The accuracy of non-contrast chest computed tomographic Scan in the detection of pulmonary thromboembolism

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Background
Pulmonary embolism (PE) is a critical chest disease resulting in high mortality rates if undetected. This study aimed to evaluate the role of noncontrast multislice computed tomography in the detection of PE.

Patients and methods
One hundred patients requested for computed tomography (CT) pulmonary angiography and underwent noncontrast and contrast-enhanced CT images of the chest, which were reviewed separately. The average CT attenuation differences between the high-attenuation clots and pulmonary arteries were computed. Findings in the noncontrast images were correlated with the contrast-enhanced images.

Results
Twenty-six of 100 patients were positive for PE in computed tomography angiography; the mean age (±SD) was 56.73 (±9.11) years, and 17 (65.4%) were female individuals. The hyperdense lumen sign has an overall sensitivity of 50% and specificity of 98.6%. As for the other 13 patients, 10 of them had more than one indirect sign. The peripheral wedge-shaped opacity was the most common indirect sign that revealed high specificity (91%) and was statistically significant.

Conclusion
Noncontrast chest CT scan has a good role in the evaluation of PE through detection of the hyperdense lumen sign, which is a good indicator of acute pulmonary thromboembolism, particularly in cases involving the central pulmonary arteries or peripheral wedge-shaped opacity, as a useful indirect sign.

Keywords:
computed tomography, hyperdense lumen sign, pulmonary thromboembolism

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Introduction

Pulmonary embolism (PE) is the third most common acute cardiovascular disease after myocardial infarction and stroke, and it results in thousands of deaths each year because it often goes undetected. It is a blockage of the main artery of the lung or one of its branches by a substance that has traveled from elsewhere in the body through the bloodstream [1,2]. Contrast-enhanced computed tomography (CT) is well established as the initial definitive imaging study after chest radiography at many institutions [3]. Visualization of complete or partial intraluminal filling defects surrounded by the contrast-enhanced blood pool in the pulmonary arteries is a direct sign of PE [4]. Unenhanced multidetector computed tomography (MDCT) of the chest is performed for various reasons; it includes patients with allergies to iodinated contrast material or with elevated serum creatinine levels and patients with nonspecific cardiopulmonary signs and symptoms. Although not performed in many centers, unenhanced imaging as part of the CT pulmonary angiography (CTA) protocol is useful for two reasons. First, it allows evaluation of the lung parenchyma, pleura, and chest wall. Second, identification of calcified lesions such as hilar lymph nodes or calcified thrombi is possible. The former may interfere with the interpretation of contrast-enhanced images, and the latter may go undetected on contrast-enhanced studies [5,6].

Recognition of hyperdense thrombus may allow the diagnosis of acute PE to be made in patients undergoing unenhanced MDCT of the chest for other suspected conditions or in cases in which injection or scan-timing errors render a CT pulmonary angiogram suboptimal [7].

Indirect signs associated with acute PE include a wedge-shaped subpleural consolidation, oligemia, pleural effusion, and dilated central or segmental pulmonary arteries (pulmonary hypertension) that may be seen with chronic PE, all of which can be detected on unenhanced CT but may be nonspecific [8]. Our study aimed to outline the accuracy of unenhanced MDCT of the chest in the detection of pulmonary thromboembolism in comparison with CTA through determining the sensitivity and specificity of the direct and indirect signs that could be evaluated by the unenhanced CT study.

Patients and methods

This study included 100 patients who were clinically suspected for PE; patients were referred from different departments of Assiut university hospital. This study received approval from Ethics Committee of the Faculty of Medicine, Assuit University. Each patient was required to sign a written informed consent from before starting the study. confidentiality was assured for all patients. It included 46 male individuals and 54 female individuals. Their ages ranged from 20 to 90 years. The study was performed during the period spanning from 1 January 2017 to 30 June 2017. Our study included patients of different age groups and both sexes that were clinically, laboratory, or radiologically suspecting PE. Our study excluded any general contraindications to radiation in some cases such as pregnancy at first trimester, and contraindications to contrast in patients who had raised renal chemistry and hypersensitivity to the contrast. All studies were performed by using GE 16 (Waukesha, WI, USA) and Toshiba Aquilion 64 MDCT scanners (Tokyo, Japan) in the Diagnostic Radiology Department, Assiut University Hospital, and the scanning protocol at the time included both unenhanced and enhanced scans. Points to be checked before starting the examination included patient's laboratory findings, mainly the renal function tests, revising the patient's file for previous investigations and helpful data, and ensuring that a functioning flexible venous cannula (18 or 20 G) is inserted in an antecubital vein. Table 1 shows the current study technique.

The automated pump was checked to make sure whether it was connected and functioning. The pump was filled with 80–120 ml of nonionic contrast media (300–370 mg/ml), iodine. The flow rate of injection of contrast material was 4 ml/s. The pressure limit was 150 mmHg. The disposable extension tube of the injector was connected to the cannula and made sure that there were no air bubbles. Smart prep technique was used in most of the cases in order to ensure scanning during maximum contrast in the pulmonary artery. The level of the pulmonary artery from the scout was chosen. Axial CT cut was taken in the chosen level, and the Regional of interest (ROI) in the region of the main pulmonary artery was used to ensure scanning when maximum contrast was present in the pulmonary artery.

Table 1 The parameters used in this study

Scan range	GE 16 detectors CT	Toshiba Aquilion 64 detectors CT
	From lung apices to diaphragm	From lung apices to diaphragm
FOV	Large	Large
Scan direction	Craniocaudal	Craniocaudal
kV	140	140
mA	380	380
Slice thickness	1.25 mm	0.5 mm
Slice interval	0.8 mm	0.8 mm
Rotation time	0.6	0.4
Pitch	1.75 : 1	1.438 : 1

CT, computed tomography; FOV, field of view.

Axial cuts were sent to the workstation (General Electric Medical Systems) for processing and reconstruction and were also sent for viewing on a Path Speed PACS (picture archiving and communication system). In cases in which a high-attenuating central clot was present on unenhanced images, average CT attenuation values were measured for the clot and the blood pool. Although no specific window setting was consistently used in this study, the high-attenuation clots were best seen with narrow window settings (window width, W = 350–380 HU; window level, WL = 150–200 HU).

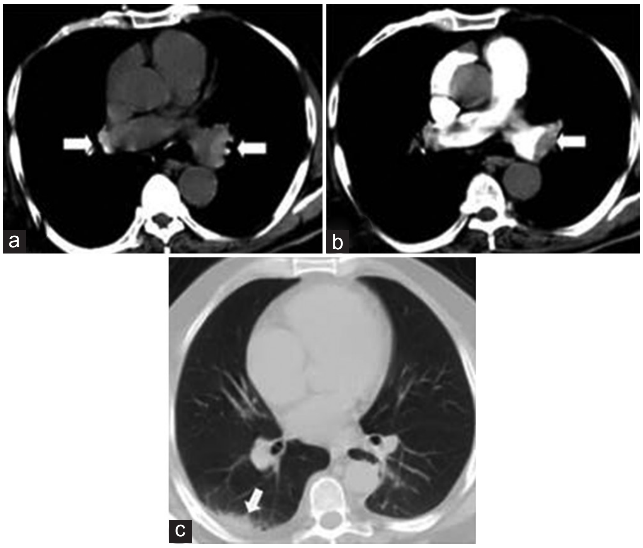
To reduce bias, the noncontrast and contrast-enhanced CT images were reviewed separately by a group of three radiologists. They evaluated the noncontrast CT images with regard to hyperdense thrombus (the direct) and indirect signs on a workstation or PACS without any clinical information about the patients or the findings in the corresponding contrast-enhanced images. In cases in which the hyperdense intraluminal clot was present on the unenhanced images, average CT attenuation values were measured in Hounsfield Unit for the clot. Average CT attenuations for the luminal (blood pool) densities of pulmonary arteries were also determined. The radiologists then evaluated the corresponding pulmonary CTAs. Pulmonary emboli were classified in to central (within the main and lobar pulmonary arteries) and peripheral (within the segmental, subsegmental, and more peripheral arteries). Findings in the pulmonary CTAs were summarized in a standardized report form.

Results

The current study included 100 patients whose condition clinically and according to laboratory findings was suggestive of PE; 54 (54%) were female patients and 46 (46%) patients were male individuals. Mean (±SD) age of the studied patients was 49.06 (±12.34) years. On the basis of CTA, 26 (26%) patients had a PE. On the basis of CTA findings, 26 patients were proved for PE, whereas, with noncontrast MDCT, only 14 patients showed PE (hyperdense thrombus) (Figs. 1–4), with the median attenuation being 90 HU and the range being between 65 and 150 HU; the median average blood pool was 30 HU, while the range was 20–60, and one of the 14 cases (Fig. 4) showed a negative filling defect at the CTA. Pulmonary emboli were localized as central (within the main and lobar pulmonary arteries) or peripheral (within the segmental, subsegmental, and more peripheral arteries). In case of noncontrast MDCT, eight (57%), two (14.3%), and four (28.5%) of the patients showed central, peripheral, and central with peripheral PE, respectively, but, in case of CTA, the majority of patients (57%) showed central with peripheral PE (Table 2).

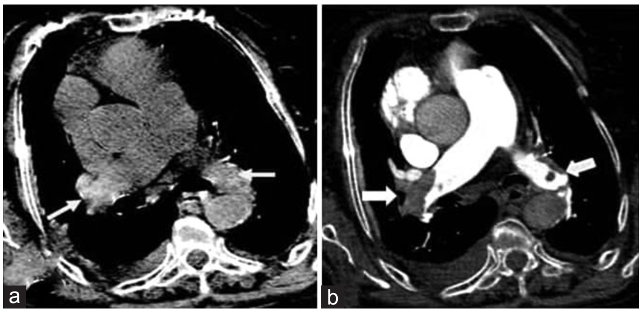
The current study concluded that the hyperdense sign at noncontrast MDCT had 50% sensitivity and 98.6% specificity, with area under the curve being 71% (P = 0.001), with 64.7% sensitivity and 98.6% specificity in diagnosing the central PE, and 20.8% sensitivity and 98.6% specificity in diagnosing the peripheral PE (Table 3).

Figure 1



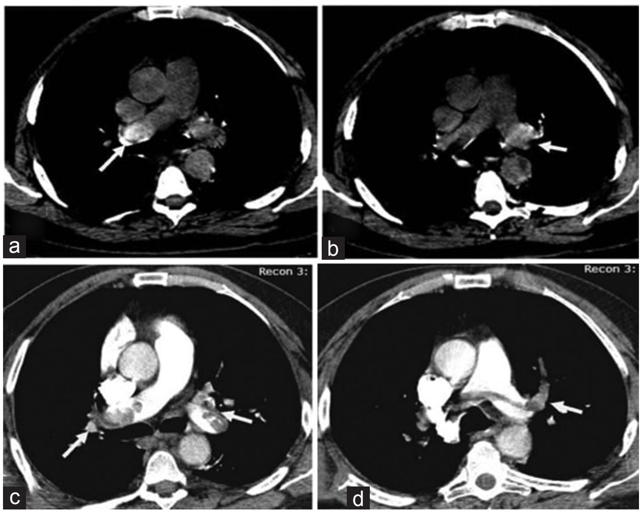
Unenhanced axial CT images of contrast CT images of a male patient 72 years old who was a heavy smoker with a history of recurrent deep venous thrombosis (DVT). He presented with atypical chest pain and showed hyperdense thrombus at both main pulmonary branches with an average density of 75 HU and average blood pool of 30 HU; peripheral wedge-shaped opacity is seen at the right lower lung lobe; pulmonary artery is dilated (arrows in a and c), and this is confirmed by CTA images that show filling defects at both main branches, and lobar and segmental pulmonary arterial branches (arrows in b). CT, computed tomography; CTA, computed tomography angiography.

Figure 2



Unenhanced CT axial images of a female patient 75 years old complaining of a chronic cough; expectoration presented with sudden dyspnea and palpitation; the images show hyperdense thrombus at both main pulmonary artery branches, with an average density of about ± 90 HU and average blood pool of about ± 40 HU, bilateral pleural effusion, and dilated pulmonary artery (arrows in a). This was confirmed by CTA axial and coronal reformatted CTA images showing filling defects of both main, lobar segmental, and subsegmental pulmonary branches (arrows in b). CT, computed tomography; CTA, computed tomography angiography.

Figure 3



Unenhanced CT axial images of a male patient 65 years old who presented with dyspnea; they show a hyperdense thrombus at both main and its branches with a density of 150 HU and average blood pool of about 40 HU (arrows in a and b). Confirmed by CTA, images show that, in the main pulmonary artery, acute overriding thromboembolism extends to both the right and left main, lobar, segmental, and subsegmental branches (arrows in c and d). CT, computed tomography; CTA, computed tomography angiography.

Figure 4

Unenhanced CT image of a female patient 60 years old complaining of dyspnea, hemoptysis, and tachycardia shows a hyperdense thrombus at the left main pulmonary artery with density measuring 90 HU (arrows in a). CTA image (b) shows no pulmonary embolism. CT, computed tomography; CTA, computed tomography angiography.

Table 2 Distribution of pulmonary embolism on noncontrast multidetector computed tomography and computed tomography angiography among the study patients

Variables	Noncontrast MDCT	CTPA
Number of patients with PE	14	26
Site		
Central	8 (57)	2 (7.6)
Peripheral	2 (14.3)	9 (34.6)
Central and peripheral	4 (28.5)	15 (57.7)
Pulmonary side		
Unilateral	7 (50)	16 (61.5)
Bilateral	7 (50)	10 (38.5)

Data were expressed in the form of frequency (%) or median (range). CTPA, computed tomography pulmonary angiography; MDCT, multidetector computed tomography; PE, pulmonary embolism.

Table 3 Diagnostic accuracy of noncontrast multidetector computed tomography of central and peripheral pulmonary embolism

Diagnostic indices	Central (%)	Peripheral (%)
Sensitivity	64.7	20.8
Specificity	98.6	98.6
Positive predictive value	91.6	83.3
Negative predictive value	92.4	79.3
The area under the curve	71	71
Accuracy	86	80
P	0.001	0.001

Table 4 Indirect signs of pulmonary embolism among the studied patients

Indirect signs	Patients without PE (*n*=74)	Patients with PE (*n*=26)	*P*
Pleural effusion	35 (47.2)	17 (65.3)	0.08
Pulmonary artery dilatation	5 (6.7)	7 (26.9)	0.2
Right side dilatation	5 (6.7)	4 (15.4)	0.99
Wedge-shaped area	6 (8)	15 (57.7)	0.01
Lung collapse	10 (13.5)	8 (30.7)	0.33
Ground-glass attenuation	16 (21.6)	9 (34.6)	0.21

Data were expressed in frequency (%). PE, pulmonary embolism.

At least one parenchymal abnormality was seen in 24 (92%) of 26 patients with PE and 62 (83.7%) of the 74 patients without PE ($P = 0.28$). The frequency of parenchymal and pleural finding is presented in Table 4. The most frequent indirect sign noticed in patients with PE was pleural effusion (Fig. 2), which was found in 52 (52%) of all patients and in 17 (65%) patients with PE ($P = 0.08$). They were more often bilateral than unilateral, with small pleural effusions being the most common. The amount of effusion did not show a statistically significant difference between the two groups. Lung collapse presented in 18 (18%) of all patients and in eight (30.7%) of the patients with PE ($P = 0.33$). The severity of PE was inversely related to the atelectasis score ($P = 0.02$). The second most common sign is the wedge-shaped opacity (Fig. 1), which is seen in 21 (21%) of all patients and in 15 (57%) patients with PE; it was found to be statistically significant ($P = 0.01$). The mean pulmonary artery diameter (29 ± 4.8 mm) presented in 12 (12%) of all patients and seven (26.9%) of patients with PE ($P = 0.2$). Enlarged right ventricle presented in nine (9%) of all patients and in four (15.4%) of patients with PE ($P = 0.99$). Mosaic appearance and different attenuation presented in 25 (25%) of all patients and in nine (34.6%) of patients with PE ($P = 0.21$).

Discussion

Contrast-enhanced helical CT is well established as the initial definitive imaging study after chest radiography at many institutions [4]. Visualization of complete or partial intraluminal filling defects surrounded by the contrast-enhanced blood pool in the pulmonary arteries is a direct sign of PE [3].

Noncontrast CT scan of the chest is usually performed for various reasons. These reasons include patients with nonspecific cardiopulmonary signs and symptoms, and patients with allergies to iodinated contrast material or with impaired renal function [9].

Acute PE can be incidentally detected as a high-attenuation sign in unenhanced multislice computed tomography (MSCT) of the chest in patients with other suspected diagnoses (Figs. 1–3). The use of contrast-enhanced CT alone to detect hyperattenuating signs is problematic because a slight increase in attenuation is obscure relative to the normal strong intraluminal enhancement. As a result, it becomes difficult to distinguish hyperattenuating findings from chronic clots, which typically show low attenuation.

In contrast, in some cases in which enhancement is poor, and scanning is ill-timed, filling defects caused by acute clots are indistinct at contrast-enhanced CT because the slightly increased attenuation appears similar to normal weak intraluminal enhancement [10]. In patients with chronic thromboembolism, clots may also demonstrate higher attenuation, possibly due to calcium deposition, and the contrast may interfere with the identification of the thrombus [11].

As regards the reasons mentioned above, the evaluation and interpretation of the precontrast study are very important. In our study, the hyperdense lumen sign has an overall sensitivity of 50%, specificity of 98.6%, positive predictive value of 93%, and negative predictive value of 84.7% ($P = 0.001$), with diagnostic value in the detection of emboli located within the main and lobar pulmonary arteries (central emboli). However, when emboli are located in segmental, subsegmental, and more peripheral arteries, the sensitivity of this sign seems to be limited, with comparable results to the previous study in 2010 [12]. Most of the false-negative results in this study were seen in patients with previous episodes of pulmonary thromboembolism. Acute thrombi 8 days old have an attenuation value of ~66 HU, and older thrombi have a lower attenuation of 55 HU [13]. The decrease in density is consistent with the progressive breakdown of red blood cells and removal of cell elements, predominantly proteins, which contribute most heavily to the high density of the clot [14].

Only one false-positive hyperdense lumen sign was reported in this study (Fig. 4), which was mainly due to the presence of a high-attenuating artifact, and it may also occur with atherosclerotic disease of the pulmonary arteries; however, the patient improved on anticoagulant therapy.

In our study, we also focused on pleuroparenchymal findings, as those are indirect signs of the PE. At least one parenchymal abnormality was seen in 24 (92%) of 26 patients with PE and 62 (83.7%) of the 74 patients without PE ($P = 0.28$). In our study, pleural effusion is the most frequent indirect sign seen among the studied cases; the amount of effusion did not show statistical significance-, and the severity of PE was inversely related to the atelectasis score ($P = 0.02$); wedge-shaped opacity was the second most common finding after pleural effusion seen in patients with PE, and it was found to be statistically significant ($P = 0.01$); mosaic appearance and different attenuation are seen in patients with PE with insignificant value ($P = 0.21$) and were comparable to previous studies [15,16]. In our study, increased ratio of the pulmonary artery to ascending aorta diameter was seen in 26.9% of patients with PE ($P = 0.2$) that is considered as a low percentage compared to the previous study dated at 2008 [16] as we considered pulmonary hypertension presented with the main pulmonary artery diameter more than 29 mm and this is in agreement with the previous study published on 2012, however diameter less than 29mm doesn't rule out pulmonary hypertension [17]. Moreover, enlarged right ventricle presented in 15.4% of patients with PE ($P = 0.99$), and this was discordant with a study carried out in 2014 that used echocardiography and not the MSCT in the detection of this sign [18].

Conclusion

Unenhanced CT in addition to its role in evaluating patients has a limitation to contrast material. It was important to differentiate between acute and chronic PE, depending on the direct and indirect signs seen. The direct sign for acute PE included (a) the hyperdense intraluminal thrombus and (b) density of the thrombus above or equal to 65 HU. The indirect signs for detection of acute PE were as follows: (a) peripheral wedge-shaped opacity, (b) pleural effusion being commonly bilateral, and (c) right ventricular dilation (severe PE). The direct sign is not helpful for the diagnosis of chronic pulmonary thrombi because the chronic thrombus may have the same density of the blood pool. However, the unenhanced MSCT has a very important role for detection of calcified thrombus that may be obscured at the contrast study; the indirect signs for detection of chronic PE include (a) pulmonary artery dilatation (pulmonary hypertension), (b) mosaic appearance of the lung parenchyma due to the abnormal blood perfusion, and (c) collapse of the infarcted area.

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Conflicts of interest

There are no conflicts of interest.

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