Abstract:

Back ground*:* MDCT pulmonary angiography is the method of choice for the detection of PE. The severity of PE as estimated by the obstruction index (OI) and right ventricular dysfunction (RVD) can be evaluated with MDCT.

Aim of the work: To evaluate the role of CT pulmonary angiography (CTPA) in the assessment of pulmonary embolism (PE) severity and the related CT cardiac changes in correlation with echocardiographic data and patient's outcome.

Patient and Methods: The study included 24 patients having PE who underwent CTPA followed by ECHO. Pulmonary artery obstructive index (PAOI) using Qanadli Score was calculated and cardiac changes recorded, also the patients' outcome was followed up for 30 days.

Results: We found that there was a significant relationship between the PAOI and the RVD diagnosed by ECHO and the patients' short outcome. We realized best cut off point for Qanadli score index as a predictor for RVD diagnosed by ECHO results was > 27.5 %and as a predictor for outcome of the studied patients was > 42.5% with 100% and 71.43% sensitivity and 81.25% and 88.24% specificity respectively.

Conclusion: Qanadli score calculated by CTPA correlates strongly and positively with RVD and can be used to predicte a higher mortality risk so PE scoring and CT cardiac changes must be essential points in our radiology reports of PE cases.

Key Words: Pulmonary embolism; Computed tomography angiography; Right ventricular dysfunction; Qanadli score; Pulmonary artery obstructive index.

INTRODUCTION

Acute pulmonary embolism (PE) is a common and potentially fatal disease with mortality ranging from 2% to 7%, even when treated with anticoagulation. Rapid risk assessment is essential in selecting the appropriate treatment strategy in patients with acute PE because high-risk patients may benefit from thrombolysis or embolectomy in addition to anticoagulation ***(Subramaniam et al., 2008).***

Mortality is thought to be caused in part by acute pulmonary arterial hypertension caused by PE, which initially results in right ventricular dysfunction (RVD), and may progress to right ventricular failure and circulatory collapse. Patients with RVD after PE have a higher mortality rate than those with normal right ventricular function even if hemodynamically stable at presentation ***(Van der Meer et al., 2005).***

Echocardiography has emerged as an important prognostic tool for risk stratification, with right ventricular dysfunction (RVD) serving as an independent predictor of short term mortality. Disadvantages of echocardiography include operator dependent, and an occasional poor imaging quality of the right ventricle (RV) ***(Goldhaber, 2002).***

Nowadays, computed tomography angiography (CTA) is by far the most commonly used modality to diagnose pulmonary embolism. CTA also allows appreciating vessel and cardiac chamber size. Furthermore, contrast medium flow is a dynamic process. Thus, it provides clues for dynamic or functional parameters, therefore making multislice chest CTA an attractive alternative to echocardiography for prognostic assessment. Using information given by a single test also avoids time consuming and often costly supplemental procedures. Our aim of this study is to investigate the prognostic validity of CTPA as a rapid and single method of identifying clinical severity and predicting poor clinical outcomes compared to Echocardiography in same patients ***(Espinosa et al., 2010).***

AIM OF THE WORK

To evaluate the role of CT pulmonary angiography (CTPA) in the assessment of pulmonary embolism (PE) severity and the related CT cardiac changes in correlation with echocardiographic data and patient’s outcome.

Chapter 1

ANATOMY

Gross Anatomy of the Lungs:

The lungs are pyramid-shaped, paired organs which are connected to the trachea by the right and left bronchi, on the inferior surface. The lungs are enclosed by the pleurae, which are attached to the mediastinum., the lungs are bordered by the diaphragm. The right lung is shorter and wider than the left lung, and the left lung occupies a smaller volume than the right. The cardiac notch is an indentation on the surface of the left lung that allows space for the heart. The apex of the lung is the superior region, whereas the base is the opposite region near the diaphragm. The mediastinal surface faces the midline. The costal surface of the lung borders the ribs. (fig 1) ***(Butler et al., 1999).***

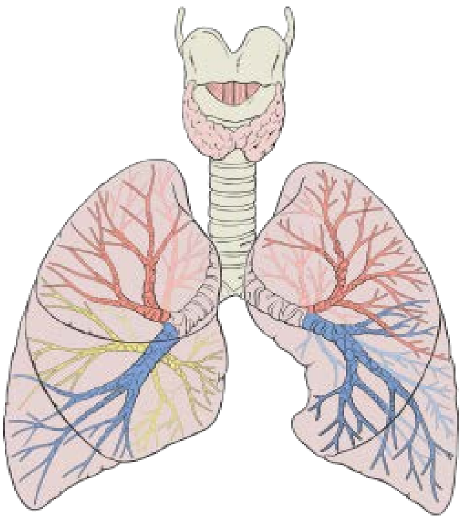

Fig. (1): Diagram of the human lungs with the respiratory tract visible, and different colours for each lobe ***(Drake et al., 2009).***

Normal anatomy of the pulmonary circulation

1. Pulmonary artery anatomy:

In the normal adult anatomy, the pulmonary trunk which is also known as main pulmonary artery, may have a diameter as great as 28 mm. The normal main pulmonary artery (MPA) divides into left and right branches before it exits the pericardium ***(Khadir et al., 2014).*** The right and left pulmonary arteries should be of approximately equal size, despite that the left pulmonary artery appears slightly larger in most subjects ***(Castañer et al., 2006).***

The left pulmonary artery (LPA) travels over the left mainstem bronchus before dividing into its two branches at the root of the left lung. At the root of the right lung, The right pulmonary artery (RPA) continues from the MPA before diving into its two main branches, the superior and inferior (interlobar) trunk, The superior trunk supplies the right upper lobe with the interlobar trunk supplying the middle and lower lobes. The lobar branches divide into segmental and subsegmental arteries. Right middle lobe medial and lateral segmental arteries may originate as a common trunk from the interlobar artery or as separate branches. The right lower lobe artery first divide in to an apical segmental branch and distal to this the right lower lobe artery is called the basal trunk. Lower lobe artery gives off the anterior basal and medial basal followed by the lateral and posterior basal segmental arteries. On the left, there is no truncus anterior, and the segmental branches originate directly from the LPA. For the left upper lobe and lingual arteries, there may be five to seven segmental branches. The superior segmental artery of the lower lobe originate from the left interlobar artery above the origin of lingular branches. Caudal to this, the left interlobar artery turns to basal trunk which givie rise to lower lobe segmental branches. The basal branches may be duplicated or triplicated (fig 2) ***(Khadir et al., 2014).***

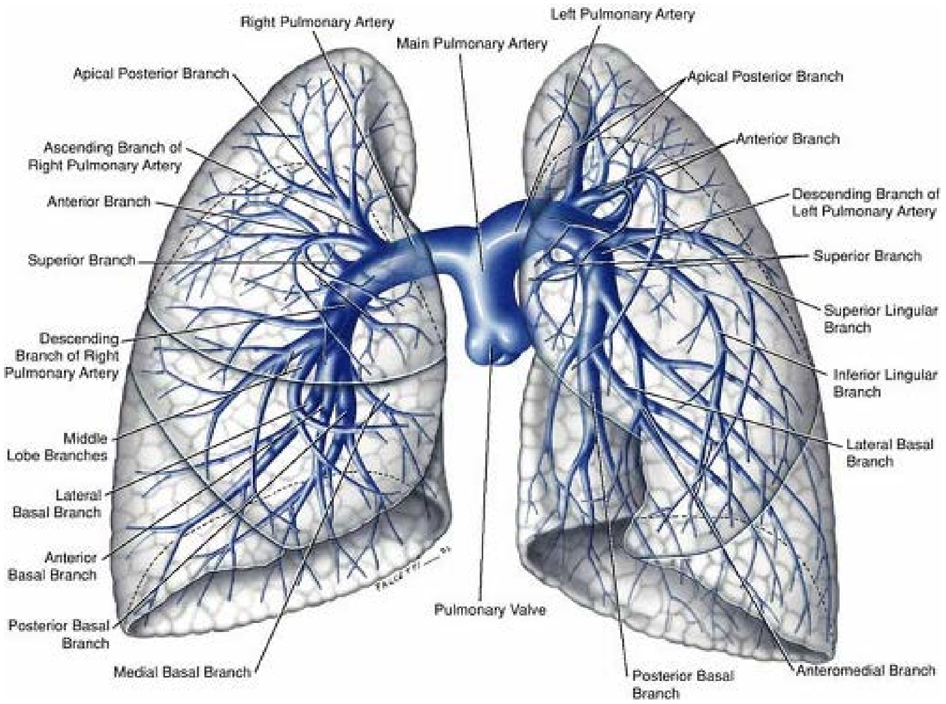

Fig. (2): Diagram of the distribution of the pulmonary arteries in both lungs ***(Uflacker, 1997).***

Pulmonary arteries (main, lobar, segmental, and subsegmental) with a diameter greater than 0.5 mm are referred to as elastic pulmonary arteries. They course downward along the bronchi to the subsegmental level, and their diameters are similar to those of the adjacent airways. Beyond the subsegmental bronchi, these vessels transition to muscular arteries, which accompany the peripheral airways downward until the level of the terminal bronchioles, where these arteries become arterioles (0.15–0.015 mm in diameter), which proceed along the respiratory bronchioles and alveolar ducts to form capillary network in the alveolar walls ***(Frazier et al., 2000).***

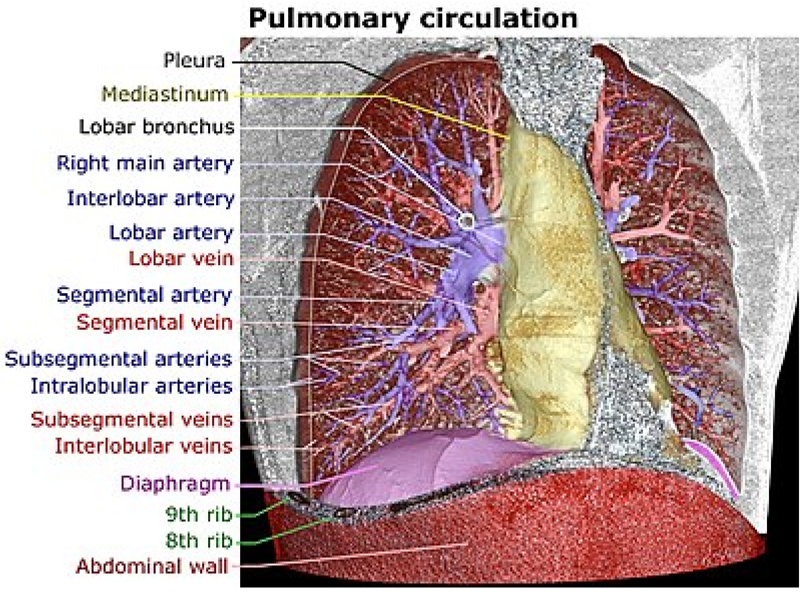

Fig. (3): 3D rendering of a high resolution computed tomography of the thorax. The anterior thoracic wall, the airways and the pulmonary vessels anterior to the root of the lung have been digitally removed in order to visualize the different levels of the pulmonary circulation ***(Drake et al., 2009).***

2. *Bronchial arteries:*

- **Gross anatomy**

The bronchial arteries typically arise from the thoracic aorta at the T3-T8 levels with ~70% (range 64-80%) arising from the T5-T6 level (fig 4) ***(Walker et al., 2015).***

- **Left bronchial arteries**

There are usually two bronchial arteries on the left that originate directly from the anterior surface of the thoracic aorta

Superior left bronchial artery: arises from the anteromedial surface of the aortic arch, lateral to the carina and posterior to the left main bronchus

Inferior left bronchial artery: also arises from the aorta and is parallel to the superior artery, but inferior to the left main bronchus.

- **Right bronchial artery**

The right bronchial artery has a common origin with a posterior intercostal artery and this is called the intercostobronchial trunk (ICBT) and arises from the right posterolateral aspect of the thoracic aorta ***(Walker et al., 2015).***

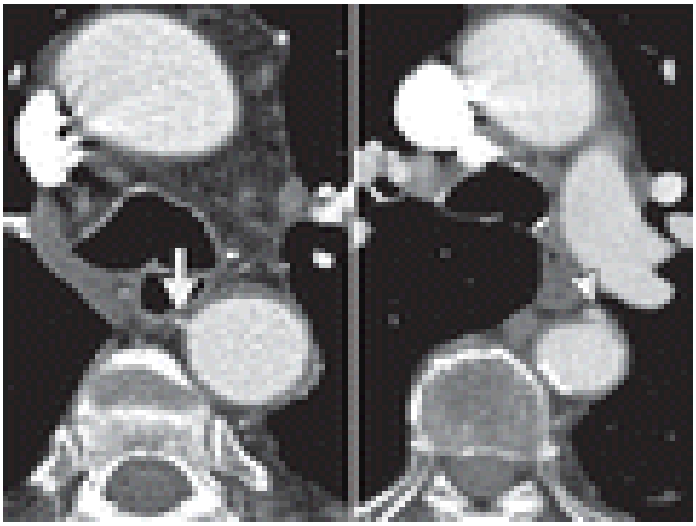

Fig. (4): Normal orthotopic and ectopic bronchial arteries. (a) Axial computed tomographic (CT) angiograms show an orthotopic right bronchial artery (arrow) originating from the anteromedial thoracic aortic wall and an orthotopic left bronchial artery (arrowhead) originating from the anterior thoracic aortic wall. The normal bronchial arteries (arrows) as small nodular or linear enhancing mediastinal structures with a small diameter (<2 mm) ***(Walker et al., 2015).***

3. The pulmonary veins:

Drain oxygenated blood from the lungs to the left atrium. A small amount of blood is also drained from the lungs by the bronchial veins ***(Cronin et al., 2004).***

Gross anatomy(fig 5)

There are typically four pulmonary veins, two draining each lung:

- **Right superior:** drains the right upper and middle lobes.
- **Right inferior:** drains the right lower lobe.

- **Left superior:** drains the left upper lobe.
- **Left inferior:** drains the left lower lobe.

The pulmonary veins course in the intersegmental septa and do not run with the bronchi like the pulmonary arteries do ***(Lacomis et al., 2003).***

The superior pulmonary veins take an inferomedial oblique course whereas the inferior pulmonary veins run horizontally peripherally before taking a more vertical course. They pass through the lung hilum, antero-inferiorly to the pulmonary arteries, to form a short intrapericardial segment draining into the left atrium. The ostia of the inferior pulmonary veins are more posteromedial and the left pulmonary veins are more superior ***(Cronin et al., 2007).***

There is great communication with deep bronchial veins within the lung and with the superficial bronchial veins at the hilum ***(Cronin et al., 2004)***.

The pulmonary veins are covered by a short (~9 mm) myocardial layer, that is often the electrical focus of atrial fibrillation with the left superior pulmonary vein being the foci for about half of cases. These abnormal foci can be treated with RFA ***(Cronin et al., 2007).***

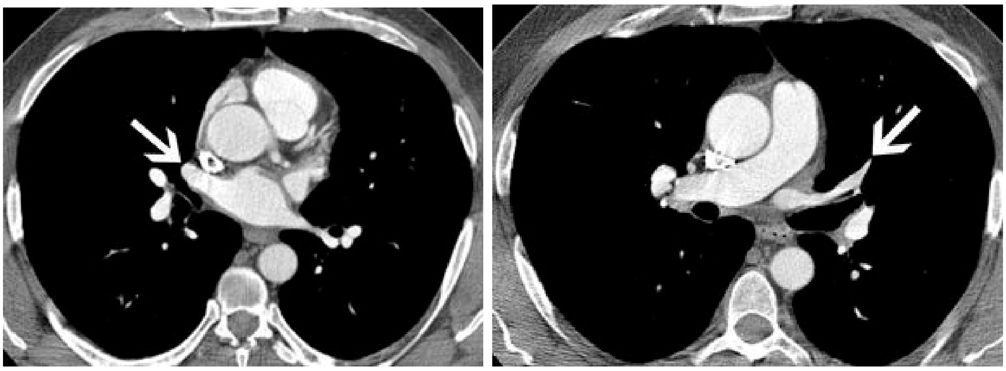

Fig. (5): Axial CT scans of normal pulmonary veins obtained in 40-year-old. Axial CT scans show right superior pulmonary vein (arrow, A) and left superior pulmonary vein (arrow, B) ***(Cronin et al., 2004).***

Anatomy of the Dual Pulmonary Circulation:

The lungs are supplied by two separate vascular systems consisting of the pulmonary and bronchial arteries. The pulmonary arteries carry deoxygenated blood at low pressure which supply 99% of the blood flow to the lungs and participate in gas exchange process at the alveolar capillary membrane. The bronchial arteries carry oxygenated blood to the lungs at a pressure which is six times that of the pulmonary arteries. The bronchial arteries provide nourishment to the supporting structures of the lungs, including the pulmonary arteries, but they do not participate in gas exchange. They are connected to the pulmonary arteries through several microvascular anastomoses at the level of the alveoli and respiratory bronchioles ***(Walker et al., 2015).***

The primary circulation is the pulmonary arteries, which convey venous blood to the lungs from the heart. A pulmonary artery branch accompanies the bronchial tree and ends in capillary network within the alveolar wall ***(Khadir et al., 2014).***

Anatomy of right ventricle:

The right ventricle is the most anteriorly situated cardiac chamber since it is located immediately behind the sternum. It also marks the inferior border of the cardiac silhouette. The left ventricle is of near conical shape, the right ventricle is more triangular in shape when viewed from the front and it curves over the left ventricle. When seen from the apex, the right edge of the right ventricle is sharp, forming the acute margin of the heart (fig 6) ***(Ho et al., 2006).***

The right ventricle has thinner walls than the left ventricle due to lower right sided pressures compared to the left ventricle. It forms almost all of the anterior and inferior borders of the heart. It is separated from the left ventricle by the interventricular (IV) septum, which is normally concave in shape (i.e. bulges into the right ventricle). It has three walls named anterior, inferior, and septal ***(Butler et al., 1999).***

The **right ventricle** is the most anterior of the four heart chambers. It receives deoxygenated blood from the right atrium and pumps it into the pulmonary circulation. Blood enters the right ventricle through the atrioventricular orifice containing the tricuspid valve during diastole and in systole is ejected out through the pulmonary valve into the pulmonary trunk ***(Ho et al., 2006).***

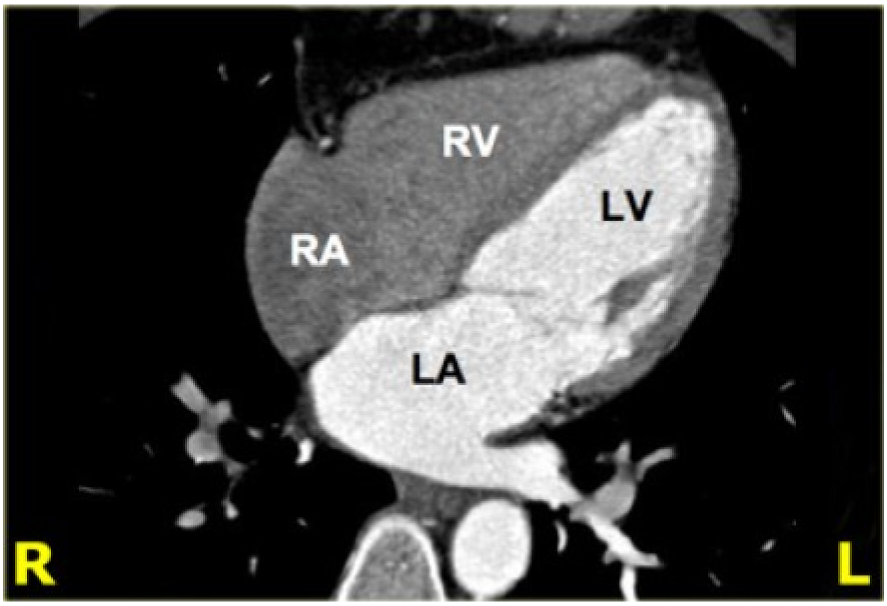

Fig. (6): CT 4chamber view showing RA=right atrium, RV=right ventricle, LA=left atrium, LV=left ventricle ***(Ho et al., 2006).***

Congenital Anomalies:

1. Pulmonary arteries:

Most congenital anomalies of the pulmonary arteries in adults are discovered incidentally on chest radiographs or CT scans ***(Castañer et al., 2006).***

A) Unilateral Proximal Interruption of Arteries

Proximal interruption of the left or right pulmonary artery is an uncommon developmental anomaly. The term interruption is used in preference to absence of a pulmonary artery, since the portion of the vessel which is in the lung is usually intact and patent. In proximal interruption, the pulmonary artery ends blindly at the hilum, and blood is supplied to the lung through collateral systemic vessels, mainly bronchial arteries but also transpleural branches of the intercostal, internal mammary, subclavian, and innominate arteries (fig 7). Interruption of the left pulmonary artery is always associated with a right aortic arch and other congenital cardiovascular anomalies, most common tetralogy of Fallot. Right pulmonary artery interruption is usually more common than left, and it is an isolated finding in most instances ***(Castañer et al., 2006).***

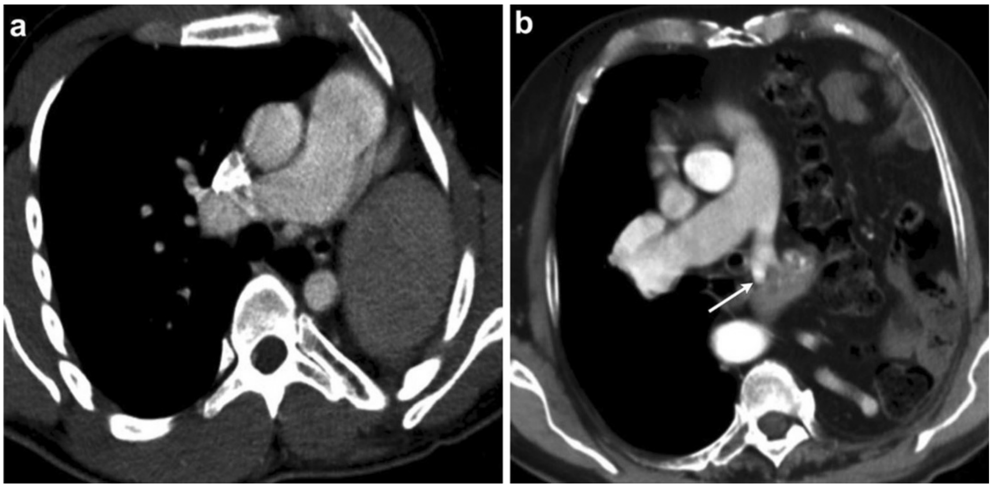

Fig. (7): Contrast-enhanced CT image (a) shows complete agenesis of left lung and left pulmonary artery. The left hemithorax is smaller with mediastinal shift toward the left and also elevation of the left hemidiaphragm. The abdominal contents can be seen in the left hemithorax. Contrast-enhanced axial CT image (b) demonstrates partial agenesis of the left pulmonary artery (*arrow*) with hypoplasia of left lung. No mediastinal shift, but the abdominal organs extend into the thorax ***(Khadir et al., 2014).***