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Role of multidetector CT in predicting patient outcome in cases of pulmonary embolism: correlation between imaging findings, ICU admissions and mortality rate

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Abstract

Background: Pulmonary embolism (PE) is a critical medical condition that requires prompt diagnosis and treatment to avoid serious morbidity and mortality risk. Multidetector CT pulmonary angiography (CTPA) is considered the first-line imaging modality for suspected acute PE. The presence of right heart strain, which supports the diagnosis, requires special attention. The aim of our retrospective study is to assess the reliability of CTPA hemodynamic indices in predicting patients' outcome in cases of PE.

Results: Sixty patients were included in our study. CTPA parameters including main pulmonary artery (MPA) diameter, left ventricle (LV) diameter, right ventricle (RV)/LV ratio, and septal deviation had a clinical prognostic value for short-term 30-day mortality and ICU admission. Statistically significant relationship between MPA diameter > 29 mm, LV diameter, RV/LV ratio > 1, left-sided septal deviation and contrast reflux into the IVC/distal hepatic veins with ICU admission was observed with *p* values 0.031, 0.000, 0.000, 0.005 and 0.028 respectively. There was a statistically significant correlation between MPA diameter > 29 mm, LV diameter, RV/LV > 1 ratio and septal deviation with 30-day mortality with *p* values of < 0.001, 0.001, < 0.001 and 0.015 respectively. No significant correlation was found between 30-day mortality and contrast reflux to IVC with *p* value of 0.070.

Conclusions: CTPA measurements including MPA diameter, RV/LV ratio and septal deviation were found to be significantly correlated to ICU admission and 30-day mortality as predictors for PE severity. CT contrast reflux was found to be correlated to ICU admission; however, it was not significantly correlated to 30-day mortality.

Keywords: Pulmonary embolism, Pulmonary angiography, Computed tomography, Right ventricular strain

Background

Pulmonary embolism (PE) is a serious life-threatening illness that necessitates immediate diagnosis and treatment to avoid its associated high mortality and morbidity risk [1].

The death from acute pulmonary embolism usually occurs within the first four hours of hospital admission. Therefore, Prompt diagnosis of such patients is crucial [2]. Pulmonary embolism can present in a variety of ways, with varying degrees of severity. Some patients present with shock and require immediate thrombolysis, whereas other patients can be handled well with anticoagulation alone in an outpatient setting [3].

PE management should be tailored based on the risk of adverse outcome according to guidelines. Echocardiography findings, electrocardiography (ECG) alterations, haemodynamic measures, cardiac biomarkers and blood gas analysis are all useful clinical parameters in assessing the risk of PE [4].

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Multidetector-row CT pulmonary angiography (CTPA) is now considered the first-line imaging tool for cases suspected of having acute PE. Aside from being a quick and accurate diagnostic tool with a high negative predictive value, CTPA offers a number of imaging findings that are relevant for assessing individual risk assessment when PE diagnosis is established [5].

The degree of pulmonary pressure and pulmonary arterial obstruction have a nonlinear relationship in previously healthy patients. The increase in pulmonary pressure is insignificant until obstruction affects more than 30 to 50% of the artery bed, then it quickly rises beyond that [3].

PE has traditionally been classified into three categories:

1. Massive PE, hemo-dynamically unstable (hypotension with arterial blood pressure < 90 mmHg, shock, or cardiac arrest), 2. Sub-massive PE (normotensive PE associated with features of right ventricular dysfunction [RVD]) and 3. Non-massive PE (normotensive PE without RVD). Both sub-massive and non-massive are hemodynamically stable [6].

Massive PE accounts for 5% of PE cases. About half of normotensive patients have pattern of RVD, and around one in 10 patients will die [7].

PE should be classified into classes of risk for adverse prognosis as recommended by the European Society of Cardiology (ESC). As a result, PE is classified into either high risk (equivalent to massive PE with short term death rate greater than 15%) or non-high risk. Non-high-risk patients have normal blood pressure [6, 8].

The aim of our study is to assess the reliability of CTPA hemodynamic indices in the prediction of patients' outcome in cases of PE.

Methods

Patient's population

Sixty patients were included in our retrospective study during the period from May 2019 to March 2021, they had PE by clinical signs, laboratory results and CTPA. Institutional ethical committee approval was obtained before data collection.

The study included all male and female patients of any age who were clinically suspected to have PE. CT Exclusion criteria were pregnant women and patients with renal impairment.

Echocardiography was done by the cardiologist to all patients on the same day of CTPA examination.

CTPA technique

The procedure was explained to the patients with all the potential risks. An informed written consent was signed by the patient. Renal function tests were done, and a normal creatinine levels was a perquisite to proceed with the CT procedure. A cannula was placed in the patient's arm.

CTPA was performed as prospective gated study using a Multislice CT Scan 128 SLICE (Revolution, GE healthcare Co.,Ltd. United States). ECG gating. Tube voltage100-120-KVp. Tube current: from 10 to 40 mA/kg. 0.4-s rotation gantry speed, 0.625 mm helical thickness and detector coverage of 40 mm. Section thickness: 0.625 mm. Pitch: 1. Wide cardiac and lungs field of view. Contrast injection: Automatic power injector for proper injection dose and rate. Iodinated contrast medium was used, 1.5 ml/kg body weight, 5 ml/sec injection rate. followed by 10 ml saline Injection speed of 5 mL/s.

Image interpretation

1. The right-ventricular diameter is measured at the level showing atrio-ventricular (AV) valves in axial images, the ratio between of the right ventricle and left ventricle diameter (RV/LV ratio) is considered abnormal if the ratio was > 1.
2. Pulmonary trunk diameter is measured.
3. Reflux of contrast medium in the inferior vena cava (IVC)/distal hepatic veins is evaluated to indirectly assess reflux through the tricuspid valve with high pressure at the right atrium.
4. Interventricular septal deviation to left is recorded to reflect increased RV pressure.
5. We assessed embolic score using Qanadli scoring system dividing the pulmonary arterial tree into 10 segments on each side [9].

Statistical analysis

Data collection and entry to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data was presented as mean, standard deviations and ranges when their distribution found parametric while nonparametric data were presented as median with interquartile range (IQR). Qualitative variables were presented as number and percentages.

1. Student's t-Test was used to evaluate the statistical significance of the difference between two study group means.
2. Fisher's exact test was used to assess the relationship between two qualitative variables when the expected count is less than 5 in more than 20% of cells
3. Paired t-test was used to examine the statistical significance of the difference between two means measured twice for the same study group. The confidence interval was set to 95%, the margin of accepted error

was 5%. Regarding the *p*-value, it was considered nonsignificant if $P > 0.05$, significant if $P < 0.05$ and highly significant if $P < 0.01$.

Results

Our study included 60 patients who were diagnosed with PE by clinical, laboratory and radiological criteria.

The male to female ratio was 1.8:1 with 39 males (65%) and 21 females (35%). The age ranged from 27–81 years with a mean of 45.1 ± 18.3 years.

Thirty six out of 60 patients (60%) were admitted into our institution intensive care unit (ICU) and 24 of those 36 patients died during a 30-day follow up period.

CTPA was used to assess the cardiac complications of PE through evaluation of RVD and hemodynamic stability based on measurements of main pulmonary artery (MPA) diameter, RV/LV ratio, septal deviation, and contrast reflux into IVC/distal hepatic veins. Table 1 summarises the CPTA findings in our study population.

Evaluation of all 36 patients requiring ICU admission following PE diagnosis was done as shown in Table 2

ICU admission was required for half of the patients with MPA diameter > 29 mm and 33 out of the 42 patients (55%) with RV/LV ratio > 1. There was a statistically significant relationship between MPA diameter > 29 mm, LV diameter and RV/LV ratio > 1 and ICU admission with *p* values 0.031, 0.000 and 0.000 respectively. Statistical significance between ICU admission and both left-sided septal deviation and contrast reflux into the IVC/distal hepatic veins was found with *p* values of 0.005 and 0.028 respectively.

Table 1 Summary of CTPA findings

CTPA imaging findings	No. (%) Mean ± SD
MPA diameter	
> 29 mm	42 (70)
< 29 mm	18 (30)
	33.4 ± 6.4
RV/LV ratio	
> 1	42(70)
< 1	18 (30)
	1.4 ± 0.40
Left sided septal deviation	
Yes	42 (70)
No	18 (30)
Contrast reflux into IVC	
Yes	36 (60)
No	24 (40)

CTPA CT pulmonary angiography, *SD* standard deviation, *No.* number, *PA* pulmonary artery, *RV* right ventricle, *LV* left ventricle, *IVC* inferior vena cava

Table 2 Comparison between CT findings in patients who require and do not require ICU admission

CTPA parameter	ICU admission		*P*
	Yes (n = 36) mm, Mean ± SD n (%)	No (n = 24) mm, Mean ± SD n (%)	
MPA diameter	37.1 ± 5.6	30.8 ± 6.0	0.031
RV diameter	53.1 ± 7.0	45.6 ± 9.6	0.074
LV diameter	29.3 ± 2.8	40.8 ± 7.4	0.000
RV/LV ratio > 1	1.8 ± 0.18	1.1 ± 0.26	0.000
IVC diameter	38.0 ± 3.3	33.1 ± 7.3	0.095
Left-sided septal deviation			0.005
Yes	36 (100)	6 (25)	
No	0 (0.0)	18 (75)	
Contrast reflux into IVC			0.028
Yes	30 (83.3)	6 (25)	
No	6 (16.7)	18 (75)	

CTPA CT pulmonary angiography, *ICU* intensive care unit, *n* number, *SD* standard deviation, *PA* pulmonary artery, *RV* right ventricle, *LV* left ventricle, *IVC* inferior vena cava

In our study, we had 24 fatalities that occurred during the 30 days follow up period after PE diagnosis. We correlated the CT measurements in our study population with 30-day death rate (Fig. 1). There was a statistically significant correlation between MPA diameter > 29 mm, LV diameter and RV/LV > 1 ratio and 30-day mortality with *p* values of < 0.001, 0.001 and < 0.001 respectively. The 30-day mortality was also correlated with left sided septal deviation and contrast reflux into IVC/distal hepatic veins (Fig. 2). Septal deviation was found to be statistically correlated to 30-day mortality with *p* value 0.015 while no significant correlation was found between 30-day mortality and contrast reflux to IVC/distal hepatic veins was found with a *p* value of 0.070 (Fig. 3).

The embolic burden was assessed using the Qanadli scoring system with a value ranging from 6–40 and

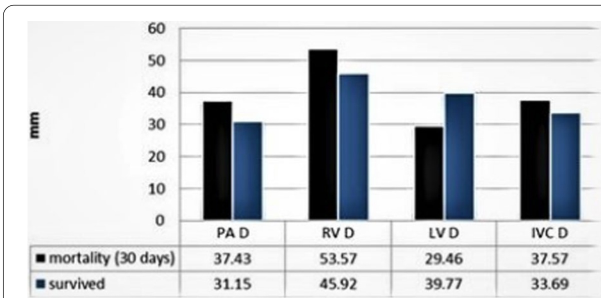

Fig. 1 CT measurements in patients with 30-day mortality versus patients who survived

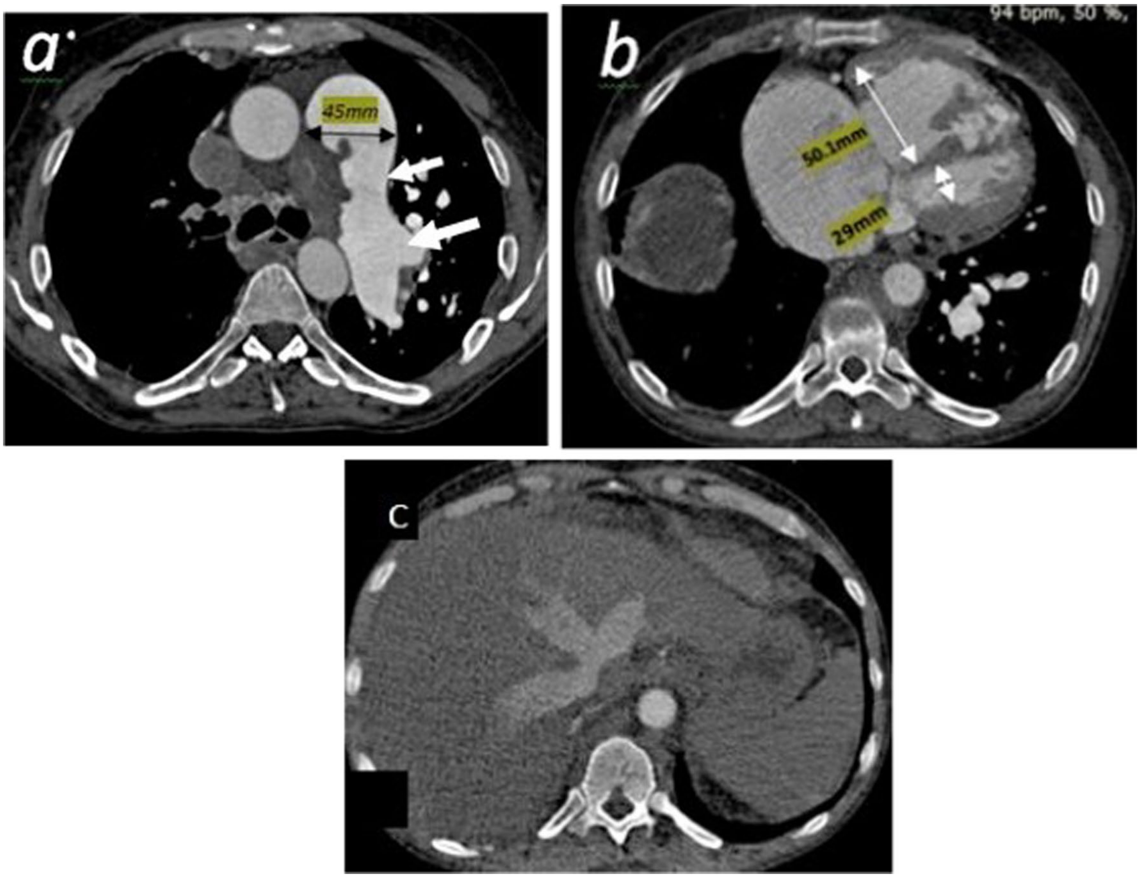

Fig. 2 **a** Axial CT cuts showing a large irregular filling defect (large thrombus) at the distal main pulmonary artery overriding the major pulmonary branches (Saddle thrombus). It extends to completely occlude the right main pulmonary artery (RPA), and partially occluding the LPA ostium (arrow). There is dilatation in the pulmonary artery (45 mm). **b** axial CT cuts showing dilated right ventricle with RV/LV ratio > 1. **c** axial Ct image shows contrast reflux in the hepatic veins

a mean of 20.7 ± 8.93. We found strong association between embolic burden score and both ICU admission as well as 30-day mortality with a p value < 0.001 (Fig. 4).

We compared the embolic burden scores against different CTPA measurements. We found that the embolic burden showed statistically significant correlation to MPA diameter > 29 mm, RV diameter, LV diameter and RV/LV ratio > 1 with p values 0.040, 0.014, 0.008 and 0.001 respectively. On the other hand, embolic burden was not found to be correlated to IVC diameter with a p value of 0.068.

Echocardiogram was performed for all patients. RV dysfunction was reported in 36 (60%) patients compared to 42 (70%) patients who had RV/LV ratio > 1 by CTPA. Left-sided septal deviation was reported by echocardiogram in 30 (50%) patients, whereas CTPA revealed septal deviation in 42 (70%) of the patients.

Our study showed that CTPA parameters including MPA diameter, RV/LV ratio > 1, and septal deviation have a clinical prognostic value for short-term 30-days mortality as well as ICU admission. The exception was contrast reflux into IVC/distal hepatic veins, which did not show significant correlation to both short-term 30-day mortality or ICU Admission.

Discussion

After myocardial infarction (MI) and cerebrovascular accidents (CVA), PE and Venous thromboembolism (VTE) are the third most common causes of cardiovascular death. PE is still a leading cause of avoidable in-hospital death. Due to its influence of the right side of the heart, it also has a high mortality rate. As a result, determining prognostic indicators is crucial in predicting the outcome and the mortality rate [10].

The diagnosis of massive PE is dependent on the presence of systemic arterial hypotension (systolic blood pressure less than 90 mm Hg). As a result, structurally large PE seen on CTPA in a patient who is hemodynamically stable is not considered massive PE and does not carry the same risk or mortality [11, 12].

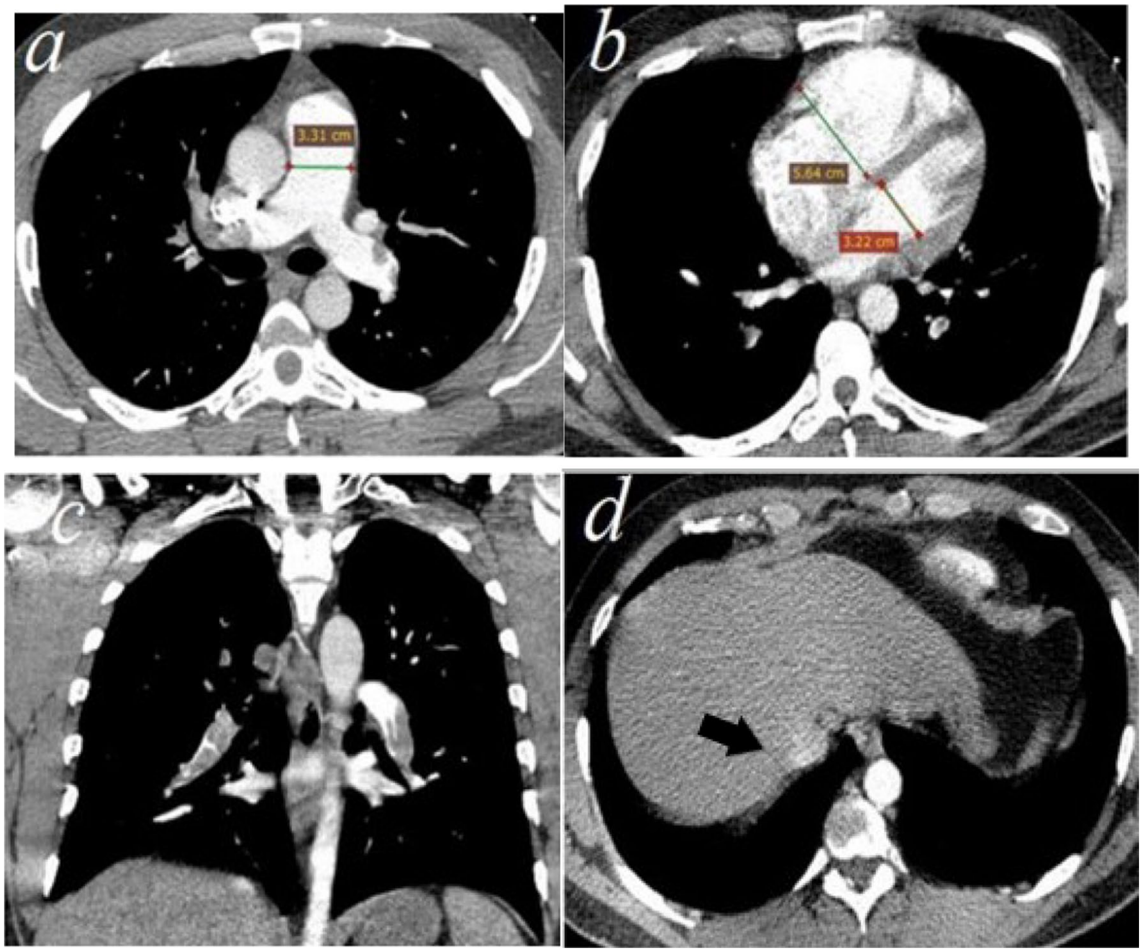

Fig. 3 **a** Axial cuts showing Extensive pulmonary emboli within the main pulmonary arteries bilaterally extending into the upper lobe, middle lobe and lower lobe divisions bilaterally. **b** Axial cuts showing dilated PA measuring about 33 mm in diameter, RV/LV ratio > 1 with associated septal deviation. **c** Coronal cuts showing Extensive pulmonary emboli extending to lower lobe divisions bilaterally. **d** Axial cuts showing no contrast opacification of the IVC or hepatic veins

We used ECG—gating throughout the cardiac cycle for RV cine evaluation to enable us to assess the wall motion, RV volume and RV function. MPA > 29 mm has been traditionally used as a threshold measurement above which PA hypertension is suggested [13–16].

In our study, patients with MPA diameter > 29 mm were considered abnormal. We calculated the RV/LV ratio by dividing the right and left ventricular diameters in the axial images at the level showing AV valves. We considered the ratio to be abnormal if > 1 as suggested by previous investigators [17].

In our study, 36 (60%) PE patients were admitted to the ICU, with 24 (40%) of them dying within a 30-day follow up period. In the study by Osman and Abdeldayem, 26.7% of PE patients needed ICU admission and 13.3% died [17].

MPA was considered dilated when diameter > 29 mm. We found a significant correlation between ICU admission and MPA diameter detected by CT with a p value of < 0.031. Significant correlation was also observed between ICU admission and RV/LV ratio > 1 detected by CTPA with a p value of 0.000. A study by Kaminetzky and colleagues reported no significant difference in clinical outcome in presence or absence of right heart strain with a p value > 0.05 [18].

Statistical significance between ICU admission and both left-sided septal deviation and contrast reflux into the IVC/distal hepatic veins was found with p values of 0.005 and 0.028 respectively which was in agreement with previous investigators [19]. Our findings were contrasted by the previously published results which showed that septal deviation and contrast reflux into

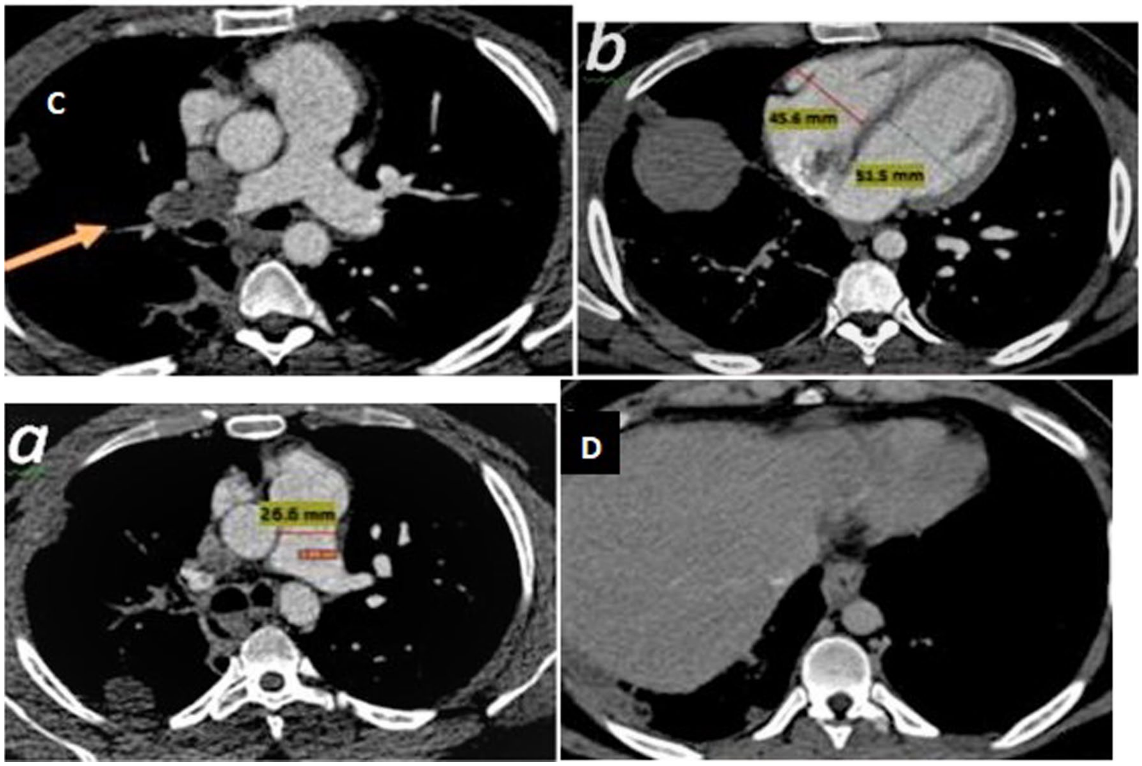

Fig. 4 **a** Axial CT images showing a non-dilated PA (26 mm) and **b** RV/LV ratio < 1. **c** Axial CT images shows a large irregular filling defect (large thrombus,) totally occluding the right main pulmonary artery (arrows) **d** axial Ct image showing no contrast reflux in the hepatic veins

IVC/distal hepatic vessels did not correlate with the severity of PE [17, 20, 21].

In our study, we correlated the 30-days mortality to different measurements obtained by CTPA. There was a statistically significant correlation between MPA diameter > 29 mm detected by CTPA and 30-day mortality with *p* value of < 0.001. Our findings were in contrast to those by Ghaye et al. who reported no significant correlation between PA dilatation detected by CTPA and mortality with a p value of 0.195 [22].

In our series, RV/LV ratio > 1 showed a significant correlation to 30-day mortality with a *p* value of < 0.001 which was similarly reported by two studies with *p* values of 0.01 and 0.04 respectively [22, 23]. Significant correlation was also found between 30-day mortality and left sided septal deviation with a *p* value of 0.015. This was contrasted to the data published by Collomb et al. and Araoz et al. who did not find correlation between PE severity and septal deviation [20, 21]. Another study reported that septal deviation was the least sensitive cardiac sign in PE severity assessment [17]. No significant correlation between reflux into IVC/distal hepatic veins and 30-day mortality was found in our series with a *p* value of 0.070 which was in agreement with previous investigators [17, 20].

Qanadli score gained attention as a prominent scoring system for embolic burden in PE patients. However, the relationship between this burden score and outcome in patients are still controversial [9, 24]. We found Qanadli score was highly correlated to both ICU admission and 30-day mortality in our population with a *p* value < 0.001.

Mean value for embolic burden in our study was 20.7 compared to 10 in the study by Wu et al. and 32 in Van der Meer et al. [23, 25]. We also studied the correlation between different radiological measurements obtained by CTPA and Qanadli score. Significant correlation was observed between embolic burden using Qanadli score and RV diameter, LV diameter and RV/LV ratio > 1 with *p* values of 0.014, 0.008 and 0.001 respectively which was similarly reported by Ghaye et al. [22].

Our results have shown that incorporating CTPA measurements in patients' reports can guide the treating physician in the management process, predicting the patients with high mortality risk or who would need ICU admission for close monitoring or thrombolysis sparing the from the patients from delay in management or additional investigations such as ECHO [26].

The strength of our study is that data were gathered based on our inclusion and exclusion criteria, all patients underwent ECG gated CTPA and ECHO, and all clinical outcomes and imaging data were blindly assessed for treatment and outcome.

The limitation of our study is that we only investigated the most commonly utilized radiological parameters and cut off values because they were the easiest to implement. Another limitation is the small sample size. More studies with larger sample size are needed in the future to confirm and further documents our results.

Conclusions

PE remains an important cause of death. Prompt diagnosis as well as risk stratification is needed to try to prevent poor outcome for those patients. MPA diameter, RV/LV ratio > 1, septal deviation, contrast reflux into IVC/distal hepatic veins and embolic burden were all correlated to ICU admission and 30-days mortality demonstrating the ability of CTPA in diagnosing PE and assessing its severity.

We conclude that measurements acquired from CTPA along with RV/LV ratio > 1 and septal deviation were predictive of PE severity and were found to be significantly correlated to ICU admission as well as 30-day mortality. CT contrast reflux was found to be correlated to ICU admission; however, it was not significantly correlated to 30-day mortality. Calculating Qanadli embolic burden score is an important predictor of PE severity.

Abbreviations

AV: Atrio-ventricular; CVA: Cerebrovascular accidents; CTPA: CT pulmonary angiography; ECG: Electrocardiography; ESC: European Society of Cardiology; ICU: Intensive care unit; IVC: Inferior vena cava; IQR: Interquartile range; LV: Left ventricle; MI: Myocardial infarction; MPA: Main pulmonary artery; PA: Pulmonary artery; PE: Pulmonary embolism; RVD: Right ventricular dysfunction; SPSS: Statistical Package for Social Science; RV: Right ventricle; VTE: Venous thromboembolism.

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Authors' contributions

H. I.: Review of literature, data collection and analysis, reviewing and editing the manuscript. S. M.: Suggestion of idea, data collection and analysis, reporting findings, writing the initial draft. Both authors have read and approved the manuscript.

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Availability of data and materials

The data sets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Local Ethical Committee of Ain Shams University hospitals approval was obtained. Reference number is not applicable. Written informed consent was not obtained because of the nature of the study and the general condition of the patient.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

1. Shayganfar A, Hajiahmadi S, Astaraki M, Ebrahimian S (2020) The assessment of acute pulmonary embolism severity using CT angiography features. Int J Emerg Med 13:15
2. Gupta R, Fortman DD, Morgenstern DR, Cooper CJ (2018) Short- and long-term mortality risk after acute pulmonary embolism. Curr Cardiol Rep 20:135
3. John G, Marti C, Poletti PA, Perrier A (2014) Hemodynamic indexes derived from computed tomography angiography to predict pulmonary embolism related mortality. Biomed Res Int. https://doi.org/10.1155/2014/363/756
4. Jeebun V, Doe SJ, Singh L, Worthy SA, Forrest IA (2009) Are clinical parameters and biomarkers predictive of severity of acute pulmonary emboli on CTPA? QJM 103:91–97
5. Albrecht MH, Bickford MW, Nance JW Jr, Zhang L, De Cecco CN, Wichmann JL, Vogl TJ, Schoepf UJ (2017) State-of-the-art pulmonary CT angiography for acute pulmonary embolism. AJR Am J Roentgenol 208:495–504
6. Masotti L, Righini M, Vuilleumier N et al (2009) Prognostic stratification of acute pulmonary embolism: focus on clinical aspects, imaging, and biomarkers. Vasc Health Risk Manag 4:567–575
7. Jaff MR, McMurtry MS, Archer SL et al (2011) Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboembolic pulmonary hypertension: a scientific statement from the American Heart Association. Circulation 123:1788–1830
8. Konstantinides SV, Meyer G, Becattini C et al (2019) 2019 ESC guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS): the task force for the diagnosis and management of acute pulmonary embolism of the European Society of Cardiology (ESC). Eur Respir J 54:1–61
9. Qanadli SD, El Hajjam M, Vieillard-Baron A et al (2001) New CT index to quantify arterial obstruction in pulmonary embolism comparison with angiographic index and echocardiography. Am J of Roentgenol 176:1415–1420
10. Goldhaber SZ, Bounameaux H (2012) Pulmonary embolism and deep vein thrombosis. Lancet 379:1835–1846
11. Kuo WT (2012) Endovascular therapy for acute pulmonary embolism. J Vasc Interv Radiol 23:167–179
12. Girardi AM, Bettiol RS, Garcia TS et al (2020) Wells and geneva scores are not reliable predictors of pulmonary embolism in critically ill patients: a retrospective study. J Intensive Care Med 35:1112–1117
13. Frazier AA, Galvin JR, Franks TJ, Rosado-De-Christenson ML (2000) From the archives of the AFIP: pulmonary vasculature: hypertension and infarction. Radiographics 2:491–524
14. Pena E, Dennie C, Veinot J, Muniz SH (2012) Pulmonary hypertension: how the radiologist can help. Radiographics 32:9–32

15. Karazincir S, Balci A, Seyfeli E et al (2008) CT assessment of main pulmonary artery diameter. Diagn Interv Radiol 14:72–74
16. Kligerman SJ, Mitchell JW, Sechrist JW, Meeks AK, Galvin JR, White CS (2018) Radiologist performance in the detection of pulmonary embolism: features that favor correct interpretation and risk factors for errors. J Thorac Imaging 33:350–357
17. Osman AM, Abdeldayem EH (2018) Value of CT pulmonary angiography to predict short-term outcome in patient with pulmonary embolism. Int J Cardiovasc Imaging 34:975–983
18. Kaminetzky M, Moore W, Fansiwala K et al (2020) Pulmonary embolism at CT pulmonary angiography in patients with COVID-19. Radiol Cardiothoracic Imaging 2:e200308
19. Mourad MA-FE, Al Gebaly AFA, Samra MFA (2017) Multi-detector computed tomography (MDCT) imaging of cardiovascular effects of pulmonary embolism: what the radiologists need to know. Egypt J Radiol Nucl Med 48:563–568
20. Collomb D, Paramelle PJ, Calaque O et al (2003) Severity assessment of acute pulmonary embolism: evaluation using helical CT. Eur Radiol 13:1508–1514
21. Araoz PA, Gotway MB, Trowbridge RL et al (2003) Helical CT pulmonary angiography predictors of in-hospital morbidity and mortality in patients with acute pulmonary embolism. J Thorac Imaging J 18:207–216
22. Ghaye B, Ghuysen A, Bruyere PJ, D'Orio V, Dondelinger RF (2006) Can CT pulmonary angiography allow assessment of severity and prognosis in patients presenting with pulmonary embolism? What the radiologist needs to know. Radiographics 26:23–39
23. Wu AS, Pezzullo JA, Cronan JJ, Hou DD, Mayo-Smith WW (2004) CT pulmonary angiography: quantification of pulmonary embolus as a predictor of patient outcome–initial experience. Radiology 230:831–835
24. Liu W, Liu M, Guo X et al (2020) Evaluation of acute pulmonary embolism and clot burden on CTPA with deep learning. Eur Radiol 30:3567–3575
25. van der Meer RW, Pattynama PM, van Strijen MJ et al (2005) Right ventricular dysfunction and pulmonary obstruction index at helical CT: prediction of clinical outcome during 3-month follow-up in patients with acute pulmonary embolism. Radiology 235:798–803
26. Ruggiero A, Screaton NJ (2017) Imaging of acute and chronic thromboembolic disease: state of the art. Clin Radiol 72:375–388

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