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Role of Multi-Detector Computed Tomography in Assessment of Pulmonary Arterial Hypertension

Aya Essam, Omnia Ahmed Kamal, **Ahmed Mohamed Osman**
Radiology Department, Ain Shams University
Corresponding author: Aya Essam, email: ayaessam894@gmail.com

ABSTRACT

Pulmonary arterial hypertension (PAH) may be suspected based on the clinical history, physical examination and electrocardiogram findings but imaging is usually central to confirming the diagnosis, establishing a cause and guiding therapy. The diagnostic pathway of PAH involves a variety of complimentary investigations of which computed tomography pulmonary angiography (CTPA) has established a central role both in helping identify an underlying cause for PAH and assessing resulting functional compromise. In particular, CTPA is considered as the gold standard technique for the diagnosis of thromboembolic disease.

This article reviews the CTPA evaluation in PAH, describing CTPA techniques, a systematic approach to interpretation and spectrum of key imaging findings.

Keywords: Pulmonary arterial hypertension (PAH); computed tomography (CT); echocardiography.

INTRODUCTION

Pulmonary arterial hypertension (PAH) is defined as an increase in mean pulmonary arterial pressure greater than 25 mmHg at rest, or greater than 30 mmHg during exercise [1]**.** It's a serious condition that can damage the right side of the heart**.**

The walls of the pulmonary arteries become thick and stiff, and can't expand as well to allow blood through**.** The reduced blood flow makes it harder for the right-hand side of the heart to pump blood through the arteries so the right-hand side of the heart has to continually work harder, it can gradually become weaker; this can lead to heart failure[2]. Transthoracic echocardiography (TTE) provides a useful initial screening tool, in which the pulmonary arterial pressure is indirectly assessed via calculation of tricuspid regurgitation jet velocity [3] **.**

TTE also provides valuable information regarding cardiac morphology and function and in some cases may elicit the cause, e.g., atrial septal defect (ASD). Right heart catheterization (RHC) is the gold standard method of quantifying the pulmonary artery pressures and can also be used to measure the pulmonary capillary wedge pressure in suspected left heart disease. RHC provides very limited information regarding the underlying cause of PAH[11] .

PATIENTS AND METHODS

This study included 36 patients with clinical and echocardiographic diagnosis of pulmonary hypertension referred for multidetector computed tomography (MDCT) examination . The study was performed in Radiology Department at Ain Shams University Hospitals using Toshiba machine.

The study was approved by the Ethics Board of Ain Shams University.

Inclusion criteria

- Both sexes were included.
- Adult patients (age from 20-75).
- Patients suspected clinicaly to have pulmonary hypertension.

Exclusion criteria

- Patients are known to have contraindication of contrast e.g. renal failure, pregnancy.
- Patient's with non-reliable Echo.

Procedure

Patients were subjected to:

1- Full history taking.

2- All patients underwent Doppler echocardiographic indices for the evaluation of patients with clinical suspicion of pulmonary arterial hypertension.

3- All patients underwent contrast enhanced CT chest.

The study was done in the CT Unit in Radiology Department at Ain shams University Hospitals.

Patient preparation

- Explanation of the study to patients or his/ her care giver and obtaining an informed consent.
- Checking serum creatinine before contrast administration.
- Measuring patient body weight for calculation of amount of contrast media and sedative material if indicated.
- Fasting for 6 hours.
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Procedure duration

The study took 10 -15 minutes.

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METHODS

- The examination was done regardless the heart rate.
- A preliminary non-contrast chest CT was taken first (All patients were scanned from the lung apex to the liver dome to cover the entire lung parenchyma).
- Dual injector was used: Syringe A: non-ionic contrast (1-2 ml /kg) and Syringe B: 20 ml saline.
- Nonionic contrast agent injected through a peripheral venous line by using a power injection followed by 20 ml saline. The total used contrast volume was 100-120 ml.
- Images were acquired by bolus tracking that involves placing a cursor in the main pulmonary artery and triggering of scan acquisition at a pre-defined threshold (typically 150 HU).
- Non-ECG gated CTPA was best acquired in a helical fashion in a caudo-cranial direction from diaphragm to apices in held shallow inspiration to minimize diaphragm related artifact. Approximately 80 ml of contrast medium is injected at 4-5 ml/s with scan triggering 5 s after peak main pulmonary artery (MPA) enhancement. Image reconstructions with 1-2 mm axial sections and 1 mm overlap was suggested.
- ECG-gated CTPA was performed using retrospective gating (continuous data acquisition through the cardiac cycle) with aggressive dose modulation to help minimize radiation exposure. Maximal exposure is typically restricted to the diastolic period of the cardiac cycle (60-70% of the R-R interval for heart rates under 60 bpm and 50-80% above 60 bpm). A craniocaudal scan direction with triggering 2 s after MPA enhancement was used with a pitch of 0.4-0.5 depending on heart rate. Image reconstructions with 1 mm axial sections and 1 mm overlap was suggested.
  All reconstructed images were transferred to a dedicated workstation. Multi-planar reformation (MPR), maximum intensity projection (MIP) and volume rendering technique (VRT) were used.

- **Data acquired**

1-Identification of CT findings

C.T measurement of the diameter of the main pulmonary artery (MPA):

The MPA is evaluated at the level of its bifurcation, orthogonal to its long axis[4]**.**

A pulmonary artery with a diameter of 29 mm or more has a positive predictive value of 97%, sensitivity of 87%, and specificity of 89% for the presence of pulmonary hypertension[18]**.**

CT measurement of MPA to ascending aorta ratio:

The main pulmonary artery (pulmonary trunk) to ascending aorta ratio, the ratio obtained on the axial image at the bifurcation of the right pulmonary artery, the normal ratio is less than 1.0[18]**.**

CT measurement of the diameter of the right and left pulmonary arteries:

Right pulmonary artery (RPA) and left pulmonary artery (LPA) diameters: the widest part of RPA and LPA after MPA bifurcation (RPA 22.5±3.7 mm, LPA 20.9±3.1 mm)[3]**.**

CT measurement of Right-to-Left Ventricular Ratio:

Right ventricle dilatation can be assessed by different methods on computed tomography angiography (CTA). The right-to-left ventricular diameter ratio is more commonly used because it is simple to measure and mirrors the concept of right ventricle dilatation at echocardiography. The fastest method is to measure the heart chambers' minor axis at the widest points between the inner surface of the free wall and the surface of the interventricular septum in the same images used for diagnosis, without reconstructions[15]**.**

CT assessment of septum deviation

Inferior vena cava (IVC) and hepatic veins congestion:

Retrograde opacification of the hepatic veins or inferior vena cava was considered to be present when the attenuation of the lumen of the hepatic veins or inferior vena cava was visibly higher than that of a more caudal segment of hepatic vein or inferior vena cava. The smallest maximal axial diameter of the inferior vena cava was measured above the level of the liver (supra-hepatic)[2] **.**

CT measurement of Superior vena cava (SVC)

The superior vena cava is measured on the same level of the ascending aorta just above the coronary orifices (Fig. 1)[1] **.**

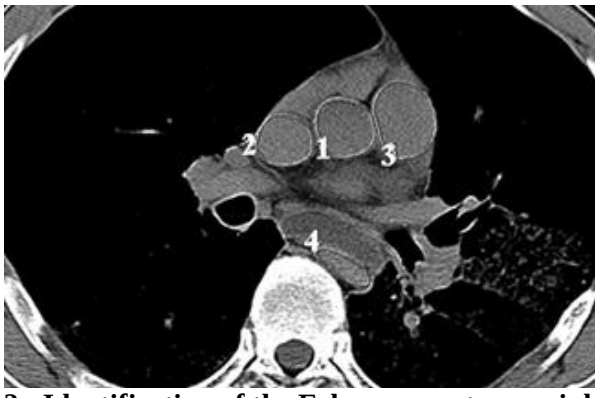

Fig. (1): Fig. 1—Axial MDCT image of thorax in one case shows measurements performed on workstation of cross-sectional areas of superior vena cava (2); main pulmonary artery (3); ascending aorta (1); and descending aorta (4) just above coronary orifices[1]*.*

2 - Identification of the Echo parameters mainly:

A – Presence or absence of pulmonary hypertension.

B – Presence or absence of Right ventricular dilatation.

C – Presence or absence of Right ventricular dysfunction.

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data were presented as mean, standard deviations and ranges when their distribution found parametric while non parametric data were presented as median with inter-quartile range (IQR). Also qualitative variables were presented as number and percentages .

The comparison between groups with qualitative data were done by using Chi-square test and Fisher exact test instead of the Chi-square only when the expected count in any cell was found less than 5.

The comparison between two groups with quantitative data and parametric distribution was done by using Independent t-test while non parametric data were done by using Mann-Whitney test.

Receiver operating characteristic curve (ROC) were used to assess the diagnostic accuracy with sensitivity, specificity, positive predictive value and negative predictive value .

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as following :

- P > 0.05: Non-significant
- P < 0.05: Significant
- P < 0.01: Highly significant.

RESULTS

Our study included 36 patients who were presented to the Department of Radiology at Ain Shams University with pulmonary hypertension and pulmonary angiography was requested for them.
The study was conducted over a period of nearly 10 months. The age of the study group ranged from 16 to 83 years with 50.03 + 17.71 years as mean age + SD (Table 1).

Table (1): The range of age and mean age of the study group as well as the clinical presentation among the studied patients.

		No. = 36
Age	Mean ±SD Range	50.03 ± 17.71 16 – 83
Clinical Presentation	***Number of patients***	***%***
Dyspnea	20	(55.6%)
Tachycardia	2	(5.6%)
Tachypnea	10	(27.8%)
Hemoptysis	4	(11.1%)
Lower limb redness	1	(2.8%)
Chest pain	11	(30.6%)
Cough	3	(8.3%)
Respiratory distress	5	(13.9%)
Cyanosis	1	(2.8%)
Lower limb oedma	2	(5.6%)

From **Table (1)** we noticed that dyspnea was the commonest clinical presentation among our study population representing 55.6 %, and cyanosis was the least clinical presentation 2.8%. No case was presented with hemoptysis during our study.

Table (2) Comparison between patients with pulmonary hypertension and those without pulmonary hypertension diagnosed by Echo regarding different cardiac changes recorded on CT pulmonary angiography

		Pulmonary hypertension "Echo"		Test value	P-value	Sig.
		Negative	Positive			
		No. = 14	No. = 22			
Main PA diameter	Mean±SD Range	25.57 ± 5.27 18 – 34	34.45 ± 11.66 22 – 80	-2.671•	0.012	S
diameter of RT PA	Mean±SD Range	19.86 ± 4.69 13 – 27	24.55 ± 4.08 19 – 35	-3.173•	0.003	HS
diameter of LT PA	Mean±SD Range	19.43 ± 3.20 14 – 24	21.68 ± 3.93 15 – 30	-1.795•	0.081	NS
ratio between PA/Asc.aorta	Low High	13 (92.9%) 1 (7.1%)	14 (63.6%) 8 (36.4%)	3.896*	0.048	S
LV/RV	Low High	3 (21.4%) 11 (78.6%)	7 (31.8%) 15 (68.2%)	0.460*	0.497	NS

NS: Non significant; S: Significant; HS: Highly significant
*:Chi-square test; •: Independent t-test

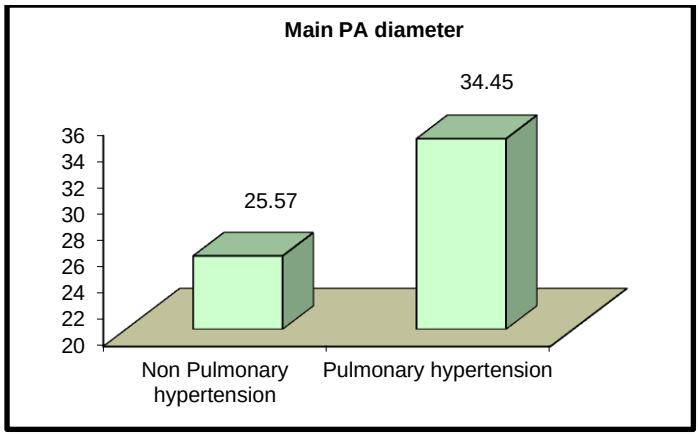

Fig. (2): Bar graph illustrating the relation between main pulmonary artery (PA) diameter and pulmonary hypertension diagnosed by Echo.

Diagnostic accuracy of CT according to echo results

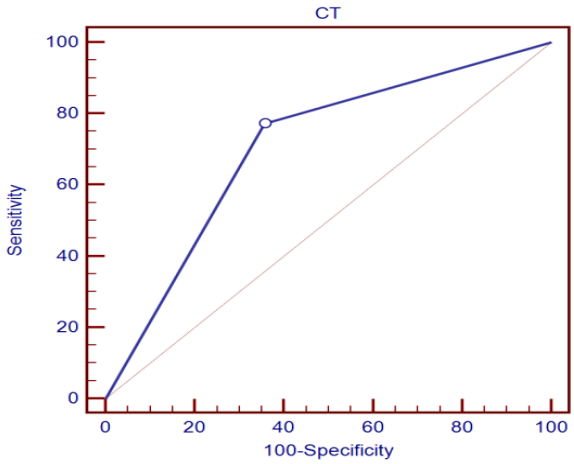

Fig. (3): ROC curve

Table (3): Results of the ROC curve

Sensitivity	Specificity	PPV	NPV	Accuracy
77.3%	64.3%	77.27%	64.29%	72.2%

The previous ROC curve shows that CT can predict Echo results of pulmonary arterial hypertension by sensitivity of 77.3%, specificity of 64.3% and accuracy of 72.2%.

DISCUSSION

Pulmonary arterial hypertension (PAH) may be suspected based on the clinical history, physical examination and electrocardiogram findings but imaging is usually central to confirming the diagnosis, establishing a cause and guiding therapy. The diagnostic pathway of PAH involves a variety of complimentary investigations of which computed tomography pulmonary angiography (CTPA) has established a central role both in helping identify an underlying cause for PAH and assessing resulting functional compromise.

In particular, CTPA is considered as the gold standard technique for the diagnosis of thromboembolic disease[17].

This study was conducted to thirty-six **(36)** patients with clinical suspicion of pulmonary arterial hypertension referred to Radiology Department at Ain Shams University Hospital, for evaluation by multislice CT (**MSCT)** pulmonary angiography.

Our study revealed

The age of patients ranged from 16 to 83 years old with 50.03 + 17.71.

In our study, the clinical presentation of patients was as followed: 16 patients presented by dyspnea representing **44.4%,** 11 patients had chest pain representing 30.6**%**, 10 patients had tachypnea representing **27.8%**, 2 patients presented by tachycardia representing **5.6 %** and 4 presented with hemoptysis representing **11.1%.**

The reported result in our study agreed with ***Hachulla ,et al.*** in the incidence of symptoms whose study showed that the most common presenting signs and symptoms were dyspnea **(83%),** followed by chest pain **(74.3%) .** Also, the reported result in our study agreed with ***Tambe, et al.*** study that showed that the most common clinical symptoms were sudden and/or unexplained dyspnea, chest pain, tachypnea and tachycardia [21,22].

A main pulmonary artery diameter (MPA) >29 mm has traditionally been used as a threshold measurement above which PAH is suggested [7,15,18]**.**

So in our study we considered patients with main pulmonary diameter >29 mm to have pulmonary arterial hypertension.

After examination by **MSCT** pulmonary angiography, the images had shown that 22 patients have main pulmonary artery diameter >29 mm representing (61.1%) and 14 patients have main pulmonary artery diameter < 29 mm representing (38.9%) [9].

In addition, and in accordance with prior report, in our study we found the mean diameter of main pulmonary arteries in group of patients diagnosed with PAH were 34.45 ± 11.66 mm, which was highly significant when compared to control group.

In our study we used echocardiography as the gold standard for the diagnosis of pulmonary arterial hypertension as in ***Devaraj et al.*** and as in ***Davarpanah et al.*** because it is non-invasive, widely available and relatively inexpensive [4,5]. But using echocardiography as the gold standard for diagnosis of PAH didn't agree with the study of ***Janda*** that reported right heart catheterization as the gold standard for the diagnosis of pulmonary arterial hypertension[12].

In our study we found within the study group, the correlation between pulmonary blood pressures measured by echocardiography and diameters of main pulmonary arteries was highly significant, which is different from ***Fakharian et al.*** who reported that pulmonary artery pressure and pulmonary artery diameter had a weak correlation, but agrees with ***Grubstein et al.*** who reported that the pulmonary blood pressure measured by echocardiography correlated significantly with the diameter of the main pulmonary artery [7,10].

we found that CT pulmonary angiography (by measuring pulmonary artery diameter) can predict echo results of PAH by sensitivity of 77.3%, specificity of 64.3% and accuracy of 72.2%**.**

Davarpanah et al. found PAH diameter estimate (sensitivity, 88%; specificity, 78%) in the diagnosis of PAH in comparison to echo. ***While Shujaat et al.*** found that sensitivity of CT in diagnosis of PAH was (75%) and specificity was (69.57%) but they compared results of CT by right heart catheter angiography (RHC)[20].

In our study 27 (75.0%) patients showed PA/A ratio > 1 and 9 (25.0%) showed PA/A ratio <1. PA/AO ratio >1 shows significant relation with pulmonary hypertension diagnosed by echo with P-value (0.048), and this agreed with ***Devaraj et al.*** and ***Davarpanah et al*** [4,5]**.**

The mean of right pulmonary arteries and left pulmonary arteries diameters in the study group were 34.45 ± 11.66 mm and 21.68 ± 3.93 mm respectively. There was statistically highly significant relation between enlargement of RPA and PAH diagnosed by echo and this is in agreement with ***Chen et al.*** and ***Lange et al*** [3,16].but it was different from ***Remy et al.*** who reported that the diameters of the left and right pulmonary arteries appear to be poorer indicators of the presence of pulmonary hypertension[19]. We found

non-significant relation between enlargement of LPA and PAH diagnosed by echo and this result disagreed with ***Chen et al.*** and ***Lange et al*** who considered LPA enlargement is also of highly significant value in diagnosis of PAH but our results agreed with those of ***Remy et al.*** [19].

One of CT signs of right ventricular dysfunction as a complication of pulmonary arterial hypertension is the ratio between the LV and RV measurements. A ratio of 1.0 or more was considered normal, and a ratio less than 1 was considered indicative of RVD [5].

REFERENCES

1. **Aghayev A, Sonnenschein M, Jackowski C *et al.*** (2006):Postmortem radiology of fatal hemorrhage: measurements of cross-sectional areas of major blood vessels and volumes of aorta and spleen on MDCT and volumes of heart chambers on MRI." American Journal of Roentgenology, 187: 209-215.
2. **Benjamin M, Philip K, Elyse F *et al.* (2004):**Clinical Relevance of Retrograde Inferior Vena Cava or Hepatic Vein Opacification During Contrast-Enhanced CT.American Journal of radiology ,183: 27-32
3. **Chen X, Liu K, Wang Z *et al.* (2015):** Computed tomography measurement of pulmonary artery for diagnosis of COPD and its comorbidity pulmonary hypertension ,International Journal of Chronic Obstructive Pulmonary Disease , 10(1) : 25—33.
4. **Davarpanah A, Hodnett P, Farrelly C *et al.* (2011):** MDCT bolus tracking data as an adjunct for predicting the diagnosis of pulmonary hypertension and concomitant right-heart failure. American Journal of Roentgenology,197 :1064-1066
5. **Devaraj A, Wells A, Meister M *et al.* (2010):** Detection of pulmonary hypertension with multidetector CT and echocardiography alone and in combination Radiology, 254:609-16.
6. **Fakharian A, Nima Hamidi, Behnam Haji H *et al.* (2011):**Chronic Respiratory Disease Research Center, Shahid Beheshti University of Medical Sciences.Tehran-Iran Correlation between the Pulmonary Artery Pressure Measured in Echocardiography and Pulmonary Artery Diameter in the CT-Scan of Patients Suffering from Interstitial Lung Disease , 10: 37-41.
7. **Frazier A, Galvin J, Franks T *et al.* (2000)**:From the archives of the AFIP pulmonary vasculature hypertension and infarction. Radiographics ,20:491-524.
8. **Galiè N, Hoeper M, Humbert M *et al.* (2009):** ESC Committee for Practice Guidelines (CPG). Heart and Lung Transplantation European heart journal , 30:2493-537.
9. **Gareth Lewis, Edward T, Hoey S *et al.*(2015):** Multi-detector CT assessment in pulmonary hypertension.Quant Imaging Med. Surgery , 5: 423–432.
10. **Grubstein A, Benjaminov O, Dayan D *et al.*(2008):** Computed tomography angiography in pulmonary hypertension. Isr Med Assoc J **,**10:117–120**.**
11. **Hemnes A, Gaine S ,Wiener C *et al.*(2008):** Poor outcomes associated with drainage of pericardial effusions in patients with pulmonary arterial hypertension. South Med J., 101: 490-495.
12. **Janda S, Shahidi N, Gin K *et al.* (2011):** Diagnostic accuracy of echocardiography for pulmonary hypertension: a systematic review and meta-analysis. Heart ,2010:60-62.
13. **John G , Marti C,Poletti P *et al* .(2014):** Hemodynamic Indexes Derived from Computed Tomography Angiography to Predict Pulmonary Embolism Related Mortality. BioMed Research International ,8:363-756.
14. ***Newman J, Rich S, Abman S et al.(2017):***Enhancing Insights into Pulmonary Vascular Disease (PVD) Through a Precision Medicine Approach.The American Journal of Medicine, 43:10-12 .
15. **Karazincir S, Balcı A, Seyfeli E *et al.*(2008):** CT assessment of main pulmonary artery diameter. Diagn. Interv. Radiol., 14:72-74.
16. **Lange T, Bornia C, Stiefel J *et al.* (2013):** Increased pulmonary artery diameter on chest computed tomography can predict borderline pulmonary hypertension. Pulmonary circulation, 3(2) :363-8.
17. **Lewis G, Hoey E, Reynolds J *et al.* (2015):** Multi-detector CT assessment in pulmonary hypertension: techniques, systematic approach to interpretation and key findings. Quantitative imaging in medicine and surgery, 5: 423.
18. **Peña E, Dennie C, Veinot J *et-al*.(2012):** Pulmonary hypertension: how the radiologist can help. Radiographics, 32 : 9-32.
19. **Remy-Jardin M, Remy J, Mayo J *et al*.(2001):** Pulmonary hypertension in CT angiography of the chest. Philadelphia. Pa: Lippincott Williams & Wilkins .
20. **Shujaat A, Bajwa A, AlSaffar F *et al.* (2017) :** Diagnostic accuracy of echocardiography combined with chest CT in pulmonary hypertension. The clinical respiratory journal,17 :10:1-5.
21. **Tambe J, Moifo B, Fongang E *et al.* (2017) :**Acute pulmonary embolism in the era of multi-detector CT: a reality in sub-Saharan Africa. Bio-Med Central (BMC) Medical Imaging, 12: 1 – 6.
22. **Hachulla, E. Gressin, V. Guillevin, L *et al*.(2005):** Early detection of pulmonary arterial hypertension in systemic sclerosis: a French nationwide prospective multicenter study. Arthritis & Rheumatology, 52: 3792-3800.