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CHEST IMAGING

ORIGINAL ARTICLE

Relationship of parenchymal and pleural abnormalities with acute pulmonary embolism: CT findings in patients with and without embolism

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PURPOSE
To compare the frequency of pleural and parenchymal abnormalities detected on computed tomography (CT) in patients with and without acute pulmonary embolism (PE), and to investigate whether the pleuroparenchymal findings correlate with the severity of PE.

MATERIALS AND METHODS
We retrospectively reviewed contrast-enhanced CT scans acquired in 128 patients suspected of having acute PE. The presence of filling defects consistent with PE was recorded, and the clot burden was quantified. The presence and the severity of parenchymal abnormalities, and the presence, size, and location of pleural effusions were recorded.

RESULTS
Forty-nine patients (38%) had CT evidence of PE with a mean degree of obstruction of 27 ± 21%. Parenchymal abnormalities were seen in 45 patients with PE (92%) and in 66 patients without PE (84%) (P = 0.28). Atelectasis, the most common finding, was present in 27 patients with PE (55%) and 42 patients without PE (53%) (P = 0.86). Wedge-shaped opacity was observed in 15 patients (31%) and consolidation was observed in 19 patients (39%) with PE (P = 0.001). Pleural effusions were present in 27 patients with PE (55%) and 42 patients without PE (53%) (P = 0.86). With regard to the severity of ancillary parenchymal findings, only the number of wedge shaped opacities showed mild correlation with the severity of PE (r = 0.34, P = 0.04).

CONCLUSION
The majority of patients with and without PE demonstrate parenchymal and pleural findings on CT. Wedge-shaped opacities and consolidation are significantly associated with PE. Other parenchymal and pleural findings on CT do not correlate with the presence and severity of PE.

Key words: • *pulmonary embolism* • *CT angiography* • *pleural effusion*

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Over the past 15 years, computed tomography pulmonary angiography (CTPA) has secured a prominent role as the first-line diagnostic imaging modality for the detection of pulmonary embolism (PE) in large and segmental vessels, replacing ventilation-perfusion lung scintigraphy and pulmonary angiography (1–5). In a recent meta-analysis of 9 studies using eight single-slice and one dual-slice helical computed tomography (CT) in 520 patients, the overall sensitivity and specificity for CTPA were reported as 86% and 93.7%, respectively (6). The multicenter PIOPED II (Prospective Investigation of Pulmonary Embolism Diagnosis II) trial prospectively investigated the accuracy of multidetector CTPA in 774 patients with conclusive studies, and reported a sensitivity of 83% and a specificity of 96% (7).

In addition to demonstrating intraluminal clot definitively, CTPA also allows concomitant evaluation of the lung parenchyma and pleural space. Data from four previous studies designed to investigate pleuroparenchymal CT findings in 124 patients with acute PE revealed that peripheral wedge-shaped opacity was significantly associated with the presence of PE, and was seen in 25–62% of patients with PE (8–11). Although CTPA reports usually describe only the presence and location of a clot, with an occasional rough visual estimate of the extent of the clot, an objective and reproducible CT quantification of the severity of PE has been reported with good correlation to pulmonary angiography indices (12). For this purpose, the degree of arterial obstruction is quantified by a reproducible specific CT index based on the location of the embolus and the degree of obstruction. Recent CT studies have evaluated the association of this CT severity index with clinical outcome (13–16) and blood gas values (17, 18). It has been reported that the CT severity index can be used as an indicator of the hemodynamic severity of PE. It correlates with blood gas values, and is a significant predictor of death (13–15, 17–19). However, no study has investigated whether the severity of pleuroparenchymal findings correlates with the severity of PE. Hypothetically, a massive embolus would be associated with parencyhmal or pleural findings different from those of an isolated subsegmental embolus.

This study was designed to answer two basic questions based on findings of CTPA performed for clinical suspicion of PE: first, whether the frequencies of pleural and parenchymal abnormalities in patients with acute PE are different from those without acute PE, and second, whether the presence and severity of the pleuroparenchymal findings correlate with the severity of PE.

Materials and methods

Study population

Contrast-enhanced CT scans obtained in 139 consecutive patients suspected of having acute PE between December 2003 and December 2006 were reviewed retrospectively. Eleven examinations were excluded from this study: nine due to poor image quality from respiratory motion artifacts or inadequate contrast in the pulmonary arteries, and two because of the presence of chronic PE. The remaining 128 patients (60 males, 68 females; age range 19–87 years; mean, 56 ± 17 years) constituted the study group. The institutional review board approved the study and waived the requirement for informed consent for our patient data review.

CT examination

Ninety-two patients were scanned on a dual-detector CT scanner (M x 8000, Philips Medical Systems, Cleveland, Ohio, USA), and 36 patients on a 16-detector CT scanner (Brilliance 16, Philips Medical Systems, Cleveland, Ohio, USA). Contrast-enhanced spiral CT of the pulmonary arteries was performed from the lung apices to the level of lowest hemidiaphragm in a supine position during suspended inspiration or shallow breathing, depending on the patient's level of dyspnea. The images were obtained on dual-detector CT using 120 kV, 125 effective mAs, collimation of 2 x 2.5 mm, slice thickness of 3.2 mm, reconstruction interval of 1.6 mm, a table speed of 8.75 mm/s per 0.75 s gantry rotation time (a pitch of 1.75). The parameters on multidetector CT (MDCT) were 120 kV, 250 effective mAs, collimation of 16 x 0.75 mm, slice thickness of 1 mm, reconstruction interval of 0.5 mm, and a table speed of 11.25 mm per 0.75 s rotation time (pitch, 0.938). The field of view was appropriately adjusted to the size of the patient, and an acquisition matrix of 512 x 512 was used. A total volume of 100–150 mL of iodine-based nonionic contrast material (300 mg I/mL) was injected through an antecubital vein using a power injector at a rate of 3 mL/s for dual-slice CT, 4 mL/s for 16-MDCT. A fixed delay time of 20 s was used for dual-slice CT, and a timing bolus technique was used for 16-MDCT. The mean scan length was 242.9 ± 47 mm (range, 102–324 mm) in men, and 215.5 ± 28 mm (range, 160–284 mm) in women at dual-slice CT. Mean scan length was 273 ± 38 mm (range, 200–367 mm) in men, and 251.5 ± 43 mm (range, 192–351mm) in women at 16-MDCT. The mean scan time was 21.4 ± 3.8 s (range, 13–32 s) on dual-slice CT, and 18.9 ± 2.7 s (range, 14–26 s) on 16-MDCT.

Interpretation of images

CT data were transferred electronically to a workstation (Mx View *exp*; release 4.01, Philips Medical Systems, Cleveland, Ohio, USA). All CT images were reviewed on a workstation monitor by a fellowship-trained chest radiologist with a 10-year experience. All axial images were viewed on the workstation using the cine stack technique with standard mediastinal (level, 50 HU; width, 350 HU), and lung window settings (level, -600 HU; width, 1600 HU). However, the observer was free to perform and review multiplanar reconstructions and to change the window and level settings to optimize the visualization of the vessels.

On data sheets for images obtained with the mediastinal window settings, the quality of both the images and the contrast opacification were graded as excellent, good, or inadequate. The main pulmonary artery diameter was measured at its widest portion within 3-cm of the bifurcation. The presence of any intraluminal filling defect(s) was recorded and localized using bronchopulmonary nomenclature. The final diagnosis of PE was made on the basis of the CT findings. The degree of obstruction was quantified according to amount and location of the thrombus on CT images using obstruction index of Qanadli et al. (12), defined as the product $\Sigma(n \times d)$, expressed in percentage of vascular obstruction, where n is the value of the most proximal clot site that equals the number of segmental branches arising distally, and d is the degree of obstruction, where partial obstruction is scored as 1 and complete obstruction as 2. Values for n range from 1 (one segment obstructed) to 20 (obstruction of both right and left main pulmonary arteries). In order to obtain to a percentage of vascular obstruction for each patient, the total Σ $(n \times d)$ product was divided by the maximum total score (20 segments x 2) and multiplied by 100 according to the formula (Σ $[(n \times d) / 40]$ x 100). The patients with CT evidence of PE were further categorized, based on the severity of PE, as mild to moderate (obstruction index <50%) or severe PE (obstruction index ≥50%).

On data sheets for the images obtained with lung window settings, the following information was recorded: image quality (graded as excellent, good, or inadequate), the presence, size, and location of pleural effusions, and the presence, location, and severity of any parenchymal abnormality according to segments using bronchopulmonary nomenclature. The size of pleural effusions was graded as small (<3 cm), moderate (3–5 cm), and large (>5 cm) according to maximum depth at transverse sections. Parenchymal abnormalities that were investigated included wedge-shaped opacity (a roughly triangular area of increased attenuation, with a broad base against pleural surface and the apex toward the hilum), atelectasis (loss of volume), linear opacity (a thin line of increased attenuation), ground-glass attenuation (a hazy increased parenchymal attenuation not obscuring bronchovascular markings), consolidation (a non-wedge-shaped area of increased attenuation obscuring bronchovascular markings), nodule (a round opacity ≤3 cm in diameter), mass (a solid lesion, >3 cm in diameter), oligemia (an area of decreased attenuation due to diminished perfusion manifested by a reduction in the caliber and number of vessels that is not attributable to emphysema or lung cysts), and vascular sign (a thickened vessel pointing to the apex of a wedge-shaped opacity). Of these, the severity score was assigned to atelectasis, ground-glass attenuation, consolidation, and oligemia according to the percentage of segment that was involved, using a 3-point scale (0, absent; 1, <50% of segment; 2, ≥50% of segment). The total score of the abnormalities was divided by the maximum total score (20 segments x 2) and multiplied by 100 to derive the total percentage of the abnormality. Only the absence or presence and the total number of findings were recorded for wedge-shaped opacity, linear opacity, nodule, mass, and vascular sign.

Statistical Analysis

Quantitative variables we expressed as mean ± standard deviation (SD) of the mean. Descriptive statistics were calculated for presence and severity of PE and pleuroparenchymal findings. Spearman correlation was used for nominal data, and Pearson correlation was used for continuous variables to assess the association of presence and severity of PE with those of pleuroparenchymal findings. The null hypothesis of no difference in parenchymal and pleural findings between patients with and without CT evidence of PE was tested using Fisher's exact test. The difference in severity

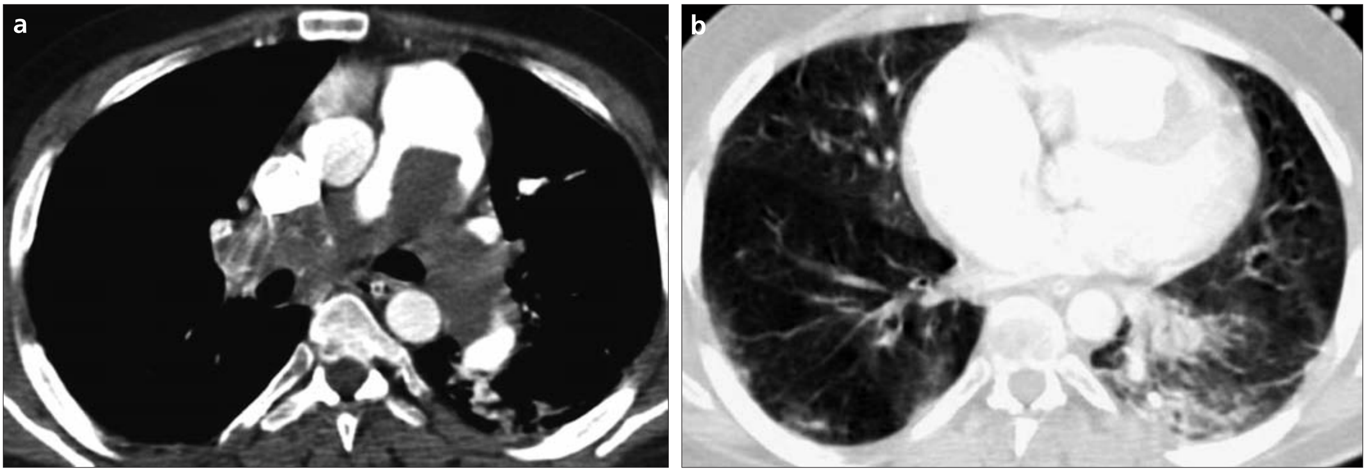


Figure 1. a–c. Axial CT pulmonary angiography images of a 28-year-old man with massive emboli; pulmonary artery obstruction index of 87.5%. Mediastinal window setting **(a)** show saddling emboli in the main pulmonary arteries. Lung window settings at the level of inferior pulmonary veins **(b)**, and through the basal segments **(c)** show oligemia in the superior segment of right lower lobe, and subsegmental atelectasis and ground-glass attenuation in both lower lobes.

of pleuroparenchymal findings between patients with and without PE was analyzed using the *t*-test. A possible association between the severity of PE and presence or severity of parenchymal findings was investigated using the Fisher's exact and Mann-Whitney U tests, respectively. Statistical significance was defined as a *P* value of <0.05. All analyses were performed using a software program (SPSS for Windows, release 11.0; SPSS Inc., Chicago, Illinois, USA).

Results

The overall quality of contrast opacification was judged to be excellent in 89 patients (70%), and good in 39 patients (30%). The overall quality of images obtained with mediastinal window settings was judged to be very good in 101 patients (79%) and adequate in 27 patients (21%), whereas the quality of images obtained with lung window settings was judged to be very good in 99 patients (77%) and adequate in 29 patients (23%).

Comparison of patients with and without pulmonary embolism

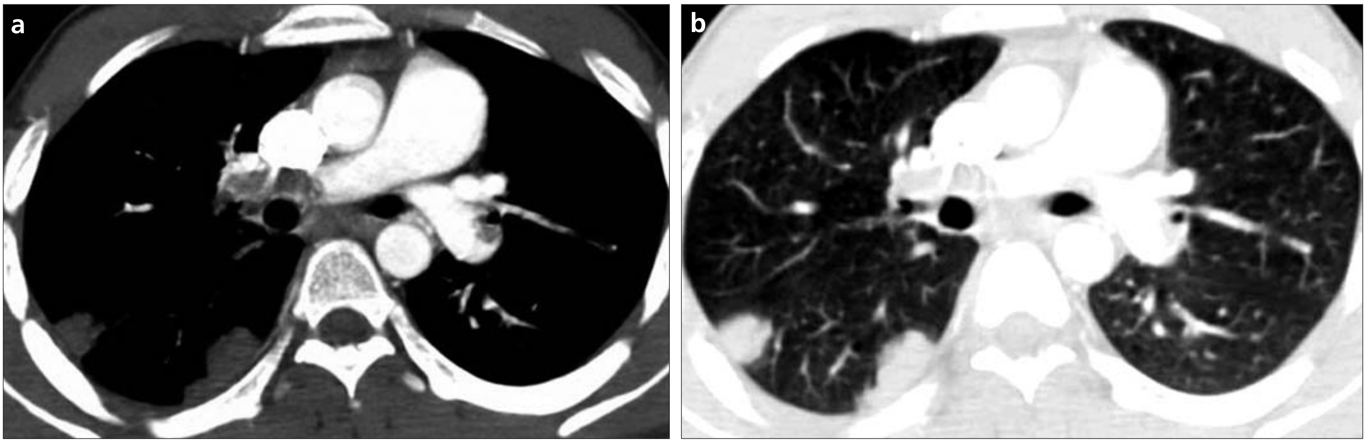
Pulmonary embolism was identified in 49 (38%) of 128 patients; 79 patients (62%) had CTPA examinations negative for PE. The mean age of patients with and without PE was comparable, 56 and 57 years, respectively. The mean pulmonary artery diameter was 29 ± 4.8 mm in patients with PE, and 27.7 ± 4.7 mm in those without PE (*P* = 0.13).

At least one parenchymal abnormality was seen in 45 (92%) of the 49 patients with PE and in 66 (84%) of the 79 patients without PE (*P* = 0.28). The frequency of pleuroparenchymal findings was tabulated in Table 1. Atelectasis was the most common finding (Fig. 1) fol-

Table 1. The frequency of parenchymal findings in patients with and without pulmonary embolism

	Patients with PE (n = 49)	Patients without PE (n = 79)	*P* value[a]
Any parenchymal abnormality	45 (92%)	66 (84%)	0.28
Atelectasis	27 (55%)	42 (53%)	0.86
Ground-glass attenuation	21 (43%)	24 (30%)	0.18
Consolidation	19 (39%)	10 (13%)	0.001
Wedge-shaped opacity	15 (31%)	2 (2.5%)	<0.001
Linear opacity	10 (20%)	16 (20%)	1.00
Oligemia	4 (8%)	1 (1%)	0.07
Vascular sign	4 (8%)	0 (0%)	0.02
Nodule	4 (8%)	8 (10%)	1.00
Mass	1 (2%)	2 (2.5%)	1.00

PE, pulmonary embolism.
[a] Fisher’s exact test



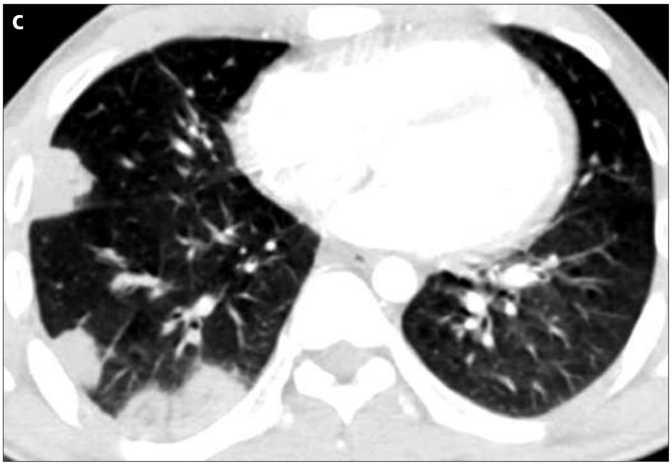


Figure 2. a–c. Axial CT pulmonary angiography images of a 23-year-old man with bilateral multiple pulmonary emboli. Mediastinal window setting **(a)** shows endoluminal clots in the right main and left interlobar arteries, receiving pulmonary artery obstruction index of 42.5%. Lung window settings at the corresponding level **(b)**, and at the level of ventricles **(c)** reveal multiple peripheral wedge-shaped opacities within the right middle and lower lobes.

lowed by the ground-glass attenuation (Fig. 1), consolidation, wedge-shaped opacity (Figs. 2, 3), and linear opacity (Table 1). Oligemia (Fig. 1), vascular sign, nodule, and mass were far less common. Among these parencymal changes, only the frequencies of wedge-shaped opacity ($P < 0.001$), consolidation ($P = 0.001$), and vascular sign ($P = 0.02$) achieved a statistically significant difference between patients with and patients without PE. Accordingly, correlations between the presence of PE and pleuroparenchymal abnormalities were found to be statistically significant only for the presence and score of the wedge-shaped opacity ($r = 0.40$, $P < 0.001$), consolidation ($r = 0.29$, $P = 0.001$), and the presence of vascular sign ($r = 0.23$, $P = 0.01$). No parenchymal abnormality was detected in four patients with PE (8%), or in 13 patients without PE (16%) (Fig. 4).

Pleural effusions were present in 27 patients with PE (55%) and in 42 patients without PE (53%) ($P = 0.86$). They were more often bilateral than unilateral, with small pleural effusions being the most common. The amount of effusion did not show statistically significant difference between two groups ($P = 0.90$ for the right side and $P = 0.27$ for the left side), and did not reveal significant correlation with the presence of PE.

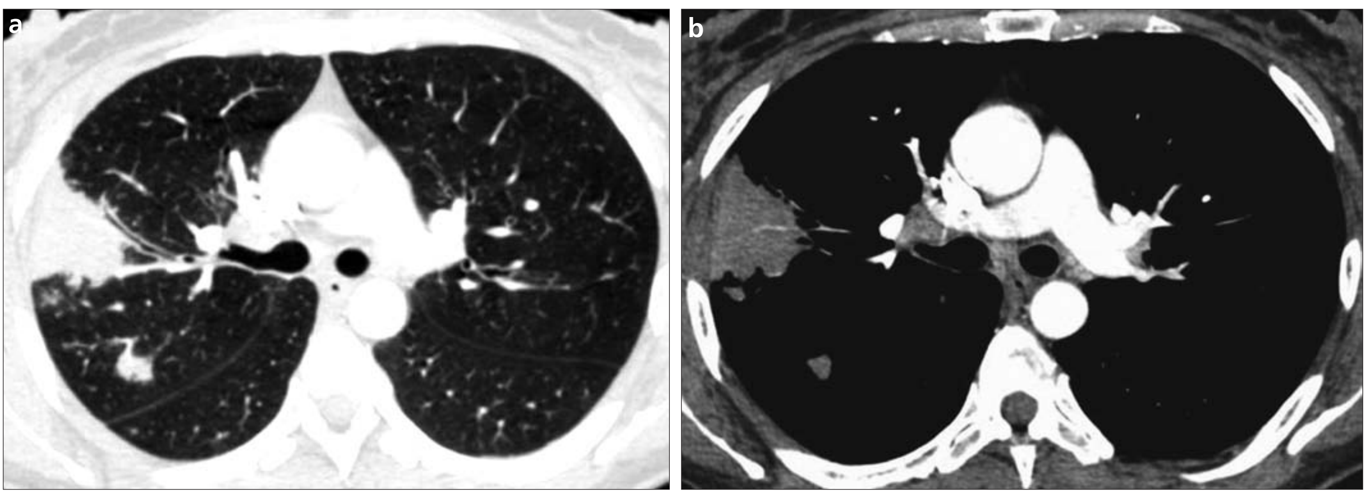


Figure 3. a, b. Axial 16-multidetector CT images at the level of right upper lobe bronchus in a 41-year-old woman without pulmonary embolus. Lung window setting **(a)** shows peripheral wedge-shaped opacity within the right upper lobe, which was proven to be pneumonia. Mediastinal window setting **(b)** shows no evidence of endoluminal clot.

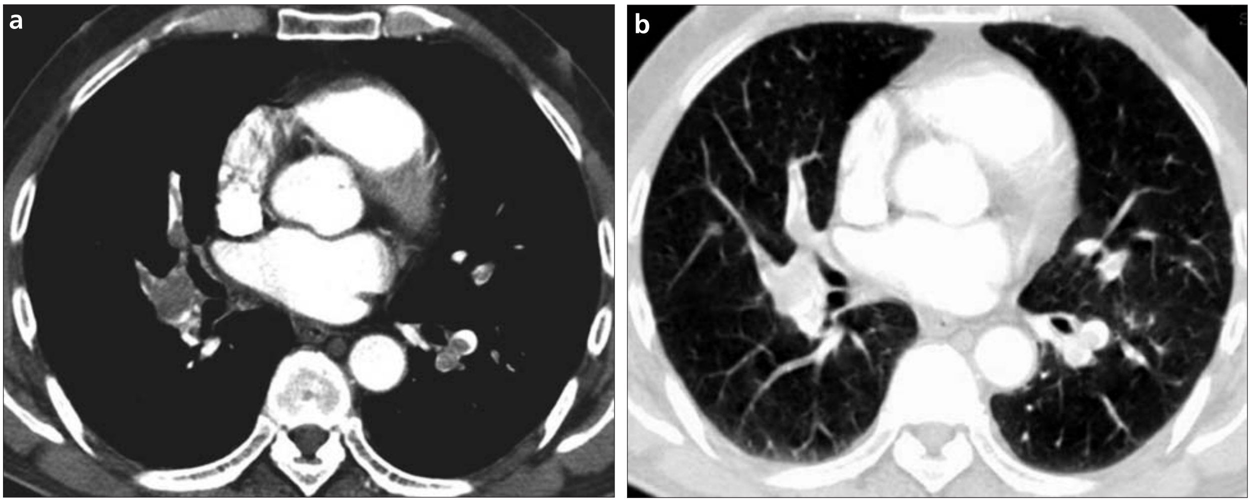


Figure 4. a, b. Axial CT pulmonary angiography images at the level of left atrium in a 66-year-old man with bilateral multiple pulmonary emboli. Mediastinal window setting **(a)** shows multiple endoluminal clots in both lower lobes, and right middle lobe arteries, receiving pulmonary artery obstruction index of 50%. Lung window setting **(b)** shows no parenchymal abnormality.

Comparison of patients according to severity of pulmonary embolism

The mean pulmonary artery obstruction index was 27 ± 21% (range, 2.5–87.5%) in patients with PE. The mean pulmonary artery diameter was larger in patients with an obstruction index of 50% or higher than those with an index of less than 50%, measuring 31.1 ± 4.7 mm and 28.1 ± 4.6 mm respectively (P = 0.04). Table 2 summarizes the score of parenchymal findings in patients with and without PE. There was no statistically significant difference in the overall frequency and severity of parenchymal abnormalities between two groups of patients with different clot burden (P > 0.05). Furthermore, the severity of PE did not significantly correlate either with the presence or with the severity of parenchymal findings (P > 0.05). When quantification of specific parenchymal findings was considered, only the number of wedge-shaped opacities achieved statistical significance between patients with and without PE (P = 0.002), and showed poor correlation with the severity of PE (r = 0.34, P = 0.04). On the other hand, severity of PE was inversely related to the atelectasis score (r = -0.41, P = 0.01). The severity of other parenchymal abnormalities did not reveal significant association with the severity of PE. The presence of pleural effusion did not show a statistically significant difference between patients with different clot burden (P = 0.06). However, the presence and size of pleural effusion correlated with the severity of PE (r = 0.34, P = 0.02, for the presence); (r = 0.34, P = 0.02, and r = 0.29, P = 0.05 for the size on the right and left, respectively).

Discussion

CTPA has dramatically changed the diagnostic work-up for suspected acute pulmonary embolism, and has become the first-line diagnostic imaging modality. CT not only provides concrete

Table 2. The severity of parenchymal findings in patients with mild-moderate or severe clot burden, and in those without pulmonary embolism

Severity of parenchymal findings[a]	Patients with PE (n = 49)				Patients without PE (n = 79)	
	Mild-moderate PE (n = 34)		Severe PE (n = 15)			
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Atelectasis[b]	4.2 ± 5.9%	0–27.5%	2.8 ± 4.4%	0–15%	6.1 ± 10.8%	0–52.5%
Ground-glass attenuation[b]	4.9 ± 8.8%	0–40%	3.3 ± 6.4%	0–25%	5.1 ± 12.8%	0–70%
Consolidation[b]	1.5 ± 2%	0–5%	1.3 ± 2%	0–5%	1.8 ± 8.5%	0–60%
Wedge-shaped opacity[c]	0.4 ± 0.7	0–3	0.7 ± 1.6	0–5	0.02 ± 0.16	0–1
Oligemia[b]	0.1 ± 0.6%	0–2.5%	1.8 ± 6.4%	0–25%	0.3 ± 2.8%	0–25%

PE, pulmonary embolism; SD, standard deviation.
[a] P values between patients with and without PE, and between patients with mild-moderate and severe PE were not significant for all variables (P > 0.05) other than wedge-shaped opacity, which achieved statistical significance only between patients with and without PE (P = 0.002).
[b] The severity score represents the total percentage of involved segment in the whole lung.
[c] The severity score represents the total number of patients with wedge-shaped opacity.

evidence of an embolus, but also allows the concurrent evaluation of other intrathoracic structures. Nevertheless, routine interpretation of CTPA findings is typically focused on the presence or absence of emboli along with a rough visual estimation of clot burden, and a description of pleuroparenchymal abnormalities. Intuitively, an isolated subsegmental embolus would have a different influence on the blood flow, gas exchange, and parencyhmal or pleural findings than would a massive embolus. Only recently have studies been focused on the quantification of clot burden on the basis of CTPA findings (12–18). The CT severity index has been shown to be correlated with blood gas levels (17, 18), and is a predictor of death in patients with PE (13–15, 17–19). Furthermore, very few studies have addressed the prevalence and spectrum of parencyhmal and pleural findings in the setting of acute PE (8–11). In this study, we sought to determine the influence of the presence and severity of pulmonary arterial obstruction from acute PE on the presence and extent of pleuroparenchymal abnormalities. To our knowledge, this is the first study performed to relate such an index to pleuroparenchymal findings.

In patients with acute PE, lung attenuation values on CT images can be altered by diminished pulmonary perfusion, bronchoconstriction, edema, or infarction. In the present study, 92% of patients with CT evidence of PE, and 84% of those without CT evidence of PE had at least one parenchymal abnormality. There was no significant difference between two groups in the frequency of abnormalities. These findings are compared with those in previously published studies (Table 3).

Atelectasis was the most common parenchymal abnormality in the present study, with a similar frequency in patients with PE (55%) and in patients without PE (53%). Shah et al. also found atelectasis to be the most frequent parenchymal abnormality; however, the rate noted above is lower than the figures reported by Shah et al. (9) (71% of those with PE, and 64% of those without), but higher than those reported by Coche et al. (8) (35% and 27%, respectively) and by Reissig et al. (10) (46% and 35%, respectively) on CTPA. This observation is not surprising, because decreased production of surfactant may lead to adhesive atelectasis in patients with PE, and pulmonary atelectasis due to various causes is a common alternative diagnosis in patients undergoing CTPA for suspected PE (20).

In the present study, linear opacity was seen in 20% of patients with and without PE; however, in previous studies, the frequency of linear opacity was present in 46–54% of patients with PE (8–10). This discrepancy can be explained by the fact that some linear opacities may have been recorded as atelectasis. Indeed, this finding is rather nonspecific and possibly represents discoid atelectasis, postinflammatory changes, or resolving infarct. However, Coche et al. (8) reported significant association of linear opacity with PE.

In our study, ground-glass attenuation was recorded as the second most common parenchymal finding, seen in 43% of patients with PE, and in 30% of patients without PE. From four previous studies (8–11) designed to identify ancillary CT findings in the setting of acute PE, only Shah et al. (9) searched for ground-glass attenuation, and reported that it was seen in 14% of patients with PE, and in 25% of patients without PE. The presence of ground-glass opacity in patients with acute PE can be explained by the alteration of lung attenuation values by diminished pulmonary perfusion, bronchoconstriction, edema, hemorrhage, or infarction. Indeed, using quantitative analysis, Matsuoka et al. (18) reported that lung attenuation is more heterogeneous in patients with PE compared with those without PE.

Among the parencymal changes investigated, only the frequencies of wedge-shaped opacity, consolidation, and vascular sign achieved a statistically significant difference between patients with and without PE. Wedge-shaped opacity at CT is likely to represent pulmonary infarction within several affected secondary pulmonary lobules. Similar to the findings of previous reports, it was significantly more common in patients with PE (31%) than in patients without PE (2.5%) in our series. Wedge-shaped opacity in patients with and

Table 3. Comparison of studies evaluating the pleural and parenchymal findings detected on computed tomography in patients with pulmonary embolism

Study	Collimation	Number of patients with PE	Any parenchymal abnormality	Atelectasis	Ground-glass attenuation	Consolidation	Wedge-shaped opacity	Linear opacity	Oligemia	Pleural effusion
Present study	2x5 mm, 16x0.75 mm	49	45 (92%)	27 (55%)	21 (43%)	19 (39%)	15 (31%)	10 (20%)	4 (8%)	27 (55%)
Coche et al.[8]	3 mm	26	NR	9 (35%)	NR	5 (19%)	16 (62%)	12 (46%)	3 (12%)	13 (50%)
Shah et al.[9]	3 mm, 5 mm	28	24 (86%)	20 (71%)	4 (14%)	4 (14%)	7 (25%)	14 (50%)	2 (7%)	16 (57%)
Reissig et al.[10]	3 mm	39	31 (79%)	18 (46%)	NR	14 (36%)	21 (54%)	14 (36%)	NR	9 (23%)
Johnson et al.[11]	3 mm, 5mm, 10 mm	31	22 (71%)	13 (42%)	NR	6 (19%)	10 (32%)	NR	NR	14 (45%)
Total		173	122/147 (83%)	87 (50%)	25/77 (32%)	48 (28%)	69 (40%)	50/142 (35%)	7/103 (7%)	79 (46%)

PE, pulmonary embolism; NR, not reported.

without PE was reported to be 67% and 27%, respectively, by Coche et al. (8), 54% and 22% by Reissig et al. (10), and 25% and 5% by Shah et al. (9).

In addition to wedge-shaped opacity, consolidation was also significantly more prominent in patients with PE (39%) than in patients without PE (13%) in our series. These findings agree with those of Reissig et al. (10), who reported significantly higher frequency of non-wedge-shaped consolidations in patients with PE (36%) than in patients without PE (9%). However, the frequency of consolidation was lower (14–19%) in other studies investigating the parenchymal findings in the setting of acute PE (8, 9, 11). The higher prevalence of consolidation in patients with PE can be explained by the proposal that it may represent a non-wedge shaped infarct, edema or hemorrhage; however, consolidation is a nonspecific pattern that can result from many different causes. The presence and severity scores of wedge-shaped opacity and consolidation also showed moderate and poor correlations, respectively, with the presence of PE. Our findings confirm the previous studies reporting significant association for wedge-shaped opacity in patients with PE (8–10). Nevertheless, other entities, such as pneumonia, septic emboli, tumor, fibrosis, hemorrhage, or edema can also give a wedge-shaped opacity. In our series, two patients without PE (2.5%) had wedge-shaped opacities that could be attributable to pneumonia, or to possible pulmonary infarction from resolved PE.

Other patterns of parenchymal abnormality, such as oligemia, vascular sign, nodule, and mass were also examined in our study. These findings are infrequent, seen in less than 10% of patients in our study. Nevertheless, oligemia and vascular sign were detected more frequently in patients with PE. This is in accordance with the radiographic study in which oligemia was the only radiographic finding significantly correlated with PE (21). A thickened vessel leading to the apex of a wedge-shaped opacity (vascular sign), indicating a congested thromboembolic vessel, was also infrequent in our study, detected in only four patients with PE (8%).

In agreement with the data reported by Coche et al. (8) and Shah et al. (9), pleural effusions were present in more than half of the patients with and without PE in our series, were usually small, and were more often bilateral. Similar to previous studies (8–10), the presence and the size of effusion did not reveal significant association with the presence of PE. In a series of 230 patients with PE, the incidence of pleural effusion was reported to be 47%, and pleural effusion was typically small and unilateral (22). All of the effusions in the setting of acute PE were exudates, suggesting an important role for vascular injury and increased capillary permeability as a mechanism of effusion.

Quantification of severity of PE has been evaluated to assess the association with blood gas values, lung attenuation, and patient outcome (13–18, 23). Significant correlation was found between the severity of arterial bed obstruction and the blood gas values (17, 18). Collomb et al. (23) found that the severity of pulmonary arterial obstruction can be used as an indicator of the hemodynamic severity of PE, and of stratification of patients requiring thrombolytic or surgical treatment. Other investigators, van der Meer et al. (13) and Wu et al. (14), reported the CT severity score to be a significant predictor of death in 59 and 120 patients, respectively. In contrast, Pech et al. (16) recently reported a lack of association between the CT severity index and patient outcome.

To our knowledge, no studies have specifically addressed the relationship between PE obstruction index and the severity of pleuroparenchymal findings. The mean percentage of pulmonary arterial obstruction in this study was 27 ± 21%. This is in accordance with the previous studies in which the mean obstruction indices were in the range of 22–39% (14, 16–18). Patients with PE were further categorized based on the severity of PE as mild to moderate (obstruction index, <50%) and severe PE (obstruction index, ≥50%). Although the mean pulmonary artery diameter was larger in patients with an obstruction index of ≥50% in those with an index of <50% in our study, the overall frequency and severity of parenchymal abnormalities were not statistically different between two groups of patients with different clot burden. Furthermore, the severity of PE did not significantly correlate either with the overall presence or the severity of parenchymal findings. When the quantification of specific parenchymal patterns is considered, only the severity of wedge-shaped opacity achieved statistical significance in the difference between patients with and without PE. Moreover, its severity was poorly correlated with PE severity. Surprisingly, severity of atelectasis was inversely correlated with PE score, possibly due to coexistent problems. The presence of pleural effusion did not show a statistically significant difference between patients with high and low clot burden. However, the presence and size of pleural effusion mildly correlated with the severity of PE.

Our study had several limitations. First, we did not specifically document the preexistent or coexistent cardiac, pulmonary, or other systemic diseases that may likely influence the frequency of various parenchymal and pleural findings on CT. This also explains the observation of at least one pleuroparenchymal abnormality in the majority of our patients regardless of the presence or absence of PE. Previous imaging findings of the chest might have been useful to determine whether the pleural and parenchymal findings are associated with PE. However, recent chest X-rays or CT studies are not available in the majority of patients with suspected acute PE. Second, we used CTPA as the standard of reference for the presence or absence of PE which may miss an embolus at the subsegmental level. In our study, isolated subsegmental clot was detected in one of 49 patients with PE. However, the consequences of isolated clot are debatable, and we do not expect this limitation to influence our results substantially.

We conclude that parenchymal abnormalities and pleural effusion are present in the majority of patients undergoing CTPA for the clinical suspicion of PE, irrespective of the presence or absence of clot. The clinical implication of this finding is that V/Q scan is likely to be indeterminate in these patients, leaving CTPA as the diagnostic modality of choice. Other than wedge-shaped opacities and consolidation, parenchymal findings on CT do not correlate with the presence and severity of PE. Therefore, the presence or severity of parenchymal and pleural findings does not predict the presence or severity of PE, nor does PE predict parenchymal or pleural findings.

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