Published online 2022 December 20 **Original Article**

Validity of the Ratio of Pulmonary Artery Diameter to Aortic Diameter in the Diagnosis of Pulmonary Embolism in the Emergency Department

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Received 2021 March 07; **Revised** 2022 March 28; **Accepted** 2022 March 31.

Abstract

Background: Pulmonary thromboembolism can be easily diagnosed with computed tomography (CT) and pulmonary angiography (CTPA). However, diagnosis is difficult since a contrast agent cannot be used. Several criteria are recommended for the diagnosis of pulmonary embolism (PE) with non-enhanced CT.

Objectives: The aim of this study is to investigate the value of the increase in the pulmonary artery diameter (PA-D) and the ratio of the pulmonary artery diameter / ascending aorta diameter (Ao-D) ratio (PA-D/Ao-D) in the diagnosis of PE in the emergency department (ED).

Methods: The CTPA of patients diagnosed with PE (n=88) and a control group (n=89) were examined retrospectively. The main PA (MPA), right MPA (RMPA), left MPA (LMPA), and Ao-D were measured. The ratio of PA-D and Ao-D was calculated.

Results: Mean age of participants of this study was 67.85±17.03 (Min:18, Max:98) in the PE group and 67.31±20.17 (Min:20, Max:91) in the control group (P=0.272). The PE diagnosis of RMPA, right segmental PA, and right subsegmental PA were found to be more than the left side. Moreover, the mean D-Dimer levels were found to be higher in the PE group (7.31±3.528 mcg/L), compared to the control group (1.52±1.042 mcg/L) (P=0.000). In the PE group, the mean Ao-D (35.14±4.55 mm) was larger, compared to the control group (34.97±5.28 mm); however, it was not statistically significant (P=0,828). In the PE group, the average MPA diameter (MPA-D) (30.45±4.77 mm) was larger than that of the control group (28.35±3.81 mm) and statistically significant (P=0,001). In addition, in the PE group, the average MPA-D/Ao-D ratio (0.87±0.15) was higher in comparison to the control group (0.82±0.13) (P=0,016).

Conclusion: The increase in PA-D and PA-D/Ao-D ratio can be used in the diagnosis of PE when contrast agent cannot be given on CT or when thrombus cannot be seen on CT for the diagnosis of PE in the ED.

Keywords: Computed tomography pulmonary angiography, Pulmonary artery diameter, Pulmonary artery and ascending aortic diameter ratio, Pulmonary embolism

1. Background

Pulmonary embolism (PE) has a high mortality rate and is the third most common cardiovascular disease in the World (1). The overall incidence of PE is approximately 39-115/100000 population in short term mortality 2-95% (2, 3). In the case of early diagnoses and its treatment mortality rate has decreased to 2-10% (4). In the diagnosis of PE blood sampling (arterial blood gas, D-dimer), chest X-ray, ultrasound, ventilation-perfusion scintigraphy, computed tomography (CT) pulmonary angiography, pulmonary angiogram, and MRI can be assessed (5).

When more than 30-50% of the PA diameter (PA-D) is occluded by thrombus, pulmonary artery (PA) pressure increases (6). This leads to an increase in the pressure of the right ventricle and according to the Frank-Starling mechanism, the right ventricle contracts more strongly and pressure increases further in the pulmonary artery. The vessel diameter also increases with the effect of pressure in the proximal part of the occluded or narrowed arteries (7,8).

The PA-D limit values were different in several studies (9). Due to the age and body mass index-related changes in the PA diameter, the ratio of PA-D to aortic (Ao-D) diameter is used in the diagnosis of PE and pulmonary hypertension (9-11). One of the most reliable signs of pulmonary hypertension is increased PA-D (12). It should be noted that there are several acute and chronic causes of pulmonary hypertension (13).

The PE is one of the causes that increase acute PA pressure (14). High sensitivity and specificity can also be diagnosed with computed tomography pulmonary angiography (CTPA) even if pulmonary angiography is the gold standard (15,16).

However, contrast agent allergy and renal failure are some limitations of using contrast-enhanced CT (17). Diagnostic rates of PE with the sensitivity and specificity of CTPA are 83% and 96%, respectively (18). Despite the usage of contrast agents, in some cases, localization of embolism can not be diagnosed exactly. With non-enhanced CT (when a contrast agent cannot be used or cannot be detected even though contrast material is given), PE can be diagnosed with an increase in the diameter of the PA and the PA-D and ascending Ao-D ratio.

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2. Objectives

The aim of this study is to investigate the diagnostic value of increase in PA-D and increase in PA-D / Ao-D ratio in patients with suspected PE and in whom contrast agent cannot be given or in patients in whom thrombus is not detected in contrast-enhanced computed tomography.

3. Methods

3.1. Study design

This retrospective study was performed on all consecutive patients referred to Istanbul Bakirkoy Dr.Sadi Konuk Training and Research Hospital Emergency Department between June 2015 and March 2018 who were above the age of 18 and had undergone CTPA. In the emergency department, 88 patients who had been diagnosed with PE after CTPA, were selected as the PE group. In the same period, 89 patients who had CTPA for several reasons but had not been diagnosed with PE were randomly assigned to the control group (Ethics Committee mediation, approval date, and number: Taksim Training and Research Hospital, Istanbul 22.2.2017; 14). However, those who had pulmonary hypertension, chronic lung disease, right ventricle hypertrophy, tricuspid regurgitation, and missing data were excluded.

The CTPA examination was obtained using a 64-row multidetector CT scanner (Siemens Medical Solutions, Enlargen, Germany) with contrast materials. The CT scans were obtained in a supine position with breath-holding in a caudocranial direction. All scans were obtained with the following parameters: a tube voltage of 120 kV, a slice thickness of 1 mm, a rotation time of 0.33 s, and a pitch of 0.8. The CT scans were reconstructed at contiguous section widths of 1-3 mm using a soft-tissue (I26f) and a sharp reconstruction kernel (I70f). All images were transferred to a commercially available workstation. Moreover, on the workstation, multiplane reformattings of images in the sagittal and coronal planes were obtained. The PA-D and PA/Ao-D ratio was evaluated by axial sections.

The CT scan was reviewed by an expert radiologist who was blinded to the clinical and hemodynamic data. Anatomical locations of the embolus were classified as the main PA (MPA), left and right main pulmonary arteries (LMPA-RMPA), left and right lober pulmonary arteries, left and right segmental pulmonary arteries, (LSPA-RSPA), left and right subsegmental pulmonary arteries, (LSSPA-RSSPA).

The following parameters, as indicated in Figure 1, were measured on axial sections in the mediastinal window: 1) The widest part of the main pulmonary artery diameter above its bifurcation and at the same level with the widest diameter of the ascending aorta and (PA diameter and ascending aorta diameter were measured from here) 2) Diameter of the left and right PA within 1 cm of the bifurcation (Figure 1).

3.2. Statistics

The obtained data were analyzed using SPSS software (version 23) and the p-value was calculated. It should be mentioned that p-values less than 0.05 were considered statistically significant. Continuous variables were given as mean±standard deviation (SD) or median (min-max). Normality of data distribution was checked with the Kolmogorov-Smirnov test. After testing for normal distribution, we used the t-test for differences in continuous variables and Pearson's chi-square test, Fisher's exact test in categorical variations. Categorical variations were presented as absolute values and percentages. The demographic, clinical, and laboratory variables were compared between the two groups.

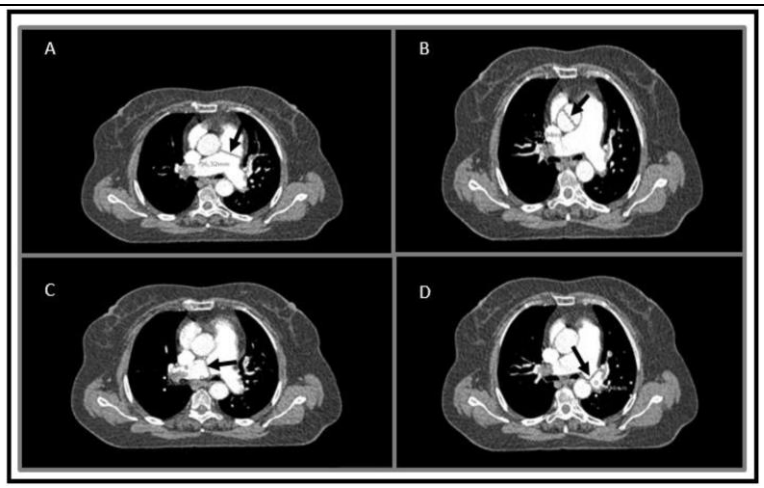

Figure 1. Radiological images of pulmonary embolism
A. MPA-D measurement (black arrow); B: Ao-D measurement (black arrow); C: RMPA-D measurement (black arrow); D: LMPA-D measurent (black arrow)

4. Results

In total, 197 patients were studied in this research. The mean age of the patients was 66.36±17.91 (min:18, max:98). Moreover, there were 64 females (54.7%) and 53 males (45.3%). This study included 88 patients with PE with a mean age of 67.85±17.03 (min: 18, max: 98), 65.9% (n=58) of whom were female and 34.1% (n=30) were male. In addition, the control group consisted of 89 patients, with a mean age of 67,31±20,17 (min: 20; max: 91) (p=0.272), 50.6% (n=45) of whom were female and 49.4% (n=44) of whom were male.

The mean D-Dimer level in patients with PE (7.31±3.528 mcg/L) was found to be higher, compared to the control group (1.52±1.042 mcg/L) (P=0.000). On CTPA, 89.8% (n=79), 77.3% (n=68), and 67% (n=59) of the patients had an embolism in the RMPA, LMPA, and bilateral main pulmonary arteries, respectively. In the main pulmonary arteries, most embolisms were found on the right (65.91%), and mostly in the segmental branches on both the right (68.18%) and left (57.95%) sides. Embolisms were found in RMPA, RSPA, and RSSPA more than those on the left side (Figure 2).

There was no difference (P=0.973) between men (n=74) (35.04±4.85 mm) and women (n=103) (35.06±5.00 mm) in terms of mean Ao diameter. However, the mean PA-D in women (35.0±4.72mm) was statistically significant (P=0.032) and higher than in men (28.55±3.87 mm).

Although the mean Ao-D in the group with PE (35.14±4.55 mm) was larger than that in the control group (34.97±5.28 mm), it was not statistically significant (P=0.828).

The mean MPA-D in the group with PE (30.45±4.77 mm) was larger than that in the control group (28.35±3.81 mm) (P=0.001). The mean left MPA-D (LMPA-D) in the group with PE (24.45±3.38 mm) was larger than that in the control group (22.06±3.18 mm, P=0,000). Furthermore, the mean right MPA-D (RMPA-D) in the group with PE (23.41±3.63 mm), was larger than that in the control group (21.36±3.43 mm, P=0,000).

The mean MPA-D/Ao-D ratio in the group with PE (0.87±0.15) was higher than the control group (0.82±0.13, P=0,016). The mean LMPA-D/Ao-D ratio in the group with PE (0.70±0.16) was higher, compared to the control group (0.64±0.11, P=0.002). The mean RMPA-D/Ao-D ratio in the group with PE (0,67±0,12) was larger than that in the control group (0.61±0.10, P= 0.002) (Table 1).

Thrombolytic therapy was provided for 13.6% (n=12) of the patients (7 patients in the Emergency Department and 5 patients in the Intensive Care Unit) with PE. No statistically significant correlation was found between the patients who received thrombolytic therapy and those who did not in terms of LMAP-D, RMAP-D, Ao-D, LMAP-D/Ao-D, RMAP-D/Ao-D, and MAP-D/Ao-D (P>0,05).

Figure 2. Embolism localizations in pulmonary arteries
LMPA: Left main pulmonary artery, LLPA: Left lober pulmonary artery, LSPA: Left segmental pulmonary artery, LSSPA: Left subsegmental pulmonary artery, RMPA: Right main pulmonary artery, RLPA: Right lober pulmonary artery, RSPA: Right segmental pulmonary artery, RSSPA: Right subsegmental pulmonary arery

Table 1. Mean diameters of the pulmonary embolism (PE) and control groups

Diameters	PE Mean±SD	Control Mean±SD	P	t	%95 CI	
					Lower	Upper
Ao-D	35.14±4.55	34.97±5.28	0.828	-0.218	-1.62716	1.30332
MPA-D	30.45±4.77	28.35±3.81	0.001	-3.235	-3.38194	-0.81892
LMPA-D	24.45±3.38	22.06±3.18	0.000	-4.829	-3.35950	-1.41004
RMPA-D	23.41±3.63	21.36±3.43	0.000	-3.861	-3.10057	-1.00292
MPA-D/Ao-D	0.87±0.15	0.82±0.13	0.016	-2.439	-0.096227	-0.01014
LMPA-D/Ao-D	0.70±0.16	0.64±0.11	0.002	-3.181	-0.109059	-0.02554
RMPA-D/Ao-D	0.67±0.12	0.61±0.10	0.002	-3.211	-0.090254	-0.02154

Moreover, 39.8% (n=35) and 53.4% (n=47) of patients with PE were hospitalized in the service and the Intensive Care Unit, respectively. It should also be mentioned that 5 patients (5.7%) were discharged from the emergency department, while 1 patient (1.1%) passed away in the emergency department.

5. Discussion

Pulmonary embolism is a clinical condition with high mortality (1). Different methods are used for the diagnosis of PE, from blood tests to radiological imaging methods (5). The test with high sensitivity in the diagnosis of PE is pulmonary angiography; however, CTPA has replaced traditional pulmonary angiography in EDs because it is both easily accessible and presents additional pathologies.

The D-Dimer is recommended to be used for exclusion due to its high negative predictive value, except in high-risk PE patients (19-21). In previous studies, it was reported that the D-Dimer value was high in patients with PE (22-24). However, since the positive predictive value of elevated D-Dimer levels is low, D-Dimer testing is not useful for the confirmation of PE. In addition, D-dimer specificity drops one below with age (25).

In the present study, the average D-Dimer level in patients with PE on CT was found to be statistically higher, compared to that in patients without PE; however, the average D-Dimer level in patients without PE was higher than 500 ng/dl. It was thought that this was due to the average age of both groups, which was over 50 years.

The CTPA is the first preferred imaging method for the diagnosis of PE and is found in almost every emergency department (26). The CTPA can rapidly show both vascular structures and additional pathologies. It has started to replace pulmonary angiography due to its easy applicability, high sensitivity and specificity. Nevertheless, it has some limitations, such as renal failure and contrast allergy. For these reasons, the diagnosis of PE in the emergency department becomes difficult and delayed in patients who cannot have contrast-enhanced CT (17). Delay in diagnosis also negatively affects the treatment and management of the patient. The sensitivity of CTPA in detecting PE is 83% (18). In some cases, despite the administration of contrast agent, it is more difficult to detect emboli localization, especially in subsegmental pulmonary arteries.

The distribution of the thrombus in PE varies. In general, it was thought that the more frequent incidence in the right-sided structures was due to anatomical reasons. In addition, it is observed that proximal vascular structures are more frequently affected (27-29). The reason that embolism is detected more in the main pulmonary arteries and bifurcation may be that the PE clinic is more prominent than subsegmental embolism. Incidentally detected subsegmental emboli present with less clinical presentation (30, 31). Thrombosis is less common in isolated subsegmental arteries (29). In addition, the rate of diagnosis of an isolated subsegmental embolism differs between radiologists and its diagnosis can be missed (32-34).

It is known that PA-D is affected by conditions, such as chronic lung diseases, body mass index, and valvular heart diseases. Results of a few studies have shown the limits of PA-D in healthy individuals (9,29,35-37). In a study performed by Lee et al., the mean MPA and the mean Ao values were reported at 25.9 mm and 30.0 mm in healthy participants, respectively (35).

In a study conducted by Edwards et al., the mean MPA-D and the upper limit in healthy people were reported at 27.2 mm and 33.2 mm, respectively (9). According to a study carried out in Turkey, in healthy adults, MPA, right PA-D, and left PA-D upper limits were found to be 29.5 mm (mean: 24.0±2.8 mm), 19.8 mm, and 22.1 mm, respectively (29). In another study performed in Turkey, the upper limit of MPA-D was found to be 32.6 mm (mean MPA-D: 26.6±2.9 mm, in men: 27±2.8 mm, and in women: 25.9±3.0 mm). It was also reported in the aforementioned study that MAP-D had a significant relationship with age and body surface area (37).

In pulmonary embolism, the pressure increases in the vessel proximal to the obstruction and the vessel wall widens. This enlargement varies according to the degree of occlusion of the PA (14). It has been shown that the Modified Miller score (MMS>7) is high in patients with acute PE, and as the occlusion rate in the lumen increases, the PA-D and PA pressure increase as well (14,38). In a study comparing cases with severe PE (those who recieved thrombolytic therapy), non-serious PE (anticoagulant therapy), and without PE, it was found that MPA-D increase was one of the factors that increased the hemodynamic severity of PE (39). In a similar study performed on high- and low-risk PE patients, it was stated that MPA and PA/Ao ratios were associated with increased mortality (40).

In another study conducted to minimize individual differences (e.g., height and weight), the PA/Ao ratio was found to be 0.87 (35). In another study that included patients with PE, it was shown that thrombus volume and PA/Ao-D ratio had a direct relationship. In the same study, the ratio of Pa/Ao-D was determined as 0.9±0.16 (P=0.041) (41).

In the present study, it was investigated whether the increase in PA-D and PA-D/Ao-D ratio on CT can be used for the diagnosis of PE in the emergency department. In the present study, the mean MPA-D in the control group (28.35±3.81 mm) was higher than those in two studies (9, 35) performed outside of Turkey (25.9 mm and 27.2 mm) and two studies

(29, 37) conducted in Turkey (24.0±2.8 mm and 26.6±2.9 mm).

In a multi-ethnic study conducted among 6,814 people within the age range of 65-74, including the Turkish population, the Ao-D (ascending aorta) was reported at 30.6 mm (min: 24.2, max: 40.0 mm) in females and 34.2 mm (min: 27.8, max: 43.9 mm) in males (42). The mean age of participants in the present study (66.36±17.91) was 42 years old. Moreover, the average Ao-D in the PE group and the control group were 35.14±4.55 mm and 34.97±5.28 mm, respectively, which were within the value limits, which is inconsistent with the results of previous studies. Besides, the mean Ao-D of female participants was found to be higher than the study in this atrium (female: 35.06±5.00 mm vs male: 35.04±4.85 mm).

In the present study, in the PE group, the mean MPA-D (30.45±4.77 mm vs. 28.35±3.81 mm), the mean LMPA-D (24.45±3.38 mm vs 22.06±3.18 mm), and the mean RMPA-D (23.41±3.63 mm vs 21.36 ± 3.43 mm) values were statistically significant (P<0.05) and higher than those in the control group. It is noteworthy that this is in line with the findings of previous studies.

In the present research, the mean MPA-D/Ao-D ratio (0.87±0.15 vs. 0.82±0.13), the mean LMPA-D/Ao-D ratio (0.70±0.16 vs. 0.64±0.11), and the mean RMPA-D/Ao-D ratio (0.67±0.12 vs. 0.61±0.10) were higher in patients with PE, compared to the control group. It should be mentioned that this difference was statistically significant (P<0.05).

The pressure increase in the proximal lumen of the PA that is occluded or narrowed due to PE causes the PA to expand. However, there is no significant enlargement of the ascending aorta. As a result, both an increase in PA diameter and an increase in PA-D and PA/Ao ratios are observed.

This study showed that thrombus can be diagnosed by an increase in pulmonary artery diameter in patients with suspected PE. In patients with non-contrast CT (in whom contrast material cannot be used or thrombus cannot be detected on CT even if contrast material is given), PE can be diagnosed with the ratio of PA-D and PA-D/Ao-D.

6. Conclusion

PE is an emergency health problem with a difficult diagnosis and high mortality. Both the gold standard pulmonary angiography and contrast-enhanced CT cannot be used in every patient due to the harm of contrast agents. However, thrombus may not always be detected in patients undergoing contrast-enhanced CT.

This study showed that PE can be diagnosed with an increase in PA-D and an increase in PA-D/Ao-D ratio in patients who underwent non-contrast-CT because contrast material could not be used, or in patients who could not detect thrombus in contrast-enhanced CT in the ED.

Acknowledgments

The authors would like to thank the staff of İstanbul Bakırköy Dr. Sadi Konuk Training and Research Hospital Emergency Medicine and Radiology Clinics for their time and also their support of the questionnaire during the thesis study process.

Footnotes

Conflict of Interest: There is no conflict of interest between the authors in this study.
Limitations: This study is the article of Dr.Dijan TAV ŞİMŞEK's graduation thesis (Emergency Medicine Specialization), which was conducted under the supervision of Prof.Dr.Doğaç Niyazi ÖZÜÇELİK.
Fınancial Support: No financial support has been received for this study.
Ethics Statement: All authors declared that they comply with the Research and Publication Ethics rules (Ethics committee mediation, approval date, and number: Taksim Training and Research Hospital, İstanbul. 22.02.2017; 14). Identity information was not requested from the participants in accordance with the purpose of the study and on the basis of the confidentiality principle.
Authors' Contributions: Tav Simsek D is the owner of the research and thesis.
Simsek C is one of the thesis advisors and contributed to the planning and preparation of the thesis.
Dogan H is one of the thesis advisors and contributed to the planning and writing of the thesis.
Erdil I contributed to the radiological evaluations and the article.
Özüçelik DN contributed to the planning and writing of the thesis and article.

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