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ORIGINAL RESEARCH

Axial CT measured main pulmonary artery diameter to predict the presence and degree of pulmonary hypertension

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Abstract

We performed this study to investigate if main pulmonary artery (mPA) diameter measured by axial chest computed tomography (CT) can predict the presence and degree of echocardiography-measured pulmonary hypertension (ePH) among emergency department (ED) patients. This retrospective cross-sectional study enrolled patients who underwent both chest CT and echocardiography within 24 h at the ED. The ePH was estimated using right ventricular systolic pressure (RVSP). RVSP <40 mmHg was classified as normal; 40–49 mmHg, mild ePH; 50–75 mmHg, moderate ePH; and ≥76 mmHg, severe ePH. Among 485 adult patients, 297 (61.2%) had normal RVSP and mean mPA of 30.3 mm. The numbers of patients with mild, moderate and severe ePH were 92 (19.0%), 85 (17.5%) and 11 (2.3%) with corresponding mean mPA diameters of 32.4, 34.5 and 35.9 mm, respectively. The best mPA diameters for predicting mild, moderate and severe ePH were 30.6, 31.8 and 33.8 mm, with area under the receiver operating characteristic curve of 0.697, 0.727 and 0.797 and sensitivities of 72.9%, 71.9% and 81.8%, respectively. Axial CT-measured mPA diameter can predict the presence and degree of ePH among ED patients. If the CT-measured mPA diameter is greater than 30.6 mm, the possibility of pulmonary hypertension should be considered and applied to the patient's treatment.

Keywords

Pulmonary artery; Pulmonary hypertension; Computed tomography; Thoracic radiography

1. Introduction

Pulmonary hypertension (PH) is a fatal progressive disease, and the recently reported 1-, 2- and 3-year mortality rates remain extremely high at 8%, 16% and 21%, respectively [1]. PH is caused by several factors; thus, long-term appropriate management should be focused on the specific treatment of the underlying cause of PH [2–4]. Although long-term PH management requires treatment for each underlying cause, the presence of PH has a significant impact on acute symptom management. This is because patients with PH usually have reduced cardiac reserve, reduced and fixed stroke volume, and poor tolerance to volume depletion/overload or medications that exert negative inotropic and chronotropic effects [5]. Therefore, awareness of the presence of PH is very important in the management of patients with PH at the emergency department (ED).

However, patients or doctors often fail to recognize the presence of PH [6]. The symptoms of PH, such as progressive dyspnea, unexplained dyspnea, fatigue and syncope, are not specific to this condition and can also be observed in many other diseases. In many cases, the symptoms of PH gradually worsen without being recognized by the patient. About 21.1% of patients' experience symptoms for >2 years before being diagnosed with PH [6]. Because PH is difficult to diagnose based on clinical suspicion, an objective diagnostic test is important.

The diagnosis of PH can only be confirmed *via* right heart catheterization when the mean pulmonary artery pressure is more than 20 mmHg in the resting state [7, 8]. However, invasive right heart catheterization usually cannot be performed immediately in the critical care setting. Therefore, a presumptive diagnosis of PH is generally made through noninvasive tests, particularly echocardiography [3, 4]. Once PH is suspected, echocardiography is recommended to assess the structure and function of the heart and determine the probability of PH [3, 4]. One meta-analysis revealed that the summary sensitivity and specificity for echocardiography for the diagnosis of PH were 83% and 72%, respectively [9]. Another recent meta-analysis showed that transthoracic echocardiography had a sensitivity and specificity of 53% and 83%, respectively [10].

Although echocardiography is the best rule-in test in critical care settings, such as the ED, for patients suspected to have PH, it is not usually possible during nighttime or holidays. Echocardiography is labor-intensive and takes a considerable amount of time (10–20 min for a normal patient and up to 1 h for abnormal patient) even if performed by an expert. Due to the growing demand for echocardiography, significant delays of several days to weeks occur even in developed countries [11]. Meanwhile, recent studies have reported that PH can be predicted using main pulmonary artery (mPA) diameter measured on axial computed tomography (CT) image [12, 13]. Given the 24/7 availability of chest CT in most EDs, authors conducted this study to determine whether echocardiography-measured PH (ePH) can be predicted using mPA diameter and mPA/ascending aorta (AA) ratio measured on axial chest CT image obtained from ED patients.

2. Methods

2.1 Study design and subjects

This retrospective cross-sectional study enrolled adult patients who underwent both (contrast- or noncontrast-enhanced) chest CT and echocardiography within 24 h at the ED from 01 January 2020, to 31 December 2021. Despite the lack of references, we assumed that if there was a considerable time interval between CT and echocardiography, the right ventricular systolic pressure (RVSP) would change over time (right atrial pressure (RAP) may change over time if changes occur in systemic vascular resistance or effective circulating volume). Therefore, we arbitrarily set the time limit between the two tests to 24 h. The exclusion criteria were (1) patients who underwent both CT and echocardiography at a time interval of more than 24 h and (2) patients in whom the mPA or AA diameter could not be accurately measured due to severe motion artifact and abutting mass or fluid (Fig. 1).

2.2 Sample size calculation

Studies conducted in the United States reported that about 0.8% of ED patients had PH [14, 15], but in South Korea, the prevalence of PH among ED patients is unknown. However, our echocardiography data for the past 3 months indicated that the proportion of patients with RVSP $\geq$40 mmHg was approximately 15%. The sample size for single receiver operating characteristic (ROC) curve analysis obtained using the formulas presented in the study by Hanley *et al*. [16] was 257 when the area under the ROC curve (AUC) was set to 0.700 and the required standard error to 0.05. To calculate the sample size for logistic regression, the following formula based on the concept of event per variable was used: $n = 100 + 50(i)$, where i denotes the number of independent variables in the final model [17]. When five independent variables are used, about 350 patients are needed. To satisfy the calculated sample size of 257–350, the study period of this retrospective study was set to the past 2 years.

2.3 Outcome measures

During the study period, CT scans were performed using Brilliance iCT-SP 128 (Philips Medical Systems, Best, The Netherlands). The default value for the recombinant parameters used was 2 mm for both slice thickness and slice spacing. Measurement was performed using the length-measuring tool built into the INFINITT PACS viewer (version 3.0.11.5, INFINITT Healthcare, Seoul, South Korea) program in a 27-in full high definition (1920 $\times$ 1080) resolution monitor environment. The mPA diameter was measured in the axial plane at the pulmonary artery bifurcation, orthogonal to the long axis of the pulmonary artery. To select the maximum mPA diameter, the axial images were continuously moved up and down on the mediastinum window setting (width, 350 HU; level, 40 HU) on noncontrast images. The AA diameter was measured on the same image that the maximum mPA diameter was measured on (Fig. 2). The maximum mPA and AA diameters were measured by three emergency physicians, and the interobserver agreement between the observers was assessed using the intraclass correlation coefficient (ICC). The ICC and 95% confidence interval (CI) were calculated using the two-way random-effects model under the condition of absolute agreement and mean rating (k = 3).

The ePH was estimated using the RVSP calculated based on the parameters extracted from the final report of the echocardiography. RVSP was calculated from the peak tricuspid regurgitant jet velocity (TRVmax) using the simplified Bernoulli equation ($RVSP = 4 \times TRVmax^2 + RAP$) [18–20].

The values of RAP were estimated according to the following conditions: inferior vena cava (IVC) diameter less than 2 cm and collapse of more than 50% during the respiratory cycle, 5 mmHg; IVC diameter less than 2 cm and collapse of less than 50% or IVC diameter more than 2 cm and collapse of more than 50%, 10 mmHg; and IVC diameter more than 2 cm and collapse of less than 50%, 15 mmHg [21, 22]. According to the calculated RVSP, RVSP $<$40 mmHg was classified as normal; 40–49 mmHg, mild ePH; 50–75 mmHg, moderate ePH; and $\geq$76 mmHg, severe ePH. During the study period, echocardiography was performed by certified sonographers, and the final report was confirmed by the attending cardiologist.

2.4 Statistical analysis

STATA for Windows (version 15.1; StataCorp LLC, College Station, TX, USA) was used to conduct statistical analysis. Continuous variables were expressed as mean $\pm$ standard deviation, and one-way analysis of variance with *post hoc* Tukey's test was used to compare the groups. Nominal variables were analyzed using chi-squared test and expressed as frequencies and percentages. $p < 0.05$ was considered to indicate statistical significance. Linear regression analysis was conducted to predict the relationship between mPA and RVSP. Furthermore, logistic regression analysis was conducted to determine the odds ratio. Through ROC curve analysis, the best cutoff values of the mPA diameter and mPA/AA ratio for predicting mild, moderate and severe ePH were determined, and the sensitivity and specificity of these values were calculated. AUC values between 0.9 and 1 were classified as excellent; 0.8 and 0.9, good; 0.7 and 0.8, fair; 0.6 and 0.7, poor; and 0.5 and 0.6, failed.

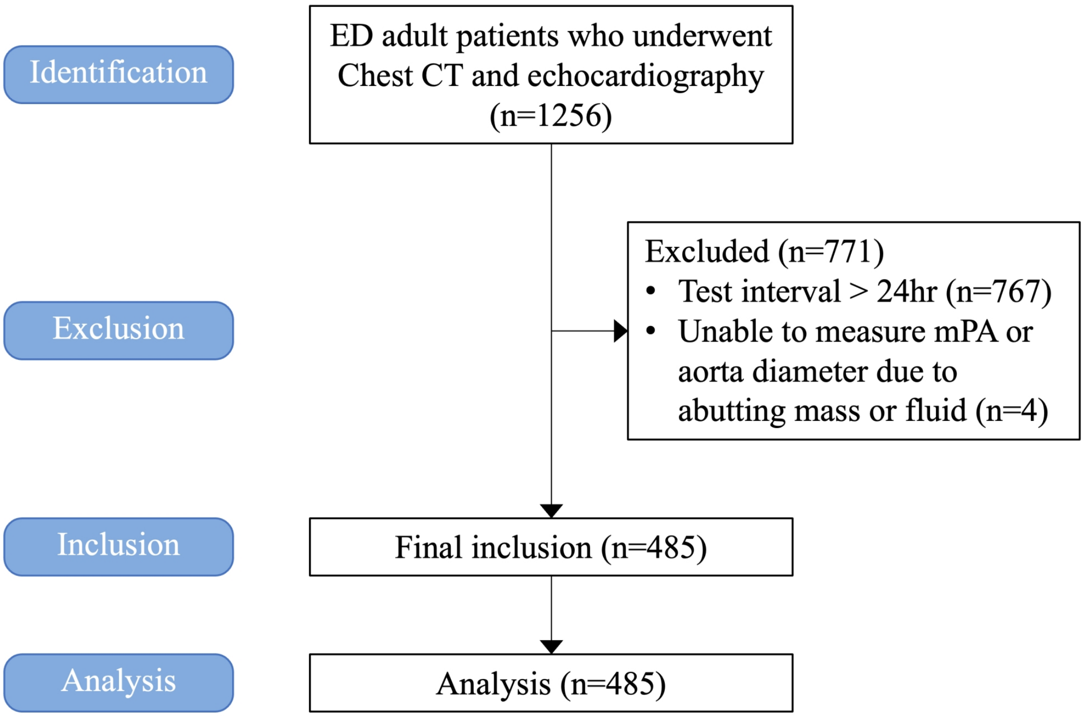

FIGURE 1. Patients selection diagram. ED: Emergency Department; CT: computed tomography; mPA: main pulmonary artery.

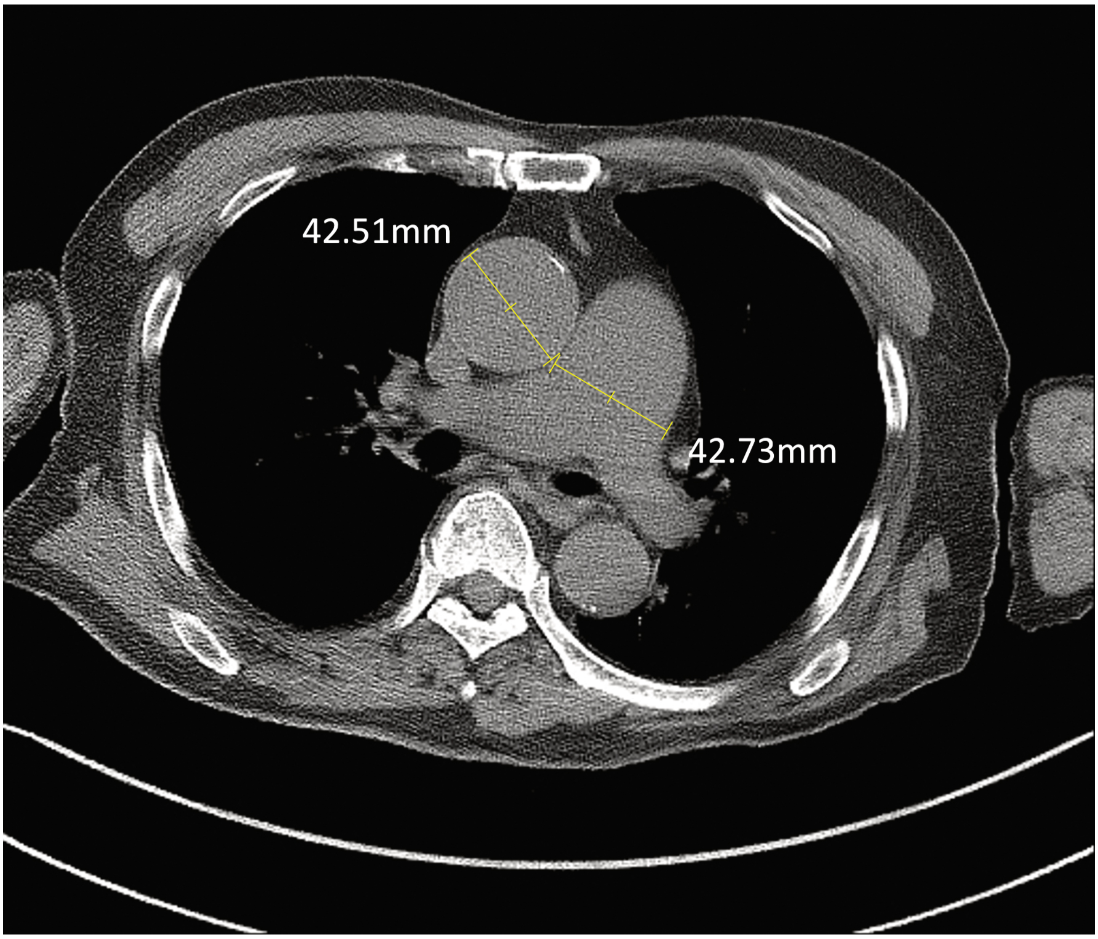

FIGURE 2. Measuring the maximum main pulmonary artery diameter and Aorta on axial CT image. Diameter of mPA was measured in the axial plane at the pulmonary artery bifurcation, orthogonal to the long axis of the pulmonary artery. The diameter of aorta was measured in the same image that measured the diameter of mPA.

3. Results

3.1 Patient characteristics

During the study period, 1256 adult patients underwent both (contrast- or noncontrast-enhanced) chest CT and echocardiography in our ED. The reasons for exclusion were time interval between chest CT and echocardiography of more than 24 h for 767 patients and failure to measure the mPA or AA diameter due to abutting mass or fluid for 4 patients. Thus, only 485 patients were included in the final analysis (Fig. 1).

The consistency between the three measurers for the maximum mPA and AA diameters was excellent. The average ICCs for the maximum mPA and AA diameter measurements were 0.927 (95% CI 0.851–0.965, $p < 0.001$) and 0.946 (95% CI 0.881–0.975, $p < 0.001$), respectively.

Patient characteristics as well as echocardiographic and CT findings are presented in Table 1. The mean mPA diameters of normal, mild ePH, moderate ePH and severe ePH were 30.3, 32.4, 34.5 and 35.9 mm, respectively. Furthermore, the mean mPA/AA ratios of normal, mild ePH, moderate ePH and severe ePH were 0.85, 0.88, 0.92 and 0.95, respectively. The mPA diameter and mPA/AA ratio were significantly different between the normal group and the mild, moderate, and severe ePH groups. The main reason for performing CT was dyspnea (27.2%), followed by fever (23.1%), abnormal findings on simple chest radiography (21.4%), chest pain (16.9%), trauma (4.3%) and others (7.0%).

3.2 Regression analysis

Multivariate linear regression analysis (adjusted for age and oxygen saturation) revealed that every 0.92-mm increase in the PA diameter can predict a 1-mmHg increase in RVSP [RVSP (mmHg) = 0.92 × mPA (mm) + 0.13 × Age (year) − 0.7 × Sat (%) + 66.1].

Multivariate logistic regression analysis (adjusted for age, sex and oxygen saturation) for predicting RVSP ≥40/50/76 is demonstrated in Table 2. The mPA diameter and mPA/AA ratio can independently predict ePH.

3.3 ROC curve analysis

The best mPA diameters for predicting mild, moderate and severe ePH were 30.6, 31.8 and 33.8 mm, respectively. The sensitivities of "mPA ≥30.6 mm for mild ePH", "mPA ≥31.8 mm for moderate ePH" and "mPA ≥33.8 mm for severe ePH" were 72.9%, 71.9% and 81.8%, respectively. The negative predictive values of "mPA ≥31.8 mm for moderate ePH" and "mPA ≥33.8 mm for severe ePH" were 90.2% and 99.4%, respectively (Table 3).

The best mPA/AA ratios for predicting mild, moderate and severe ePH were 0.85, 0.88 and 0.89, respectively. The sensitivities of "mPA/AA ≥0.85 for mild ePH", "mPA/AA ≥0.88 mm for moderate ePH" and "mPA/AA ≥0.89 for severe ePH" were 65.4%, 64.6% and 81.8%, respectively (Table 4).

The AUC value of the maximum mPA diameter for predicting ePH was greater than that of the mPA/AA ratio. The AUC values of mPA diameter and mPA/AA ratio for predicting mild ePH were 0.697 and 0.654; mild ePH, 0.727 and 0.643; and severe ePH, 0.797 and 0.714, respectively. This suggests that both the mPA diameter and mPA/AA ratio are poor predictors of mild ePH. While the mPA diameter is a fair indicator of moderate ePH, the mPA/AA ratio is a poor indicator of moderate ePH, but both were fair predictors of severe ePH.

4. Discussion

Patients with PH may often visit the ED with new acute symptoms or acute exacerbation of existing chronic symptoms, even without knowledge of the presence of PH. Because PH is difficult to diagnose based on symptoms alone, the development of an objective measurement tool can be of great significance. This study demonstrated that CT-measured mPA diameter can predict ePH among ED patients. In previous studies, axial CT mPA <29 mm was considered as upper normal limit [3, 12, 23]. However, a recent study suggested that ≥31.6 mm is a more statistically robust cutoff value for patients without interstitial lung disease [13]. A systematic review of the sensitivity and specificity of different PA diameter cutoff values for diagnosing PH reported an average cutoff value of 29.5 (range, 25.0–33.2) mm among 12 studies that included patients with different degrees of PH [18]. The present study suggested ≥30.6 mm as the best cutoff value for mild ePH. Because no number of 29 mm, 30 mm or 31 mm exactly determines the PH, it should be desirable to consider "29 to 31.6 mm" as a reference value to start suspecting the possibility of PH. In patients who visit the ED and undergo CT scans, the mPA diameter must be measured, and if it is ≥30.6 mm, the possibility of PH must be considered.

The most novel point of this study is that the optimal cutoff values for predicting mild, moderate and severe PH were presented. Mild PH may not be of great significance in the treatment of patients with acute symptoms, but PH of a moderate degree or higher can have important significance. Particularly, physicians should keep in mind that mPA diameter ≥31.8 mm fairly predicts moderate or severe ePH. If patients are suspected to have moderate to severe PH, certain medications such as beta-blockers should be avoided and volume depletion or hypoxemia corrected as soon as possible.

Previous studies reported that the mPA/AA ratio was strongly correlated with RHC-derived mean PA pressure and that dilatation of the mPA and an mPA/AA ratio >0.9–1.0 are highly indicative of PH [18, 23, 24]. The results of this study also further proved that the mPA/AA ratio can predict ePH. Interestingly, the optimal cutoff value for predicting mild ePH was found to be 0.85, which significantly differs from the previously known value of 1.0. Even the optimal cutoff value for predicting more than moderate ePH was 0.88 and did not exceed 0.9. This can be attributed to the difference in the study population. This study enrolled patients who underwent both CT and echocardiography within 24 h in the ED. It is presumed that only patients with acute symptoms such as dyspnea or chest pain were included. For patients with acute symptoms, authors suggest that mPA/AA ratio >0.85–0.89 predicts PH rather than the previously known values >0.90–1.0.

TABLE 1. General characteristic of subjects, main echocardiographic findings and CT measurements.

Characteristics	All (n = 485)	normal PAP (n = 297)	mild ePH (n = 92)	moderate ePH (n = 85)	severe ePH (n = 11)	*p*	mild *vs.* normal	moderate *vs.* normal	severe *vs.* normal	moderate *vs.* mild	severe *vs.* mild	severe *vs.* moderate
Age, years	72.9 ± 16.1	69.4 ± 17.4	77.3 ± 11.8	80.9 ± 10.9	66.7 ± 9.3	<0.001*	<0.001†	<0.001†	0.328	0.313	0.128	0.018†
Male, n (%)	237 (48.9%)	154 (51.9%)	42 (45.7%)	31 (36.5%)	10 (90.9%)	0.002						
Initial vital signs												
Heart rate, /min	90.9 ± 21.8	89.6 ± 20.3	92.3 ± 24.5	92.2 ± 23.6	107.5 ± 16.4	0.043*	0.828	0.989	0.205	0.988	0.142	0.206
BT, °C	36.8 ± 0.9	36.8 ± 0.9	37.1 ± 1.1	36.7 ± 1.0	37.1 ± 0.8	0.009*	0.209	<0.001†	0.706	0.189	0.973	0.965
SBP, mmHg	142.2 ± 33.1	141.8 ± 33.1	141.2 ± 29.3	146.3 ± 37.0	133.2 ± 32.0	0.526						
DBP, mmHg	77.6 ± 16.9	78.4 ± 17.2	74.4 ± 13.8	77.3 ± 18.6	82.4 ± 20.0	0.189						
Saturation, %	96.2 ± 5.1	97.1 ± 2.7	95.2 ± 6.6	95.0 ± 7.1	89.3 ± 11.5	<0.001*	0.002†	<0.001†	<0.001†	0.863	<0.001†	<0.001†
Echography findings												
LVEF, %	59.3 ± 14.3	60.7 ± 13.3	59.8 ± 15.3	55.4 ± 15.1	49.7 ± 16.6	0.003*	<0.001†	<0.001†	<0.001†	<0.001†	<0.001†	0.171
RVSP, mmHg	37.3 ± 15.9	27.5 ± 8.7	43.9 ± 2.7	58.5 ± 6.5	83.5 ± 12.2	<0.001						
CT measurements												
mPA diameter, mm	31.5 ± 4.8	30.3 ± 4.2	32.4 ± 4.5	34.5 ± 5.2	35.9 ± 3.5	<0.001*	<0.001†	<0.001†	<0.001†	0.070	0.110	0.711
AA diameter, mm	37.3 ± 15.4	37.1 ± 19.4	37.4 ± 4.3	37.7 ± 4.2	38.0 ± 3.7	0.987						
mPA/AA ratio	0.87 ± 0.14	0.85 ± 0.14	0.88 ± 0.14	0.92 ± 0.14	0.95 ± 0.09	<0.001*	0.009†	<0.001†	0.033†	0.036†	0.440	0.997
Time interval of CT and echo, h	8.5 ± 7.7	7.8 ± 7.5	10.1 ± 8.0	9.2 ± 7.7	9.8 ± 9.4	0.054						

PAP: pulmonary artery pressure; ePH: echocardiographic pulmonary hypertension; BT: Body temperature; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; LVEF: left ventricular ejection fraction; RVSP: right ventricular systolic pressure; CT: computed tomography; mPA: main pulmonary artery; AA: ascending aorta.

*One-way Analysis of Variance has shown that there are statistically significant differences between at least two groups.

†Statistically significant differences in post hoc analysis using the Turkish method.

TABLE 2. Multivariate logistic regression analysis in predicting mild, moderate and severe ePH.

	Adjusted odds ratio* (95% confidence interval)	p value
For RVSP ≥40 mmHg		
mPA diameter	1.15 (1.09–1.20)	<0.001
LVEF	0.98 (0.97–1.00)	0.016
AA diameter	1.00 (0.98–1.02)	0.781
Increase in the mPA/AA ratio of 0.01	1.04 (1.02–1.06)	<0.001
For RVSP ≥50 mmHg		
mPA diameter	1.17 (1.11–1.24)	<0.001
LVEF	0.97 (0.96–0.99)	<0.001
AA diameter	1.00 (0.98–1.02)	0.971
Increase in the mPA/AA ratio of 0.01	1.05 (1.03–1.07)	<0.001
For RVSP ≥75 mmHg		
mPA diameter	1.40 (1.18–1.65)	<0.001
LVEF	0.97 (0.93–1.00)	0.068
AA diameter	1.01 (0.98–1.04)	0.427
Increase in the mPA/AA ratio of 0.01	1.05 (1.01–1.09)	0.014

**Adjusted for sex, age and oxygen saturation.*
ePH: echocardiographic pulmonary hypertension; RVSP: right ventricular systolic pressure; mPA: main pulmonary artery; LVEF: left ventricular ejection fraction; AA: ascending aorta.

When comparing the maximum mPA diameter and mPA/AA ratio for ePH prediction, the AUC of simple mPA was greater than that of the mPA/AA ratio. Presumably, the mPA diameter itself has a larger AUC than the mPA/AA ratio because the AA diameter widens as the mPA diameter widens. It is estimated that ePH can be predicted by simply measuring the maximum mPA diameter.

Given that both indicators are poor predictors of mild ePH, caution needs to be taken when applying the best cutoff value determined in this study in clinical practice. An axial CT-measured mPA diameter ≥30.6 mm (or mPA/AA ≥0.85 mm) should be considered as a rough indicator of PH. However, it is a very significant finding that mPA diameter ≥31.8 mm is a fair predictor of moderate or severe ePH. This is because PH may have no characteristic symptoms or signs despite being a potentially fatal disease, making it difficult to clinically estimate; thus, the development of objective measurement tools is necessary. Authors strongly recommend that the mPA diameter be measured without omission in patients undergoing chest CT at the ED.

It is noteworthy that mPA has a very high NPV. The NPV of "mPA ≥31.8 mm for moderate to severe ePH" and "mPA ≥33.8 mm for severe ePH" were 90.2% and 99.4%, respectively. This means that if the mPA diameter is less than 31.8 mm, there is a 90% probability that there is no moderate to severe PH, and if the mPA diameter is less than 33.8 mm, there is a 99.4% probability that there is no severe PH. If the mPA diameter is less than 31.8 mm in the chest CT performed to determine the cause of the patient's symptom, it means that the cause is very unlikely to be PH, and other causes of dyspnea should be actively investigated.

The limitations of this study are as follows. First, a sampling bias should have occurred in the process of selecting only patients who had undergone both chest CT and echocardiography within 24 h. The indications to obtain a CT and/or echocardiography are somewhat arbitrary and varies depending on the physician's experience, time of the day, crowdedness of the ED, and technical issues, *etc*. There is a high possibility that only older patients with more severe symptoms were included. The mean age of the patients included in the final analysis was 72.9 (±16.1) years. Therefore, the results of this study cannot be extrapolated to general adult population. Second, the interobserver agreement between echocardiographers for TRVmax, maximum IVC diameter, and IVC collapsibility during respiratory cycle measurement was not tested. Third, the presence of underlying diseases that can affect the measurement of TRVmax and IVC collapsibility (such as chronic obstructive pulmonary disease, heart failure, previous heart surgery) was not investigated due to the retrospective nature of the study. The medications and amount of fluid administered to the patients during the study period were also not investigated. If fluid or intravenous vasoactive agents were administered to the patient at the time of the study, it may have affected the measurement of the echocardiographic parameters. Lastly, echocardiography is not a gold standard diagnostic tool for diagnosing PH.

5. Conclusions

mPA dilatation can predict ePH. The best cutoff values of axial CT-measured mPA diameter for predicting mild, moderate, and severe ePH were found to be 30.6, 31.8 and 33.8 mm, respectively. CT-measured mPA diameter ≥31.8 mm can be used as a fair indicator of moderate to severe ePH. The CT-

TABLE 3. Best mPA diameter to predict mild, moderate, severe echocardiographic pulmonary hypertension.

	Cutoff values of mPA diameter	SN (%)	SP (%)	Accuracy (%)	PPV (%)	NPV (%)	OR	*p* value
Mild ePH	30.6 mm	72.9	57.6	63.5	52.1	77.0	3.65	<0.001
Moderate ePH	31.8 mm	71.9	64.0	65.6	33.0	90.2	4.55	<0.001
Severe ePH	33.8 mm	81.8	74.3	74.4	6.9	99.4	12.98	<0.001

mPA: main pulmonary artery; ePH: echocardiographic pulmonary hypertension; SN: sensitivity; SP: specificity; PPV: positive predictive value; NPV: negative predictive value; OR: odds ratio.

TABLE 4. Best mPA/AA to predict mild, moderate, severe echocardiographic pulmonary hypertension.

	Cutoff values of mPA/AA	SN (%)	SP (%)	Accuracy (%)	PPV (%)	NPV (%)	OR	*p* value
Mild ePH	0.85	65.4	53.9	58.4	47.3	71.1	2.21	<0.001
Moderate ePH	0.88	64.6	58.6	59.8	27.8	87.0	2.58	<0.001
Severe ePH	0.89	81.8	58.9	59.4	4.4	99.3	6.44	<0.001

mPA: main pulmonary artery; AA: ascending aorta; ePH: echocardiographic pulmonary hypertension; SN: sensitivity; SP: specificity; PPV: positive predictive value; NPV: negative predictive value; OR: odds ratio.

measured mPA diameter had high NPV for ePH; thus, if the mPA diameter is less than 31.8 mm, then the possibility of moderate to severe ePH is very low.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

JHL, JUN and DHS—performed the research. DHS—designed the research study. JUN—analyzed the data. DHS and JUN—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was implemented after approval of the Institutional Research Ethics Committee (IRB No. 2022-06-058). The Institutional Review Board exempted written informed consent due to the retrospective nature of the study. Personal information such as patient name, date of birth, and social identification number were deleted after assigning research subject numbers to ensure anonymity.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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