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Correlation of qanadli obstruction index (QOI) and atrial size on CT pulmonary angiography (CTPA) in patients with pulmonary thromboembolism

Vishnu Dakshin* and Rudresh Hiremath

Abstract

Background: Pulmonary thromboembolism (PTE) is a potentially fatal and life-threatening variation of venous thromboembolism (Faghihi Langroudi et al. in Radiol Res Pract 2:1–6, 2019). Computed Tomography Pulmonary Angiography (CTPA) has been proven to be an invaluable first-line diagnostic tool in the early identification of pulmonary thromboembolism (Aviram et al. J Thromb Haemost 9(2):293–299, 2011; Ghaye et al. in RadioGraphics. 26 1 23 39, 2006). Preliminary studies have suggested the correlation between atrial size and clot burden in the pulmonary arteries in patients with pulmonary thromboembolism (Faghihi Langroudi et al. in Radiol Res Pract 2:1–6, 2019; Aviram et al. J Thromb Haemost 9(2):293–299, 2011). Clot burden is calculated by applying the CTPA dependent score—Qanadli Obstruction Index (QOI)/Pulmonary Arterial Obstruction Index (PAOI) in the pulmonary arteries.

Results: There was a significant negative correlation between left atrial/right atrial area, left atrial/right atrial short axis and left atrial/right atrial long axis with the PAOI, especially the left atrial/right atrial area ratio and left atrial/right atrial short axis ratio, which showed the most significant negative correlation. Additionally, an LA/RA area of ≤ 0.60 correlated with a PAOI of >20 and an obstruction percentage of $>50\%$, which can serve as a predictor of right ventricular dysfunction.

Conclusions: These atrial dimensions can serve as additional early parameters that reflect changes in the cardiac morphology in response to the clot load within the pulmonary arteries, and can thus contribute towards a more comprehensive risk assessment in patients with acute pulmonary thrombo-embolism.

Keywords: Qanadli index, Pulmonary thromboembolism, CTPA, Atrial

Background

Pulmonary embolism is a life-threatening complication involving the circulatory system. It causes an abrupt vascular occlusion which leads to an increase in pulmonary arterial vascular resistance. This leads to an increase in right ventricular afterload which sequentially gives rise to right ventricular dysfunction and an increased right ventricular volume. This dilatation of the right ventricle results in a leftward inter-ventricular septal bowing causing decreased left ventricular preload [[3]]. Ultimately, a decrease in the sizes of left atrium and pulmonary veins manifests owing to the decreased pulmonary venous return. This is useful in risk stratification for the assessment and evaluation of patients with pulmonary thromboembolism [[4]].

Therefore, an increased clot burden in the pulmonary arteries would correlate with a decrease in the left atrial size and a relatively increased right atrial size, as measured on CTPA [[1]]. The presence of these indicators

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would thus serve as early parameters in assessing the severity of PTE [[2]]. There have been a meagre amount of studies which have done research on this topic [[1], [2]]. Moreover, there has been no cognizable study of this sort to have been done in the Indian subcontinent. Hence, this study intends to investigate and prove the correlation between the pulmonary arterial obstruction index and the atrial size in patients with pulmonary thromboembolism.

Methods

This is a prospective study conducted on 45 patients with clinical suspicion of pulmonary thromboembolism over a period of 18 months (October 2019–March 2021) at the Department of Radiodiagnosis, JSS Hospital, Mysuru. CT Pulmonary Angiography was performed, following which the pulmonary arterial obstruction index & atrial measurements were assessed.

Patients will be selected according to inclusion criteria, which include patients with clinical suspicion of pulmonary thromboembolism. After obtaining relevant clinical history and consent from the patients, they are subjected to CTPA imaging using a 128 SLICE MDCT SCANNER (Ingenuity Core 128 v3.5.7.25001; Philips Healthcare). Reconstructed slice thickness was 1.0–2.0 mm, with an increment of 0.5–1 mm. The protocol consists of intravenous contrast injections of 60 mL of iodinated non-ionic contrast material at a concentration of 300 mg iodine/mL at rates of 3–4 mL/s. All scans were obtained in a caudo-cranial direction at end-of-inspiration during a single breath-hold. The images will then be analysed following which pulmonary arterial obstruction index & atrial measurements will be correlated using volumetric analyses.

Left and right atrial measurements were obtained in the planes of maximum dimensions. To define the Qanadli index/Pulmonary Arterial Obstruction Index, the arterial tree of each lung was regarded as having 10 segmental arteries (three to the upper lobes, two to the middle lobe and to the lingula, and five to the lower lobes). Embolus in a segmental artery was scored 1 point, and the presence of emboli in a proximal arterial level was scored a value equal to the number of segmental arteries arising distally.To provide additional information about the distal residual perfusion, a weighting factor was assigned to each value, depending on the degree of vascular obstruction. This factor was equal to zero, when no thrombus was noted; 1, when partially occlusive thrombus was noted; or 2, with total occlusion. Thus, the maximal Qanadli index was 40 per patient.

Statistical analysis

Using a region-of-interest (ROI) based approach depending on the anatomic landmarks; Qanadli Obstruction Index (QOI) and Atrial sizes are measured in pulmonary arteries and left & right atria respectively. The data derived from the volumetric analyses of CTPA is then evaluated longitudinally. Data are entered in the Microsoft Excel sheet and statistical analysis will be done using IBM SPSS Statistics V23.0. All results are expressed as mean ± SD/ frequency/percentage. A Chi-square test/Cramer's V test will be used to correlate the values of the Qanadli Obstruction Index (QOI) and atrial sizes and test its significance (significant with $p < 0.05$) in the evaluation of patients with varying severity of pulmonary thromboembolism.

Results

The age of the patients included in the study ranged from 19 to 88 years of age with the mean age being 38 years. Majority of them i.e., 44.4% of the patients were between the age of 31 and 50 years. The second most common was the above 50 age group, comprising 35.6% of the patients. The least common age group was the less than 30 age group, comprising 20% of the patients.

There was a slight female preponderance in the study population, with 53.3% of them being females and 46.7% being males.

The LA long axis showed a statistically insignificant negative correlation with the PAOI (p value 0.776). The LA area, although statistically significant (p value 0.011) showed a weak negative correlation (r value −0.376) with the PAOI. The LA short axis shows statistically significant (p value 0.000) and strong negative correlation (r value −0.598) with the PAOI.

The RA long axis showed a weak positive correlation (r value 0.359) with the PAOI, while the RA short axis and area showed moderate correlation (r value 0.459 and 0.478 respectively) with the PAOI.

There was a significant negative correlation between left atrial/right atrial area, left atrial/right atrial short axis and left atrial/right atrial long axis with the PAOI, especially the left atrial/right atrial area ratio and left atrial/right atrial short axis ratio, which showed the most significant negative correlation. Therefore, a higher clot load was associated with increased RA and decreased LA parameters.

Additionally, an LA/RA area of ≤ 0.60 correlated with a PAOI of > 20 and an obstruction percentage of > 50%, which can serve as a predictor of right ventricular dysfunction.

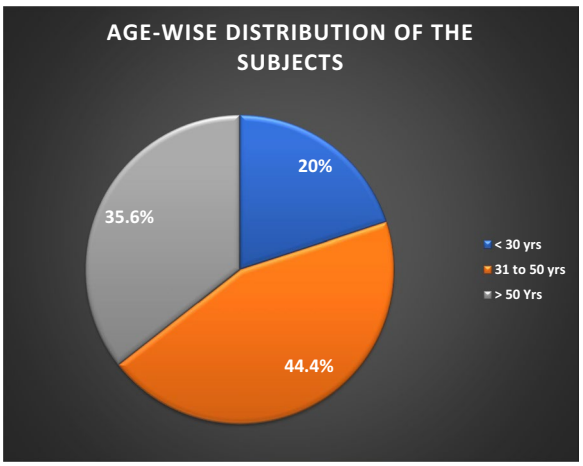

Fig. 1 Age-wise distribution of subjects

Table 1 Age-wise distribution of subjects

Age(in yrs)	Frequency	Percent
< 30	9	20.0
31 to 50	20	44.4
> 50	16	35.6
Total	45	100.0

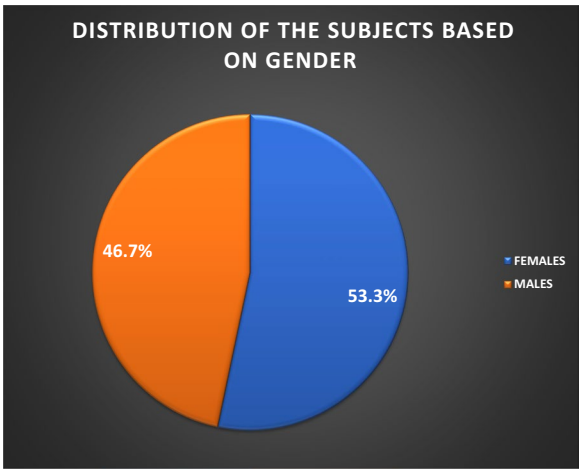

Fig. 2 Gender-wise distribution of subjects

Discussion

This study was conducted in the department of Radiodiagnosis, JSS Hospital over a period of 18 months. 45 patients were included in the study, the age group of which ranged from 19 to 88 years, with an average of 38 years (Fig. 1, Table 1). Maximum number of the study group was between the age groups of 31–50 years (44.4%). Higher arterial obstruction index was noticed in the older age group (> 38 year age group) than in the younger age group (< 38 year age group). Out of the 45 patients, 24 were females and 21 were males (Fig. 2, Table 2).

Table 2 Gender-wise distribution of subjects

Gender	Frequency	Percent
FEMALES	24	53.3
MALES	21	46.7
Total	45	100.0

Pulmonary embolism is a life-threatening complication involving the circulatory system. There are two sets of events contributing towards mortality in a patient with pulmonary embolism [[1]]. Firstly, the massive pulmonary embolism results in pulmonary arterial hypertension, which eventually causes pressure overload in the right ventricle. This leads to a decrease in the right heart output, resulting in right ventricular dysfunction and probably right ventricle failure [[7]]. Subsequently, there would be a decrease in the blood flow to the left atrium and ventricle. Secondly, increased afterload in the right ventricle would cause chamber dilatation. This dilated right ventricle could displace the intraventricular septum towards the left ventricle, thus impairing left ventricular preload [[8]]. These events could decrease cardiac output, ultimately resulting in hypotensive shock that could prove catastrophic [[4]].

Study done by Stein et al. [[9]] to determine the incidence of acute pulmonary embolism (PE) according to age, sex, and race in a tertiary care general hospital revealed a linear relationship between the incidence of acute pulmonary embolism to age, as is observed in our study.

Study done by Rossman [[10]] to evaluate the discrepancy between autopsy incidence and vital statistics reporting for fatal pulmonary embolization, revealed no significant difference of the incidence of pulmonary embolism based on sex, as is observed in our study.

Study done by Grifoni et al. [[11]]revealed a significant proportion of normotensive patients with acute pulmonary embolism present with RV dysfunction; these patients with latent hemodynamic impairment have a 10% rate of pulmonary embolism-related shock and a 5% rate of in-hospital mortality and may require aggressive therapeutic strategies. Therefore, assessing different LA & RA parameters with CTPA that predicts right and left heart failure could be lifesaving, especially in patients with a higher clot load.

Table 3 Pearson's correlation between QAI and long, short axis, area OF LA and RA

			QAI
Long axis	LA diameter	*r* value	− .044
		p value	.776
	RA diameter	*r* value	.359
		p value	.015*
Short axis	LA diameter	*r* value	− .598
		p value	.000*
	RA diameter	*r* value	.439
		p value	.003*
Area	LA	*r* value	− .376
		p value	.011*
	RA	*r* value	.478
		p value	.001*
LA/RA	Long axis	*r* value	− .445
		p value	.002*
	Short axis	*r* value	− .847
		p value	.000*
	Area	*r* value	− .898
		p value	.000*

* Significant

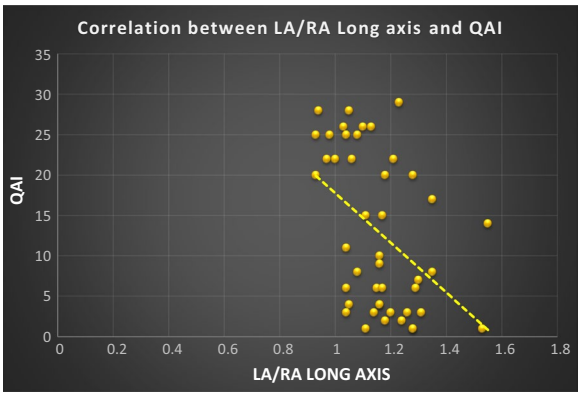

Fig. 3 Correlation Between LA/RA long axis and QAI

The CT obstruction/Pulmonary arterial obstruction index (PAOI) was initially proposed by Qanadli et al.; hence, it is also known as the Qanadli obstruction index (QOI) [[6]]. This index was correlated with the previously described pulmonary angiography index, which could predict and quantify the degree of obstruction, without taking into account the residual perfusion of the lung. They came to the conclusion that a CT obstruction index of more than 40% could identify 90% of patients with dilated right ventricle, while a CT

Table 4 Range of LA/RA area and corresponding PAOI in our study

LA/RA area (range)	Qanadli index & obstruction %	Number of patients in study
0.72–1.21	< 10 (< 25%)	22
0.62–0.79	10–20 (25–50%)	8
0.41–0.60	> 20 (> 50%)	15

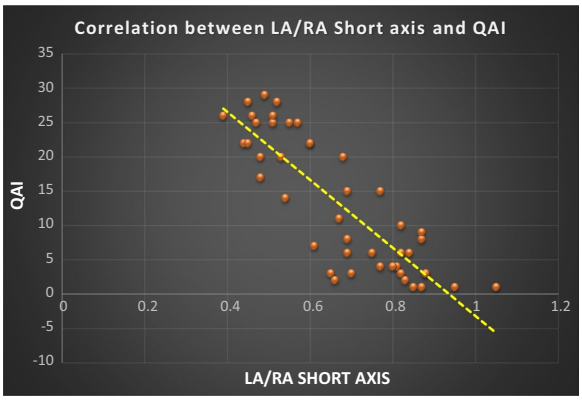

Fig. 4 Correlation Between LA/RA short axis and QAI

Table 5 correlation between the PAOI and radiologic parameters of left atrium in current and related previous studies

Study	LA long diameter	LA short diameter	LA area
Current study	*r* − 0.044	*r* − 0.598	*r* − 0.376
	p + 0.776	*p* + 0.000	*p* + 0.011
Langroudi et al. [[1]]	*r* − 0.205	*r* − 0.380	*r* − 0.449
	p + 0.152	*p* + 0.006	*p* + 0.001
Aviram et al. [[2]]	*r* − 0.144	*r* − 0.327	*r* − 0.256
	p + 0.096	*p* < 0.001	*p* + 0.003

Abbreviations: LA: left atrium; PAOI: Pulmonary atrial obstruction index; RA: Right atrium

Table 6 Correlation between the PAOI and radiologic parameters of right atrium in current and related previous studies

Study	RA long diameter	RA short diameter	RA area
Current study	*r* + 0.359	*r* + 0.439	*r* + 0.478
	p + 0.015	*p* + 0.003	*p* + 0.001
Langroudi et al. [[1]]	*r* − 00.089	*r* + 0.334	*r* + 0.041
	p + 0.538	*p* + 0.018	*p* + 0.776
Aviram et al. [[2]]	*r* + 0.204	*r* + 0.309	*r* + 0.276
	p + 0.017	*p* < 0.001	*p* + 0.001

Abbreviations: LA: left atrium; PAOI: Pulmonary atrial obstruction index; RA: Right atrium

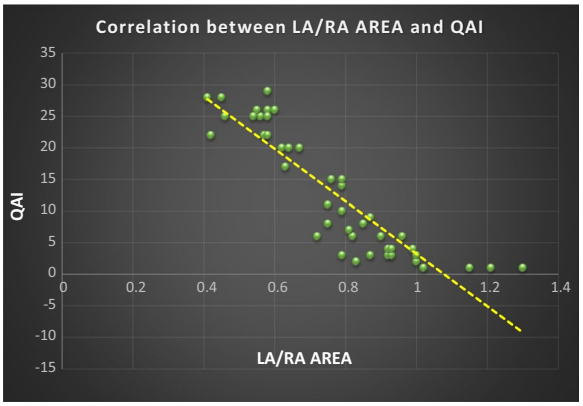

Fig. 5 Correlation Between LA/RA Area And QAI

Table 7 Correlation between the PAOI and LA/RA radiologic parameters in current study and study by Aviram et al.

Study	LA/RA long diameter	LA/RA short diameter	LA/RA area
Current study	$r-0.445$	$r-0.847$	$r-0.898$
	$p+0.002$	$p+0.000$	$p+0.000$
Aviram et al. [[2]]	$r-0.246$	$r-0.453$	$r-0.447$
	$p+0.004$	$p<0.001$	$p<0.001$

Abbreviations: LA: left atrium; PAOI: Pulmonary atrial obstruction index; RA: Right atrium

obstruction index of less than 40% would be unlikely to be seen in a patient suffering from acute right ventricular dysfunction.

In our study, we divided our sample into tertiles based on PAOIs: PAOI < 10 (Obstruction of < 25%), PAOI 10 – 20 (obstruction of > 25—< 50%), PAOI > 20 (obstruction of > 50%), and compared the various measurements between the three tertiles. The main finding of this study was that a higher PAOI – which signifies a higher clot load, is associated with a decreased LA/RA ratio, which indicates increased RA and decreased LA parameters. All the left atrial measurements were smallest for the group with the highest PAOIs (PAOI > 16), and the values were found to gradually increase as the PAOIs became smaller. Similarly, all the right atrial measurements were positively correlated with the PAOIs.

The short axis & area parameters were observed to have a significant increase in the RA and decrease in the LA with patients with a higher clot load. Although both LA/RA short axis and LA/RA area parameters were found to be significantly decreased in patients with higher clot load, a consistently strong inverse correlation with statistical significance was observed with the LA/RA area parameter than with the LA/RA short axis (Tables 3 and 4, Figs. 3, 4 and 5).

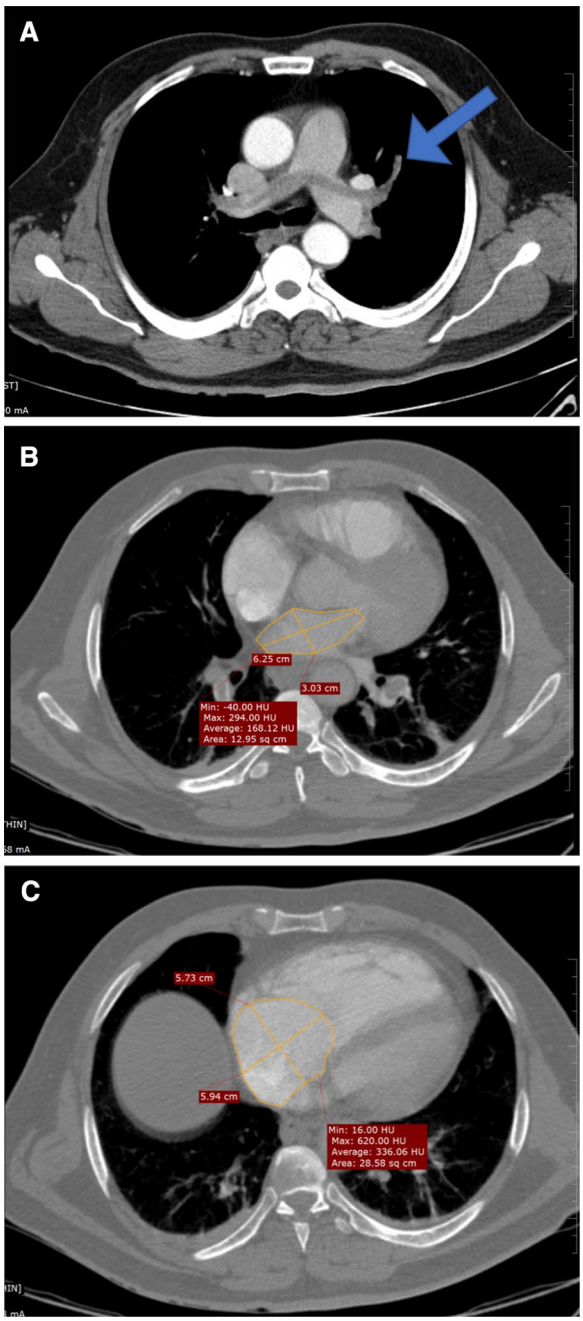

Fig. 6 First case was a 61 year old male patient who presented with history of breathlessness since 1 week and an elevated d- Dimer level of 8.9 µg FEU/ml. **a** CTPA showing saddle-shaped thrombus in the bilateral pulmonary arteries. **b** CTPA – Left atrial parameters. **c** CTPA – Right atrial parameters

An LA/RA area of ≤ 0.60 could accurately correlate with a PAOI of > 20 and an obstruction percentage of > 50%. Furthermore, it is important to establish the presence of right ventricular dysfunction as it may indicate a high likelihood of recurrent and possibly fatal

Table 8 Correlation of atrial parameters with Qanadli Index in Case 1

LA/RA long axis diameter	**0.81**
LA/RA short axis diameter	0.32
LA/RA area	0.33
Qanadli index	28

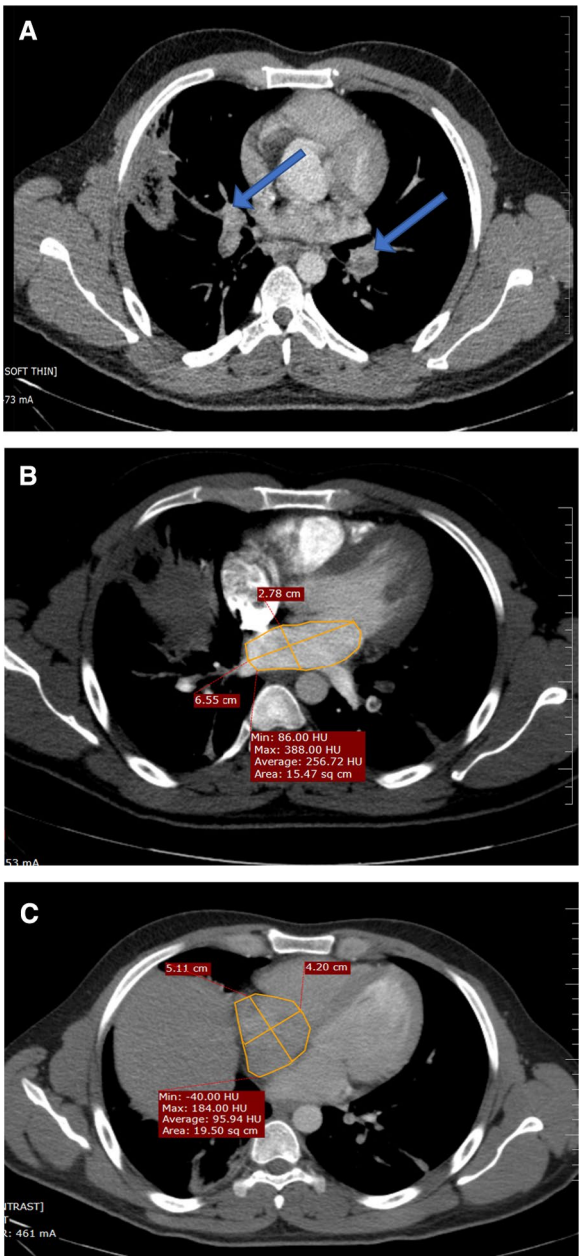

Fig. 7 Second case was a 28 year old male patient who presented with complaints of pleuritic type of chest pain with haemoptysis since the last 4 days. D-dimer was elevated—5.26 µg FEU/ml. **a** CTPA showing thrombi in the bilateral pulmonary arteries. **b** CTPA – Left atrial parameters. **c** CTPA – Right atrial parameters

Table 9 Correlation of atrial parameters with Qanadli Index in Case 2

LA/RA long axis diameter	1.55
LA/RA short axis diameter	0.54
LA/RA area	0.79
Qanadli index	14

pulmonary embolism, despite adequate anticoagulation therapy. The degree of pulmonary vascular obstruction is considered the most important factor in determining the right ventricular response to acute pulmonary embolism [41–43]. In our study, it was observed that a LA/RA area of ≤ 0.60, PAOI of >20 and an obstruction percentage of $>50\%$ could accurately identify $>93\%$ of patients with right ventricular dilatation. These findings were corroborated with the concurrent echocardiography data.

Langroudi TF et al. [[1]] conducted a study to infer the association between the Qanadli index and atrial size in 50 proven cases of pulmonary thromboembolism. There was a significant negative correlation between almost all LA measurements and the PAOI. Regarding RA, only its short diameter was positively correlated with the PAOI. Consequently, RA/LA Short Diameter, RA/LA Area, and RA/LA Volume ratios were positively correlated with the PAOI.

Few other similar studies, investigating the association between clot load and atrial sizes were done with a limited set of patients. One such study, done by Aviram et al. [[2]] came to the conclusion that the higher the clot load in the pulmonary arteries, the smaller the left atrial area and the larger the right atrial area.

In the study done by Aviram et al., there was a significant negative correlation between the PAOI and all left atrial measurements, particularly those of the left atrial area and left atrial short axis diameter, while all right atrial measurements were positively correlated with the PAOIs. Consequently, left atrial/right atrial area ratios yielded the greatest negative correlation with the PAOI among all the atrial measurements.

Correlation between the PAOI and radiologic parameters of left atrium, right atrium & LA/RA in current and related previous studies are as tabulated (Tables 5, 6 and 7).

Hence, these LA & RA dimensions in patients with pulmonary embolism could convey to the clinician important information about the clot load and serve as an added prognostic factor for pulmonary embolism (Fig. 6, Table 8; Fig. 7, Table 9; Fig. 8, Table 10).

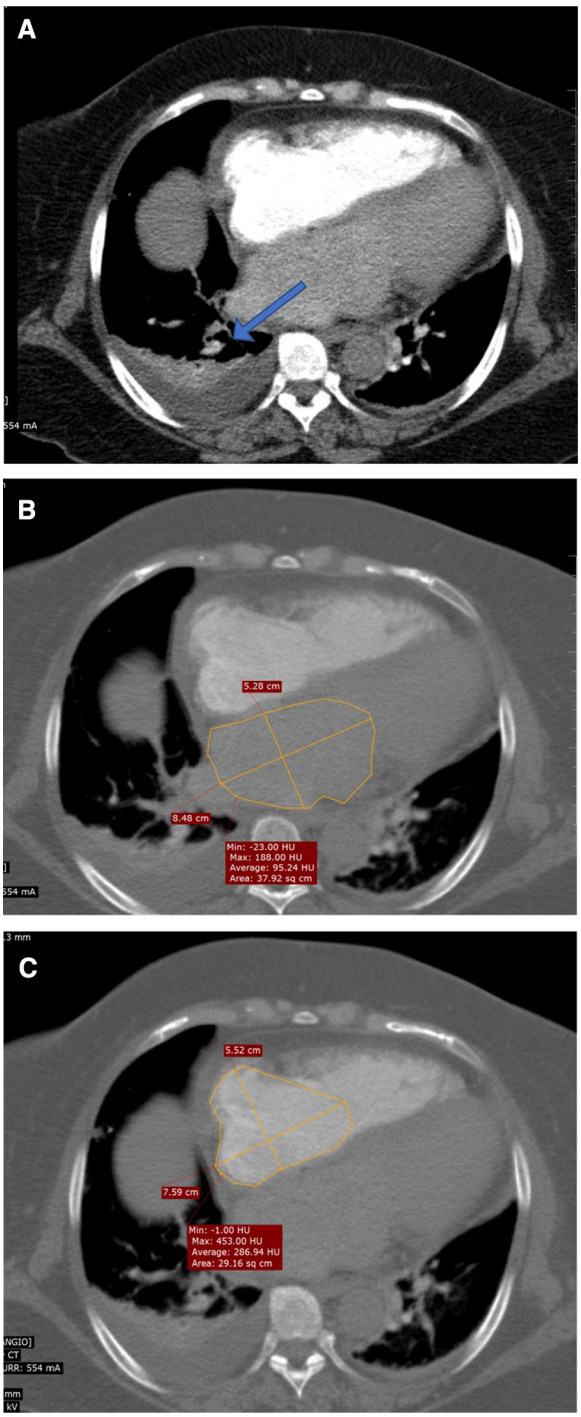

Fig. 8 Third case was a 58 year old female patient who presented with breathlessness since 5 days, which was of sudden onset. D-dimer was elevated—1.17 µg FEU/ml. **a** CTPA showing a focal partially obstructing thrombus in the posterior basal segmental branch of right pulmonary artery. **b** CTPA – Left atrial parameters. **c** CTPA – Right atrial parameters

Table 10 Correlation of atrial parameters with Qanadli Index in Case 3

LA/RA long axis diameter	1.11
LA/RA short axis diameter	0.95
LA/RA area	1.3
Qanadli index	1

Limitations

The left atrial & right atrial parameters measured on CTPA were done in the planes of maximum dimensions. This is mildly subjective and could lead to differences in measurement.

Long term follow up of the patients was not done to assess the morbidity associated with pulmonary embolism.

Lack of data on cardiac comorbidities, which may influence atrial dimensions as well as comparison in real time with echocardiography, which could provide functional correlation.

Comorbid conditions, such as obesity, diabetes mellitus, hypertension, dyslipidemia, current smoking, chronic obstructive pulmonary disease (COPD), asthma, congestive heart failure and ischemic heart disease were not reviewed and compared with in this study.

Conclusions

Following conclusions were drawn from this study of 45 participants with acute pulmonary thromboembolism:

- There was a significant negative correlation between left atrial/right atrial area, left atrial/right atrial short axis and left atrial/right atrial long axis with the PAOI, especially the left atrial/right atrial area ratio and left atrial/right atrial short axis ratio, which showed the most significant negative correlation.
- An LA/RA area of ≤ 0.60 could accurately correlate with a PAOI of >20 and an obstruction percentage of $>50\%$, which would serve as a predictor of right ventricular dysfunction.

Abbreviations

PTE: Pulmonary thromboembolism; CTPA: Computed Tomography Pulmonary Angiography; QOI: Qanadli Obstruction Index; RA: Right atrium; LA: Left atrium; PAOI: Pulmonary Arterial Obstruction Index.

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Authors' contributions
VD—Study conception, Analysis and interpretation of data, draft manuscript preparation, Data collection. RH—Study supervision, Analysis and interpretation of data. All authors discussed the results and contributed to the final manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analysed during the current study are not publicly available due to privacy of the study participants.

Declarations

Ethics approval and consent to participate
This study is approved by the Ethics committee of the JSS Academy of Higher Education and Research, Mysore, Karnataka, India. Only anonymous patient details were used for data collection and analysis. No interventions were done. The Institutional Ethics committee's reference number—JSS/MC/PG/5189/2019-20.

Consent for publication
Not applicable.

Competing interests
All authors declare no competing interests.

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References

[1] T Faghihi Langroudi M Sheikh M Naderian M Sanei Taheri A Ashraf-ganjouei I Khaheshi 2019 The Association between the Pulmonary Arterial Obstruction Index and Atrial Size in Patients with Acute Pulmonary Embolism Radiol Res Pract. 2 2019 1 6
[2] G Aviram A Steinvil S Berliner G Rosen J Sosna A Man 2011 The association between the embolic load and atrial size in acute pulmonary embolism: left atrium and clot load in pulmonary embolism J Thromb Haemost. 9 2 293 9
[3] B Ghaye A Ghuysen P-J Bruyere V D'Orio RF Dondelinger 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 1 23 39
[4] I Ocak C Fuhrman 2008 CT angiography findings of the left atrium and right ventricle in patients with massive pulmonary embolism Am J Roentgenol. 191 4 1072 6
[5] G Aviram E Soikher A Bendet H Shmueli T Ziv-Baran Y Amitai 2016 Prediction of mortality in pulmonary embolism based on left atrial volume measured on CT pulmonary angiography Chest. 149 3 667 75
[6] SD Qanadli M Hajjam EI A Vieillard-Baron T Joseph B Mesurolle VL Oliva 2001 New CT index to quantify arterial obstruction in pulmonary embolism: comparison with angiographic index and echocardiography Am J Roentgenol. 176 6 1415 20
[7] RW Meer Van der PM Pattynama MJ Strijen van AA Berg-Huijsmans van den IJ Hartmann H Putter A Roos de MV Huisman 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 3 798 803
[8] KE Wood 2002 Major pulmonary embolism: review of a pathophysiologic approach to the golden hour of hemodynamically significant pulmonary embolism Chest. 121 3 877 905
[9] PD Stein HL Huang A Afzal HA Noor 1999 Incidence of acute pulmonary embolism in a general hospital: relation to age, sex, and race Chest. 116 4 909 13
[10] I Rossman 1974 True incidence of pulmonary embolization and vital statistics Jama. 230 12 1677 9
[11] S Grifoni I Olivotto P Cecchini F Pieralli A Camaiti G Santoro A Conti G Agnelli G Berni 2000 Short-term clinical outcome of patients with acute pulmonary embolism, normal blood pressure, and echocardiographic right ventricular dysfunction Circulation. 101 24 2817 22

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