European Journal of Radiology 84 (2015) 2526–2532

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Evaluation of right atrium-to-right ventricle diameter ratio on computed tomography pulmonary angiography: Prediction of adverse outcome and 30-day mortality

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ARTICLE INFO

Article history:
Received 11 June 2015
Received in revised form 31 July 2015
Accepted 30 August 2015

Keywords:
Pulmonary embolism
Computed tomography
Right atrium
Mortality
Adverse outcome

ABSTRACT

Objective: The aim of this study was to examine the association between right atrium (RA) and right ventricle (RV) diameters on computed tomography (CT) pulmonary angiography in response to acute pulmonary embolism (APE), in addition to 30-day mortality and adverse outcomes in patients with APE.
Methods: This retrospective study was accepted by the institutional ethics committee. From January 2013 to March 2014, 79 hospitalized adult patients with symptomatic APE were included. Inclusion criteria were a CT pulmonary angiography positive for pulmonary embolism, availability of patient records, and a follow-up of at least 30 days. A review of patient records and images was performed. The maximum diameters of the heart chambers were measured on a reconstructed four-chamber heart view, and the vascular obstruction index was calculated on CT pulmonary angiography.
Results: There were statistically significant relationships in both the RA/RV diameter ratio and the RV/left ventricle (LV) diameter ratio between patients with and without adverse outcomes ($p < 0.001$ and 0.002, respectively). Furthermore, there was a statistically significant difference in the RA/RV diameter ratio, but not in the RV/LV diameter ratio, between those with and without 30-day mortality ($p = 0.002$ and 0.148, respectively).
Conclusions: Measurement of the RA/RV diameter ratio may be an alternative and useful method for predicting 30-day mortality and adverse outcome in patients with APE.

1. Introduction

Acute pulmonary embolism (APE) is a common disease that may cause mortality or morbidity [1]. At the time of diagnosis, the existence of acute excess right ventricular (RV) pressure is an important pathophysiological predictor of PE severity and of adverse outcomes [2,3]. Massive or high-risk APE presenting with hypotension or shock is evidence of overt RV failure [3]. Patients with submassive or intermediate-risk APE who are normotensive at diagnosis have a low risk of death and an even more positive clinical outcome when anticoagulation is started rapidly [4]. Nevertheless, the in-hospital mortality of normotensive patients has been reported to vary from 3 to 15% [4]. Thus, precise and prompt risk stratification is important in planning an appropriate treatment strategy for normotensive intermediate-risk patients who might benefit from more aggressive therapies, such as thrombolysis or embolectomy, because early detection of subclinical RV dysfunction or injury may identify a patient group with an elevated risk of adverse outcomes[1,2,5].

Today, computed tomography (CT) is recognized as a valuable and quick method to identify RV dysfunction [3]. The ratio of the short axes of the RV and left ventricle (LV) diameters is the most commonly used measure to detect RV dysfunction [6]. Additionally, the diameters of the great thoracic vessels and of the inferior vena cava (IVC) are commonly measured [6].

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http://dx.doi.org/10.1016/j.ejrad.2015.08.019
0720-048X/

The right atrium (RA) is a dynamic structure and atrial compliance markedly improves the heart's output [7,8]. Also, the RA exhibits a compensatory response to RV pressure overload [9]. However, RA morphological changes in APE and prediction of long-term survival have been evaluated in only a few studies [10,11]. In pulmonary hypertension involving right heart strain, increased RA volume assists the RV during chronic pressure overload [12,13].

To our knowledge, no reported CT pulmonary angiography or transthoracic echocardiography (TTE) study to date has examined the usefulness of the RA/RV diameter ratio in predicting the risk of 30-day mortality and adverse outcomes in APE. Thus, the aim of this study was to examine the association of morphological changes in RA, as a response to APE, with 30-day mortality and adverse outcomes in patients with APE.

2. Materials and methods

This retrospective study was approved by the institutional ethics committee. All individuals provided written informed consent to participate in the study. Hospitalized adult patients with symptomatic APE were reviewed from January 2013 to March 2014.

The patients were identified by a computerized search of the PACS archives and medical records of our hospital. Inclusion criteria were performance of CT pulmonary angiography that was positive for central, segmental, and sub-segmental or both APE, availability of patient records, a follow-up of at least 30 days, and patients who were normotensive at presentation. Exclusion criteria were chronic pulmonary embolism, cardiogenic shock, hypotension (systolic blood pressure <90 mmHg), atrial fibrillation at presentation, and poor CT image quality. In total, 91 consecutive patients with symptomatic APE were identified. Nine patients were excluded because of incomplete imaging of the heart or insufficient contrast enhancement of the ventricular chambers for reliable delineation of the endocardial borders, causing poor CT image quality. Three patients were excluded because of cardiogenic shock or hypotension. Finally, 79 patients (39 women and 40 men) were included in the study.

The medical records of the included patients were examined for the presence of congestive heart failure, chronic renal dysfunction, pulmonary hypertension, cancer and myocardial infarction, and for adverse outcomes of APE. Adverse outcomes were defined as death within 30 days after APE, admission to an intensive care unit, cardiopulmonary resuscitation, mechanical ventilation, vasopressor therapy, and thrombolysis [4]. Three senior physicians determined 30-day mortality and adverse outcome after carefully reviewing all available data.

2.1. CT imaging techniques

A multi-detector CT system (Activision 16-row CT scanner; Toshiba Medical Systems, Otawara, Japan) was used for CT imaging. Protocols for routine CT pulmonary angiography without ECG gating were used for all patients (120 kV, 144 effective mAs, a pitch factor of 0.938, a helical factor of 15.0, a rotation time of 0.75 s and a reconstruction interval of 1 mm). In total, 100 mL non-ionic contrast agent (Ultravist 370; Bayer Schering Pharma, Berlin, Germany) was administered by a power injector at a rate of 3.0 mL/s via a peripheral venous line. Automatic bolus tracking (SureStart, Toshiba Medical Systems) was performed within the lumen of the pulmonary trunk as the region of interest, with a diagnostic scan starting threshold of 120Hounsfield units.

2.2. CT imaging analysis

All CT images were analyzed using a multimodal workstation (Infinitt PACS ver. 3.0.9.1, Infinitt Co., Ltd, Seoul, Korea). For each patient, CT parameters were measured in consensus by two radiologists with 8 and 6 years of experience in pulmonary imaging, respectively. The radiologists performing the measurements were blinded to the clinical presentations and outcomes. The reviewers were allowed to take any action to optimize visualization of the vessels and cardiac chambers. A four-chamber heart (4-CH) view was constructed as described previously by Quiroz et al. (Fig. 1a–c) [14]. The maximum transverse diameters of the RV and LV were measured on the reconstructed 4-CH view between the inner aspect of the interventricular septum and ventricular endocardium and perpendicular to the long axis of the heart (Fig. 2a). In the same image as the ventricular measurement, the maximum transverse diameters of the RA and LA were measured on reconstructed 4-CH views between the interatrial septum and the anterior wall of the RA and posterior wall of the LA (Fig. 2a).

The vascular obstruction index was calculated as defined previously by Qanadli et al. [15] The maximal obstruction index was 40 per patient, which is equivalent to obstruction of 100%. The pulmonary trunk diameter was measured in the axial plane as the short axis distance on a plane that displayed the pulmonary trunk and bifurcation (Fig. 2b). The maximum diameter of the ascending aorta was measured on the same image.

2.3. Statistical analysis

Statistical analyses were performed using SPSS software (ver. 19.0 for Windows; SPSS Inc., Chicago, IL, USA) and MedCalc (ver. 15.6 for Windows; MedCalc Software, Ostend, Belgium). Descriptive statistics of continuous variables are given as mean, standard deviation, median, minimum, and maximum values. Categorical variables are presented as frequencies and percentages. The Shapiro–Wilk test was used to test normality. The Mann–Whitney *U*-test was used for non-parametric two-group comparisons. To determine optimal cutoff values for the RA/RV diameter ratio for detecting adverse outcomes and 30-day mortality, receiver-operating characteristic curves were analyzed, and the areas under the curve (AUC) were calculated. For all statistical comparisons, a p value < 0.05 was considered to indicate statistical significance.

3. Results

In this study, 79 patients with APE who were normotensive at presentation were included. Of these patients, 12 (15.2%) suffered from adverse outcomes and 8 (10.1%) died from cardiopulmonary arrest related to APE within 30 days. The baseline characteristics and comorbidities of the patients are presented in Table 1. The CT findings of the patients are presented in Tables 2 and 3. No significant difference was found in age, gender, systolic or diastolic blood pressure or in risk factors between patients with and without adverse outcomes. There were statistically significant differences in age and presence of diabetes mellitus between patients with and without 30-day mortality ($p < 0.001$ and 0.014, respectively).

3.1. RA/RV diameter ratio

The median RA/RV diameter ratio in all patients was 1.18 (min 0.77, max 1.99). There was a statistically significant relationship between the RA/RV diameter ratio and 30-day mortality associated with APE ($p = 0.002$). The median RA/RV diameter ratio was 0.97 (min 0.77, max 1.24) in the 30-day mortality group and 1.20 (min 0.83, max 1.99) in the non-mortality group. Also, a statistically significant relationship was found between the RA/RV diameter ratio and adverse outcomes ($p < 0.001$). The median RA/RV diameter ratio was 1.01 (min 0.77, max 1.32) in the adverse outcome group and 1.21 (min 0.90, max 1.99) in patients without an adverse outcome. The decreased RA/RV diameter ratio in both the 30-day mortality