

# The Correlation between Right Descending Pulmonary Artery Diameter and Echocardiography-Estimated Systolic Pulmonary Artery Pressure

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**Background:** Enlargement of the hilar branches of the pulmonary artery, in particular of the right descending pulmonary artery, has been accepted as a sign of pulmonary hypertension (PH). To clarify its diagnostic value, we investigated the relationship between right descending pulmonary artery diameter (RDPAD) and systolic pulmonary artery pressure (SPAP).

**Methods:** In a total of 229 subjects enrolled, SPAP was estimated by transthoracic Doppler echocardiography. PH was defined as SPAP greater than 30 mmHg. RDPAD was measured on a chest X-ray (postero-anterior view) taken within one month of the echocardiography. We applied two-sample Student's *t*-test to test the difference of RDPAD between groups with and without PH. Linear regression analysis was performed to assess the relationship between SPAP and RDPAD. Receiver operating characteristic (ROC) curve was done to seek a potential cut-off point of RDPAD that discriminated between PH and non-PH.

**Results:** Two-sample Student's *t*-test revealed RDPAD were higher in the PH group than the non-PH group ( $p = 0.024$ ). Linear regression analysis showed  $SPAP = 20.9 + 0.53 \times RDPAD$  ( $p = 0.047$ ), which implied a positive association between RDPAD and SPAP. However, ROC curve analysis did not find any satisfactory cut-off point of RDPAD for predicting PH. Even with RDPAD value of mean + 2SD of the non-PH group, its sensitivity and specificity, positive predictive value, negative predictive value, overall accuracy, positive likelihood ratio, and negative likelihood value were 6.7%, 97.9%, 66.8%, 62.3%, 62.5%, 3.1, and 0.95, respectively.

**Conclusion:** Our study demonstrated RDPAD on the chest radiographic film significantly correlated with echocardiography-estimated SPAP. But as a diagnostic tool, RDPAD was not good enough to predict PH.

**Key Words:** Pulmonary artery pressure • Right descending pulmonary artery

## INTRODUCTION

Pulmonary hypertension (PH) is defined as a sustained elevation of mean pulmonary arterial pressure more than 25 mmHg at rest or more than 30 mmHg with exercise by right heart catheterization.<sup>1,2</sup> No matter what kind of etiology it has, PH may lead to right heart enlargement and failure. Clinically, early recognition of PH is difficult because there are no specific symptoms or reliable physical examination findings.

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Electrocardiography provides suboptimal sensitivity to detect PH, although its specificity is relatively satisfactory.<sup>3</sup> Right heart catheterization is the gold standard, but it is invasive and expensive. On the other hand, echocardiography has been a more practical, easy-to-use, and accurate way to identify PH since the 1980's. In most textbooks available, the upper limit of normal systolic pulmonary artery pressure (SPAP) is 30 mmHg.<sup>4</sup>

The normal diameter of the right descending pulmonary artery on the postero-anterior chest radiography, established by Dr. Chang, is 10-16 mm for adults over 40 years old.<sup>5</sup> Dilated pulmonary artery is the consequence of elevated pulmonary artery pressure (PAP) or increased blood flow. It has been well accepted that the most reliable radiographic sign of PH is the increased width of the descending branch of the right pulmonary artery.<sup>6-8</sup> In order to assess the clinical utility of this quantity, we conducted this study to investigate the relationship between right descending pulmonary artery diameter (RDPAD) and echocardiography-estimated SPAP. We also assessed its diagnostic value for predicting PH.

## METHODS

From September 2004 to June 2007, there were a total of 229 subjects enrolled in this study. The subjects consisted of 96 males and 133 females. Their ages ranged from 15 to 96 years old. Most of the subjects came from cardiovascular and chest outpatient clinics. No subject had atrial fibrillation or congenital diseases of the pulmonary artery such as pulmonary valve stenosis. All subjects had detectable tricuspid valve regurgitation (TR) by transthoracic Doppler echocardiography (Sonos5500, Agilent Technologies, California, USA), so the SPAP was able to be estimated. Briefly speaking, the continuous-wave Doppler detected the flow of TR. The TR pressure gradient ( $\Delta P$ ) was calculated from its peak velocity ( $V$ ) according to the Bernoulli equation ( $\Delta P = 4V^2$ ). Then SPAP was estimated by TR pressure gradient added with right atrial pressure that was estimated by the dimension of the inferior vena cava during inspiration.<sup>9</sup> We defined PH as SPAP greater than 30 mmHg.<sup>4</sup>

Standing chest X-ray films (standard postero-anterior view) of each subject were taken within 1 month of the echocardiography examination. All subjects were

asked to fully inspire while undergoing the chest X-ray exam. RDPAD were measured at the level of the first bifurcation of the right pulmonary trunk on the Picture Archive Communication System. In order to avoid inter-observer bias, all the measurements were made by a single physician.

Shapiro-Wilk W test was done to test the normality of SPAP and RDPAD. Without the violation of normal distribution in RDPAD, we chose the parametric approach for statistics. RDPAD was compared by two-sample Student's *t*-test between the PH and non-PH groups. Simple linear regression was used to build the model of SPAP predicted by RDPAD. Receiver operating characteristic (ROC) curve was used to find an optimal cut-off point for detecting PH. P value below 0.05 was considered as statistically significant. The statistical software used was Stata 9 (StataCorp, 4905 Lakeway Drive, College Station, Texas 77845, USA. <http://www.stata.com>).

## RESULTS

First, we conducted Shapiro-Wilk W test to check the assumption of normal distribution in the data of RDPAD and SPAP. RDPAD did not violate the assumption of normality, as  $p = 0.90$ . However, SPAP seemed not distributed normally, as  $p < 0.00001$ . Nevertheless, with our relatively adequate sample size and by the Central Limit Theorem, to avoid more complex statistics, we still chose the parametric approach for statistical analyses.

There were 89 subjects in the PH group and 140 subjects in the non-PH group. Their baseline characteristics are shown in Table 1. In the PH group, RDPAD was  $15.9 \pm 3.1$  mm. In the non-PH group, RDPAD was  $15.0 \pm 2.8$  mm. RDPAD was significantly different between the two groups ( $p = 0.024$ ).

To elucidate the relationship between SPAP and RDPAD, we first drew the scatter plot for SPAP and RDPAD. We then analyzed their relationship by simple linear regression. It was found that  $SPAP = 20.9 + 0.53 \cdot RDPAD$ , with merely R-square = 0.017 and  $p = 0.047$  for the null hypothesis of slope = 0 (Figure 1).

With the definition of PH as SPAP over 30 mmHg, we then checked whether RDPAD could act as a satisfactory diagnostic tool to differentiate PH. We trans-

formed RDPAD from a scale variable to an ordinal variable by increments of 1 from 7 to 25 (the range of RDPAD was 7~25) with the Gaussian function that generates the closest smaller integer. With the PH as the binary reference variable and transformed ordinal RDPAD as the classifying variable, we obtained the sensitivity and specificity values of each RDPAD cut-off point

**Table 1.** Baseline characteristics of the pulmonary hypertension (PH) and non-PH groups

	PH (n = 89)	non-PH (n = 140)	P-value
Male (n, %)	39 (43.8%)	57 (40.7%)	0.64
Age	75.7 ± 13.4	66.4 ± 14.4	0.05
Hypertension (n, %)	38 (42.7%)	47 (50.0%)	0.21
COPD (n, %)	13 (14.6%)	13 (9.3%)	0.26
LVEDD (mm)	46.2 ± 6.8	44.8 ± 5.7	0.11
LVEF (%)	67.1 ± 14.7	69.6 ± 9.6	0.06
SPAP (mmHg)	40.4 ± 10.9	21.8 ± 4.7	0.001
RDPAD (mm)	15.9 ± 3.1	15.0 ± 2.8	0.02

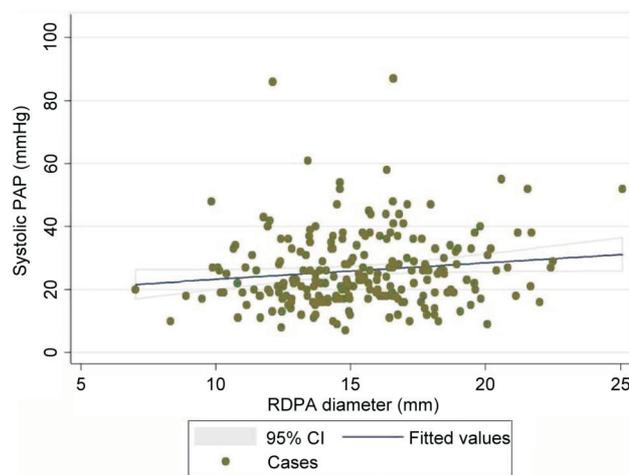
COPD, chronic obstructive pulmonary disease; LVEDD, left ventricular end-diastolic dimension; LVEF, left ventricular ejection fraction; RDPAD, right descending pulmonary artery diameter; SPAP, systolic pulmonary artery pressure.

**Table 2.** List of sensitivity and specificity of different cut-off points for right descending pulmonary artery diameter in discriminating pulmonary hypertension (as systolic pulmonary artery pressure > 30 mmHg)

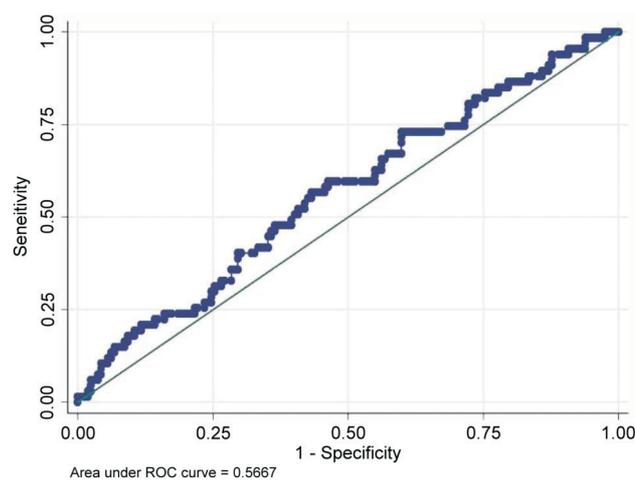
Cut-off point (mm)	Sensitivity	Specificity	Correctly classified
≥ 7	100.00%	0.00%	38.86%
≥ 8	100.00%	0.71%	39.30%
≥ 9	100.00%	2.14%	40.17%
≥ 10	97.75%	2.86%	39.74%
≥ 11	94.38%	7.86%	41.48%
≥ 12	89.89%	12.86%	42.79%
≥ 13	82.02%	25.00%	47.16%
≥ 14	73.03%	39.29%	52.40%
≥ 15	60.67%	55.71%	57.64%
≥ 16	49.44%	64.29%	58.52%
≥ 17	30.34%	76.43%	58.52%
≥ 18	21.35%	84.29%	59.83%
≥ 19	14.61%	92.14%	62.01%
≥ 20	11.24%	96.43%	63.32%
≥ 21	6.74%	97.86%	62.45%
≥ 22	3.37%	99.29%	62.01%
≥ 25	1.12%	100.00%	61.57%
> 25	0.00%	100.00%	61.14%

(Table 2) and then plotted them into the ROC curve (Figure 2). The area-under-curve of the ROC curve was 0.57, and the ROC curve showed a non-convex outline that offered no optimal maximal distance from the straight line with slope of -1. These findings implied RDPAD might not be a satisfactory tool to discriminate PH.

Usually, we may take two standard deviations away from the mean in the control group as the abnormal value since the likelihood of being more extreme is less than



**Figure 1.** Linear regression analysis showed a significant correlation between right descending pulmonary artery diameter (RDPAD) and systolic pulmonary artery pressure (SPAP).  $SPAP = 20.9 + 0.53 * RDPAD$  ( $p = 0.047$ ).



**Figure 2.** Non-convex ROC curve implied there was no satisfactory cut-off value of right descending pulmonary artery diameter (RDPAD) that discriminated pulmonary hypertension that was defined by echo-measured systolic pulmonary artery pressure (SPAP) over 30 mmHg. An area under the ROC curve close to 0.5 also implied poor performance in differentiating SPAP more than 30 mmHg.

2.5%.<sup>10</sup> Similarly we might take the mean + 2SD of the RDPAD in the non-PH group as the arbitrary cut-off point for distinguishing from the PH group. We found that value to be 21 mm. We tested how good that value was in diagnosis of PH. With the cut-off point of RDPAD as 21 mm, we found its sensitivity, specificity, positive predictive value, negative predictive value, overall accuracy, positive likelihood ratio, and negative likelihood ratio to be 6.7%, 97.9%, 66.8%, 62.3%, 62.5%, 3.1 and 0.95, respectively (Table 2). These parameters suggested RDPAD might be an unsatisfactory diagnostic tool to discriminate PH.

## DISCUSSION

Our study demonstrated RDPAD on chest radiographic films had a significant correlation with echocardiography-estimated systolic PAP. Although RDPAD had favorable specificity, it lacked sensitivity. Both the positive and negative predictive values were disappointing. RDPAD provided suboptimal accuracy in predicting the presence of PH. Therefore, we should not regard RDPAD as an accurate diagnostic tool in screening PH.

The first study about RDPAD and PH was reported by Viamonte et al.<sup>6</sup> They grouped signs of roentgenography into categories that based on mean PAP by right heart catheterization. If RDPAD less than 14 mm was used as a cut-off value, they found the accuracy of diagnosis of mean PAP less than 20 mm Hg was 69.23%.<sup>6</sup> Chen et al. analyzed the relationship between RDPAD and catheter-derived mean PAP. A RDPAD of 16 mm or more indicated the presence of PH. On the other hand, PH could be virtually excluded with RDPAD of 11 mm or less. Intermediate RDPAD measurements were of limited use in predicting the presence of PH.<sup>7</sup> Teichmann et al. found there was a positive association between RDPAD and catheter-derived mean PAP, but they noted the sensitivity of correct radiographic diagnosis in patients with PH was only 72% if the cut-off point of RDPAD was set as 18 mm.<sup>8</sup> Similarly, Matthay et al. and Chetty et al. also declared that RDPAD correlated well with catheter-derived mean PAP.<sup>11,12</sup>

In the above studies, measurements of PAP were obtained by cardiac catheterization. Although right heart catheterization is the gold standard for the measurement of PAP, the procedure is not without expense and risk.

Doppler-derived calculation using echocardiography gives a noninvasive means of estimating SPAP. Echocardiography is widely used for the diagnosis of PH in our daily practice. Previous studies proved a good agreement between Doppler-estimated and catheterization-measured SPAP. Its validation and reliability has been confirmed in the past few decades.<sup>13-15</sup>

However, there are still some methodologic issues which should be taken into consideration. The first issue is that the atrial pressure at the time of peak transtricuspid flow could not be precisely measured by echocardiography. Second, poorly detectable tricuspid regurgitation always makes the assessment of spectral contour difficult. In addition, possible technique errors might also be encountered, including large beam-to-flow angle, changes in signal-to-noise ratio caused by different cardiac cycle lengths and respiration variation.<sup>13</sup>

Chhabra et al. analyzed the relationship between RDPAD on chest X-ray films and echocardiography-estimated SPAP. They found the correlation was significant ( $r = 0.42$ ,  $p < 0.05$ ). The utility of RDPAD widened more than 20 mm in identifying patients with PH was evaluated. Its specificity was 100%, but sensitivity and negative predictive value were low (41% and 20%, respectively).<sup>16</sup>

The design and results of our study are similar with those done by Chhabra et al.<sup>16</sup> Although the specificity was high, the relatively low sensitivity and low negative predictive value suggest that RDPAD on chest radiographs could not serve the purpose of being a screening test for PH. Even though our study supported the concept that the larger RDPAD is, the higher PAP is, this radiological sign has limitations in predicting PH.

As for the limitations and potential sources of bias of our study, our ROC analysis used the surrogate gold standard of measurement by echo instead of catheterization. Thus, our reported sensitivity and specificity might be biased. Our simple linear regression model had a low R-square, implying the RDPAD-only model might have sub-optimal goodness of fit; we might seek more covariates in the model in a future study.

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