ORIGINAL ARTICLE

Evaluation of Predictive Value of CT Pulmonary Angiography for Right Ventricular Failure in Patients with Pulmonary Embolism

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Abstract

Purpose: Right ventricle failure is a well-known complication following pulmonary thromboembolism. Although Computed Tomography Pulmonary Angiography (CTPA) findings are supposed to be a surrogate for patients' outcome, investigations based on this issue is not still elucidated. Thus, in the current study, we assessed patients' CTPA findings and compared the result with echocardiographic findings.

Materials and Methods: A total of 36 patients with proven pulmonary thromboembolism were enrolled and a comparison was made between indices in CTPA (interventricular septal deviation to the right side, inferior vena cava contrast reflux, and right ventricle diameter to left ventricle diameter ratio) and echocardiographic findings for detecting right ventricular failure. Also, the reliability of the aforementioned indices was sought for predicting mortality.

Results: No significant correlation was found between CTPA indices and echocardiographic findings. The highest sensitivity and positive predictive value in CT pulmonary angiography for detecting right ventricle dysfunction were revealed to be for Right Ventricle Diameter (RVD) / Left Ventricle Diameter (LVD) > 1 (63.64%), abnormal septal deviation (75.00%), respectively.

Conclusion: Our results revealed that CTPA indices can reliably predict the upcoming mortality risk. On the other hand, these indices were not well-correlated with echocardiographic findings.

Keywords: Computed Tomography Pulmonary Angiography; Echocardiography; Pulmonary Thromboembolism; Heart Failure.

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1. Introduction

Pulmonary Thromboembolism (PTE) is potentially a life-threatening condition that can lead to death in approximately 20% of cases, despite proper treatment [1, 2]. The aforementioned mortality rate can be attributed to the usual serious concomitant conditions such as cancer, trauma, etc. Accurate and early diagnosis is of great importance respecting non-specific signs and symptoms of Pulmonary Embolism (PE) which prompt utilizing proper diagnostic modalities [3].

PTE-induced Heart Failure (HF) is defined as diminished cardiac output and increased intracardiac pressure and ventricular afterload, induced by the rapid increase in pulmonary artery pressure which leads to acute right ventricular dysfunction [4, 5]. This sudden afterload increment causes consequential increased pressure of the right ventricle wall that results in the dilative hypokinesia of the right ventricle and secondary Tricuspid valve insufficiency [6].

Right ventricle failure is attributed as the culprit for mortality in the early stages of the disease. The interventricular septum can shift to the left side and this septal shift causes left ventricle filling constraint and decreased cardiac output with a resultant decrease in systemic blood pressure, ventricular ischemia, and more dilatation of the right ventricle [7].

Accordingly, adding the right ventricle diameter to the left ventricle diameter can be considered a sign of right ventricle dysfunction [8]. Massive PE is a life minatory condition and is significantly linked with mortality [9]. As so, the severity of pulmonary arteries involvement is another potential factor implying patients' status deterioration in PE.

Additionally, HF can either be a PTE mimicker or a complication of PTE [10]. Hence, the distinction of the two conditions, and also providing a quick risk assessment of patients with such symptoms are pivotal.

Computed Tomography Pulmonary Angiography (CTPA) is the cardinal diagnostic modality for PE that is capable of depicting the location of thrombosis, as well as predicting possible upcoming complications. High diagnostic sensitivity (60-100%) and specificity (81-98%) of CTPA in diagnosing lobar and segmental thromboses, as well as availability and feasibility, make it the modality of choice for assessing PE [11]. Other valuable modalities include Echocardiography and Ventilation/Perfusion (V/Q) scans. V/Q scan is most commonly used in patients for whom CTPA cannot be performed [12]. Indices of right ventricular failure in echocardiography include right ventricular size and right ventricular systolic dysfunction [13].

The prognostic value of CT angiography in predicting mortality of patients with PTE has been investigated in various studies. The CTPA indices estimating the severity of the right ventricle dysfunction and predicting the disease severity include 1) flattening or displacement of the interventricular septum toward the left ventricle, 2) contrast material reflux into the inferior vena cava, and 3) Right Ventricle Diameter (RVD) to left ventricle diameter (LVD) ratio on axial plane and 4-Chamber (4-CH) view [14].

In the current study, we aimed to evaluate the predictive value of CTPA findings in patients with PE, for right ventricle failure and compare CTPA findings with echocardiographic findings.

2. Materials and Methods

2.1. Patients

All patients with an impression of PTE with any background condition who underwent CTPA from March 2018 to March 2019 were recruited for evaluation in this cross-sectional study implemented in Ali-Ebn Abitaleb Hospital, Zahedan, Iran. Subjects with proven diagnoses of PTE after CTPA assessment were kept in. Patients with a history of right ventricle infarct, congenital heart diseases, cardiac shunts, valvular heart diseases, and pericarditis were ruled out. Finally, a total of 36 patients with PTE fulfilling inclusion criteria were enrolled in the current study. All participants were followed up for 30 days following the diagnosis for evaluation of the mortality rate.

The objectives of the study were elucidated to the research applicants, and the patients were included in the study after obtaining written informed consent about the outlined sampling method. Also, all ethical considerations of Helsinki were observed.

2.2. CTPA Acquisition

All Computed Tomography (CT) scans were obtained utilizing a 64-slice CT machine (Siemens Medical System Inc., Erlangen, Germany). The Bolus tracking approach was applied for performing CT angiography. During CTPA acquisition, patients were in a supine position, the scans covered lung apices to the diaphragm, the caudocranial direction was applied and images were taken during patients' inspiration. Sixty mL of non-ionic contrast with a 100 mL saline chaser at 4.5/5 mL/s was injected as contrast material. The monitoring slice was set under the carina at the level of the pulmonary trunk with an ROI (Region of Interest) on the pulmonary artery. Also, a threshold of 100 HU was considered.

Filling defects within the pulmonary vasculature are considered pulmonary emboli (Figure 1). CTPAs were reported by an expert attending professor of radiology. As well as confirmation of the PTE diagnosis, indices that have been attributed to right ventricular failure as 1) left-sided abnormal septal deviation, 2) IVC (Inferior Vena Cava) contrast reflux, and 3) RVD (Right Ventricle Diameter) to LVD (Left Ventricle Diameter) ratio (RVD / LVD) >1, were measured and reported in the prepared checklist.

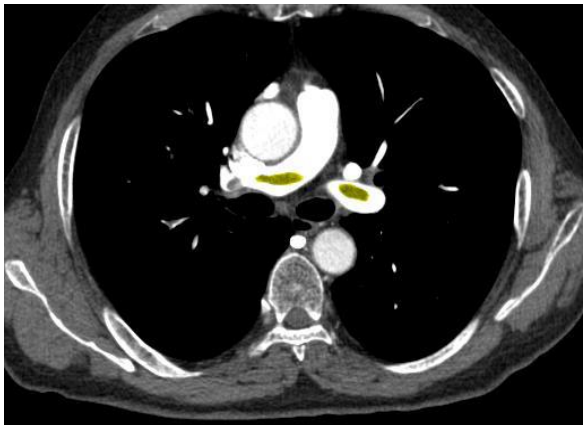

Figure 1. Bilateral filling defects in right and left main pulmonary arteries (green-colored)

2.3. Echocardiography

Echocardiographic assessments were performed by Mindray Resona I9 ultrasound scanner (Mindray Medical International Limited, Guangdong, China) equipped with a high-frequency curvilinear transducer. RV dysfunction was defined as a hypokinetic free wall which was best appreciated on parasternal long-axis projections. Based on the achieved data, subjects were divided into patients with and without RV dysfunction.

2.4. Statistical Analysis

The data were analyzed employing SPSS v24 (SPSS Inc., Chicago, Ill., USA) for Windows (Microsoft Corporations, Washington D.C, USA) with a significance level considered less than 0.05. Quantitative data were recorded as numbers and percentages and subsequently were compared with student t-test. Cohen's Kappa coefficient was used to estimate interrater reliability.

3. Results

A total of 36 subjects with PTE (Female N = 20, 55.56%) were enrolled in the current study. After 30 days of follow up, the mortality rate was 13.8% (N = 5). A significant correlation between all evaluated CTPA indices and mortality was observed which is depicted in Table 1. The predictive value of CTPA indices for RV failure was investigated separately. Results showed no significant concordance between CTPA findings and echocardiographic findings, which are depicted in Tables 2, 3, and 4. Prevalence, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of each CTPA index in RV dysfunction were calculated which are illustrated in Table 5. The highest sensitivity and positive predictive value were revealed to be for RVD/LVD>1 (63.64%), Abnormal septal deviation (75.00%), respectively.

Table 1. Comparison of CTPA finding in subjects with and without 30 days of mortality

Mortality index	Alive		Dead		P-value
	N	Percentage (%)	N	Percentage (%)	
Abnormal Septal Deviation	13	41	3	60	0.014
Contrast Reflux into IVC	12	38	2	40	0.05
RVD / LVD > 1	16	51	4	80	0.04

Table 2. Concordance of abnormal septal deviation prediction and right ventricle failure in echocardiography

Abnormal Septal Deviation	Status	Statistics	Echo		Total	κ	P-value
			Positive	Negative			
CT	Positive	Observed Count	12	4	16	0.241	0.126
		Expected Count	9.8	6.2	16.0		
		Positive in CT	75.0%	25.0%	100.0%		
		Positive in echo	54.5%	28.6%	44.4%		
	Negative	Observed Count	10	10	20		
		Expected Count	12.2	7.8	20.0		
		Negative in CT	50.0%	50.0%	100.0%		
		Negative in echo	45.5%	71.4%	55.6%		
Total	-	Observed Count	22	14	36		
		Expected Count	22.0	14.0	36.0		
		CT	61.1%	38.9%	100.0%		
		echo	100.0%	100.0%	100.0%		

Table 3. Concordance of contrast reflux into IVC prediction and right ventricle failure in echocardiography

Contrast reflux into IVC	Status	Statistics	ECHO		Total	κ	P-value
			Positive	Negative			
CT	Positive	Count	10	4	14	0.153	0.311
		Expected Count	8.6	5.4	14.0		
		Positive in CT	71.4%	28.6%	100.0%		
		Positive in Echo	45.5%	28.6%	38.9%		
	Negative	Count	12	10	22		
		Expected Count	13.4	8.6	22.0		
		Negative in CT	54.5%	45.5%	100.0%		
		Negative in Echo	54.5%	71.4%	61.1%		
Total	-	Count	22	14	36		
		Expected Count	22.0	14.0	36.0		
		CT	61.1%	38.9%	100.0%		
		Echo	100.0%	100.0%	100.0%		

Table 4. Concordance of RVD/LVD>1 prediction and right ventricle failure in echocardiography

RVD/LVD>1	Status	Statistics	ECHO		Total	κ	P-value
			Positive	Negative			
CT	Positive	Observed Count	14	6	20	0.203	0.221
		Expected Count	12.2	7.8	20.0		
		Positive in CT	70.0%	30.0%	100.0%		
		Positive in Echo	63.6%	42.9%	55.6%		
	Negative	Observed Count	8	8	16		
		Expected Count	9.8	6.2	16.0		
		Negative in CT	50.0%	50.0%	100.0%		
		Negative in ECHO	36.4%	57.1%	44.4%		
Total		Observed Count	22	14	36		
		Expected Count	22.0	14.0	36.0		
		CT	61.1%	38.9%	100.0%		
		ECHO	100.0%	100.0%	100.0%		

Table 5. Prevalence, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of each CTPA index in RV dysfunction

Variable \ Statistic	Prevalence	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
Abnormal septal deviation	61.11%	54.55%	71.43%	75.00%	50.00%	61.11%
Contrast reflux into IVC	61.11%	45.45%	71.43%	71.43%	45.45%	55.56%
RVD/LVD>1	61.11%	63.64%	57.14%	70.00%	50.00%	61.11%

4. Discussion

In the current study we investigated the correlation of CTPA findings and risk assessment for 30-day mortality, as well as the predictive value of CTPA findings for right ventricular failure. We found that positive CTPA findings, such as abnormal septal deviation to the left ventricle, contrast reflux into IVC, and RVD / LVD > 1 have a significant association with the mortality rate, 30 days following PTE. Despite the presence of numerous studies focusing on this issue, this association has not been elucidated.

Javadrashid *et al.* [15] showed that no significant correlation had existed between RVD to LVD ratio and mortality rate in patients with PTE which was contrary to our results. This discordance might be rooted in different variables and different lengths of patients' follow-up periods. They had just investigated RVD to LVD ratio and they followed their subjects for 70 days. We believed that examining a sole index could not be a reliable method, hence we increased the number of indices and investigated them all shoulder to shoulder.

In another study conducted by Kang *et al.* [16] on a sample size of 260 patients, they revealed that RVD(4-CH) / LVD (4-CH) ratio > 1.0 was predictive of 30-day death which confirms our results and is in line with ours. They have also investigated RVV (volume) / LVV (volume) ratio > 1.2 as an additive index that had empowered the hypothesis that increased volume of RV in CTPA is well correlated with echocardiographic findings of RV failure in patients with PTE.

All three CTPA indices, which were investigated in our study, and their relation with echocardiographic findings of RV failure, have been assessed in other studies, separately.

We found that abnormal left-sided deviation of the interventricular septum is not correlated with RV failure in echocardiography. This seems discordant with what Reid *et al.* [17] had explained in 1999. This discrepancy is probably due to the fact that they had just evaluated patients with massive PTE, whilst we included any type of PTE and not just massive ones. Massive PTE can lead to an abrupt increase in pulmonary artery pressure and the imposed over-pressure is directly transduced to RV and causes rapid dilatation. The aforementioned process happens with a lower intensity and pace in non-massive PTE; hence, the different reaction of RV is not unexpected.

The same justification exists for controversial results of other studies on massive PTE compared to non-massive PTE. In two separate studies, Wang *et al.* [18] and Shakeri Bavil *et al.* [19] have investigated the correlation of RVD / LVD ratio in CTPA with echocardiographic findings with regard to RV dysfunction. They both have found significant correlation and concordance between CTPA findings and echocardiographic findings in RV dysfunction. It is of great importance to insist that all included subjects were cases of massive PTE. Henceforth, this can be supposed that CTPA indices of RV failure could be potentially well correlated with echocardiography, in patients with massive PTE, nonetheless, such correlation seems not to exist in non-massive PTE.

We faced limitations while conducting the study. We did not evaluate the intensity and severity of PTE. Employing a quantitative assessment of PTE severity with an established radiological scale can be potentially a great solution for such immense confinement.

This was a single-center study and selection bias was unavoidable. Although patients enrolled for this study were referred to a referral center, collecting participants fulfilling our inclusion criteria was problematic and has resulted in the small sample size of the current study. Studies with larger sample size are recommended.

5. Conclusion

This study has investigated three commonly-used indices of CTPA, including 1) interventricular septal deviation, 2) contrast material reflux into IVC, and 3) RVD / LVD ratio in evaluating patients with PTE. Our study revealed that all three indices can be reliably used in predicting the mortality of the patients. Considering previously conducted studies, although the three conventional indices of CTPA can potentially correlate with echocardiographic findings with regard to RV dysfunction in massive PTEs, it seems that they might not be consistent with echocardiographic findings in non-massive PTEs.

Acknowledgments

This article contains studies with human participants and the ethical code is [IR.ZAUMS.REC.1397.237].

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