ≥50% in the evaluation of

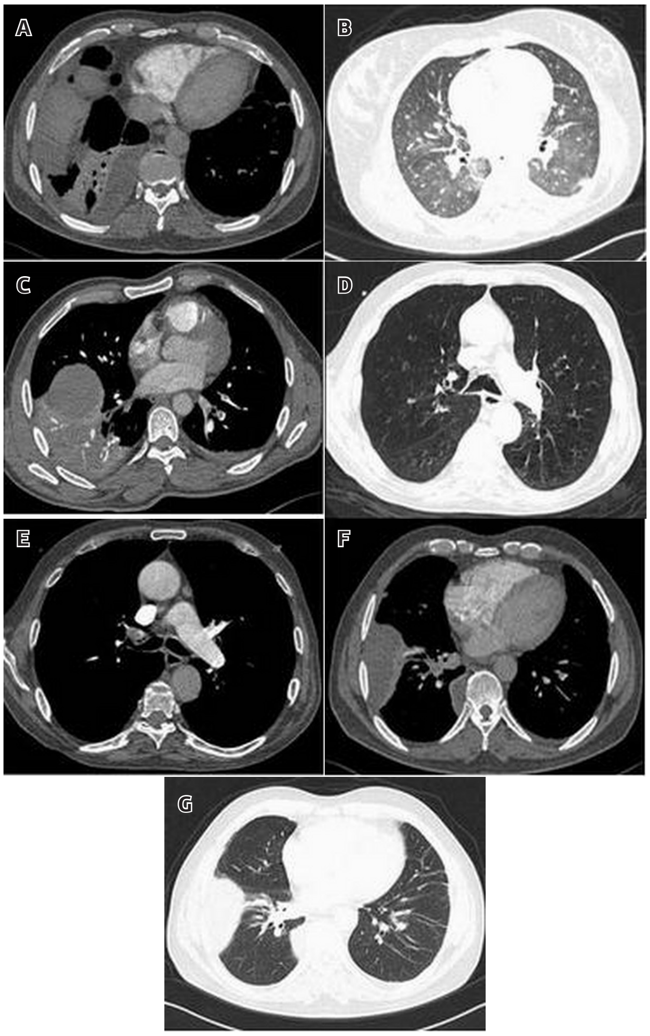

Figure 3. Atelectasis (A), Ground glass appearance (B), Consolidation (C), Oligemia (D), Nodule (E), Wedge opacification (F), Vessel sign (G).

the thickness of the pleural effusion (no pleural effusion, small: <3 cm, medium: 3-5 cm, large: >5 cm) (p=0.029). Additionally, a negative correlation was observed between OIR and left pleural effusion but no significant difference was found (r=-0.143, p=0.12) (Table 4).

Table 5. Studies and parenchymal findings correlated with PE

		PE (+)	PE (-)	p-value
Presence of a parenchymal anomaly	Current study	119 (99.2%)	53 (88.3%)	0.001
	Karabulut et al.	45 (92%)	66 (84%)	0.28
	Shah et al.	24 (86%)	56 (88%)	N/A
	Coche et al.	N/A	N/A	N/A
	Reissig et al.	31 (79%)	N/A	N/A
	Johnson et al.	22 (71%)	N/A	N/A
Atelectasis	Current study	110 (91.7%)	45 (75%)	0.002
	Karabulut et al.	27 (55%)	42 (53%)	0.86
	Shah et al.	20 (71%)	41 (64%)	N/A
	Coche et al.	9 (35%)	17 (27%)	>0.05
	Reissig et al.	18 (46.2%)	8 (34.8%)	0.434
	Johnson et al.	13 (42%)	N/A	N/A
Ground glass appearance	Current study	68 (56.7%)	23 (38.3%)	0.02
	Karabulut et al.	21 (43%)	24 (30%)	0.18
	Shah et al.	4 (14%)	16 (25%)	N/A
Consolidation	Current study	40 (33.3%)	5 (8.3%)	<0.001
	Karabulut et al.	19 (39%)	10 (13%)	0.001
	Shah et al.	4 (14%)	14 (22%)	N/A
	Coche et al.	5 (19%)	15 (24%)	>0.5
	Reissig et al.	14 (35.9%)	2 (8.7%)	0.033
	Johnson et al.	6 (19%)	N/A	N/A
Oligemia	Current study	31 (25.8%)	3 (5%)	0,001
	Karabulut et al.	4 (8%)	1 (1%)	0,07
	Shah et al.	2 (7%)	7 (11%)	N/A
	Coche et al.	3 (12%)	6 (10%)	>005
Wedge-shaped opacity	Current study	33 (27.5%)	1 (1.7%)	<0,001
	Karabulut et al.	15 (31%)	2 (2.5%)	<0,001
	Shah et al.	7 (25%)	3 (5%)	N/A
	Coche et al.	16 (62%)	17 (27%)	<0,05
	Reissig et al.	21 (53.8%)	5 (21.7%)	0,017
Nodule	Current study	46 (38.3%)	22 (36.7%)	0.828
	Karabulut et al.	4 (8%)	8 (10%)	1
	Shah et al.	2 (7%)	13 (20%)	N/A

PE: Pulmonary emboli

Table 3. Correlations between vascular, ventricular diameters and CTPAOIR

		Main PA diameter	Right PA diameter	Left PA diameter	VCS diameter	RV Diameter	LV Diameter	RV/LV
CTPAOIR	Pearson Correlation	0.149	0.209*	0.198*	0.383	-0.072	0.323	0.218
	Sig. (2-tailed)	0.104	0.022	0.030	<0.001	0.437	<0.001	0.017
	N	120	120	120	120	120	120	120

PA: Pulmonary artery, CTPAOIR: Computed tomography pulmonary artery obstruction index ratio

Table 4. Correlation between CTPAOIR and pleural effusion, atelectasis, ground glass appearance, consolidation, oligemia scores

		Atelectasis score	Ground glass appearance score	Consolidation score	Oligemia score	Bilateral pleural effusion	Right pleural effusion	Left pleural effusion
CTPAOIR	Pearson Correlation	-0.317	0.012	0.059	-0.210	-0.252	-0.143	0.202
	Sig. (2-tailed)	0.000	0.900	0.525	0.021	0.006	0.12	0.027
	N	120	120	120	120	120	120	120

CTPAOIR: Computed tomography pulmonary artery obstruction index ratio

Discussion

Although there is no new information in this study, vascular, cardiac, pleural, and parenchymal findings were significantly different in patients with PE. Also, the relationship of the findings with the location and severity of the embolism was high.

Kuriyama et al. specified that the upper limit of the main PA diameter is 28.6 ± 2 mm. If the main PA diameter exceeds this dimension, pulmonary hypertension is generally assumed to be present; however, this is not an exact diagnosis [9,10,11]. In the studies of Karabulut et al., [9] no significant difference was found in average PA diameters between patients with and without PE. This difference between the study of Karabulut et al. and our study may be the result of our higher average CTPAOIR value (average CTPAOIR in the study of Karabulut et al. was 27% ± 21%).

In our study, the average PA and right PA diameters in the patients with massive PE was found to be wider than in patients with sub-massive PE. There was also a positive correlation with OIR and PA diameters, which is similar to the data obtained in previous studies [9,11,12]. Our average left PA diameter data is similar as in the study of Coche et al. [12], and no difference was found with PE alone. But the average left PA diameter was wider with OIR ≥50% and there was a positive correlation.

The average superior vena cava diameter was wider in patients with PE and OIR ≥50%, as in the study of Collomb et al. [13]. Also, there was a positive correlation between CTPAOIR and superior vena cava diameter.

RV and LV short diameters calculated were smaller than the short diameters calculated in the study of Van der Meer et al. We consider this difference to be caused by subjective measurements and ethnic features. On the other hand, RV/LV ratios were similar [14]. We found the RV/LV ratio was significantly higher in patients with PE. Severe RV insufficiency is higher in the patients with PE. Average short RV diameter was also higher, and there is a positive correlation between the CTPAOIR and RV variables. However, no statistically significant difference was observed between the short LV diameters. Ghuysen et al. [15], specified that the RV/LV ratio measured from axial images is a more suitable prognostic indicator than OIR.

High difference has been determined in interventricular septum deviation with or without PE and OIR ≥50% or <50%. As an indicator of RV dysfunction, interventricular septum convexity toward the LV was increased in PE and even more increased in massive PE.

The indirect CT findings of RV overload are the visible extension of RV and contrast material reflux in the superior vena cava, azygos vein, or inferior vena cava [16]. Inferior vena cava reflux was observed in 51.7% of patients with PE and 25% of patients without PE; a significant difference was determined between the two groups, and there was an increase in reflux when OIR ≥50%. Collomb et al. [13] did not determine any difference between severe and non-severe patients with and without PE in terms of inferior vena cava reflux in their studies, but they had only a small number of patients. In their study, there was azygos vein reflux in 41.7% of patients with PE and in 11.7% of patients without PE, as well as an increase in frequency when OIR ≥50%.

The frequencies in the study of Shah et al. are closer to our study. In the studies of Coche et al., Reissig et al., and Johnson et al., some abnormalities were not evaluated (ground glass appearance, oligemia), and as a result, the abnormality frequencies were lower than in our study [16, 17, 18]. In the current study, 100% of the patients with OIR ≥50% and 98.7% of the patients with OIR <50% had a minimum of one parenchymal abnormality, and no difference between the two groups was identified (Table 5).

In the previous five studies evaluating the parenchymal findings in patients with PE, the ratios stated for atelectasis are lower than in our study, perhaps because linear opacity was not considered in our study and there is the possibility that some atelectasis were considered to be linear opacity. The differences between the studies lead us to believe that the small atelectasis and linear opacity definitions should be more detailed. In Sutnick and Soloff's study, the relationship between atelectasis and the pulmonary infarct was not identified clearly, but meaningful relations were found between pulmonary infarct and hemorrhagic atelectasis. They stated that, based on the occlusion in PA, this finding caused ischemia development in alveolar epithelium and a decrease in surfactant production [19]. We determined that in patients with OIR ≥50%, the atelectasis frequency did not change; however, the average atelectasis scores between the two groups were different. On the other hand, the atelectasis score displayed negative correlation with OIR.

The ground glass appearance was determined as the second most frequent finding, but only two of the previous five studies investigated its frequency. In both studies, the ground glass appearance frequency was found to be lower than in our study. Karabulut et al. did not identify any differences in ground glass appearance frequency between patients with and without PE (p=0.18), but we found that the average ground glass score and the ground glass frequency were different between groups in our study. The appearance should not be confused with consolidation, where the bronchovascular boundaries are removed and which involves an air bronchogram [20]. The reason for the identification of ground glass appearance in PE patients can be bronchoconstriction, edema, bleeding, and changes in the lung tissue due to infarct. Matsuoka et al. [21] stated that the lung tissue appears heterogeneous in PE patients but not in those without PE. This finding is similar to the ground glass density frequency determined in PE patients in our study. Consolidation frequencies are in line with the findings of Karabulut et al. and Reissig et al., and the frequency increases in PE patients. Also, similarly, the average consolidation score and consolidation frequency were found to be different in our study. The higher consolidation frequency in PE patients can be explained by a non-wedge-shaped infarct, by edema, or by bleeding representation. However, consolidation is a non-authentic finding that can be observed due to many reasons. As Karabulut et al. did, we determined that consolidation frequencies and average consolidation scores are similar in patients with OIR ≥50% and <50% [9].

There are some limitations of our study due to the fact that iodinated contrast agents may impair renal function or a severe allergy may develop to the contrast material. Subsegmental emboli may be missed with CT angiography.

In studies that evaluate the parenchymal findings in patients with PE, the oligemia frequency was lower than in our study. Karabulut et al. determined oligemia more frequently with PE; however, this difference was not statistically significant. The average oligemia score and oligemia existence with and without PE were found to be statistically meaningful in our study. This result states that oligemia is related to PE, and it is similar to the study of Wosley et al. [22]. There is positive correlation between OIR and the oligemia score. As expected, these findings demonstrate that as vascular occlusion increases, oligemia increases as well.

Our findings align with the previous studies stating that there is a strong connection between PE and wedge-shaped opacification [9,12,17,18].

It has been determined that vein mark frequency increases in patients with PE. According to PE severity, vein marks were observed at a lower ratio in patients with an obstruction index ≥50% compared to patients with <50%. It was determined that there is a negative correlation between PE severity and vein marks. As the obstruction increases, the vein mark observation frequency decreases.

No difference was found for the nodule frequency in patients with PE or OIR ≥50% and <50%. These findings we obtained are parallel to the findings of Karabulut et al.

Pleural effusion is a finding that is generally observed in patients with PE and it can be determined in up to 51% of lung radiographies [18]. In our study, the pleural effusion frequency in patients with PE were parallel to the frequencies in the studies of Karabulut et al. Shah et al., Coche et al., and Johnson et al.; however, it was higher than the frequency in the study by Reissig et al. [9,12,16,17,18].

In conclusion, CTPA can, with a single examination, display both vascular and parenchymal differences in acute PTE cases where CTPAOIR is <50% (sub-massive PE) and ≥50% (massive PE) as well as right heart dysfunction.

Competing interests

The authors declare that they have no competing interests.

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