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Original Research Article

# CT Measurement of Pulmonary Artery Size in Interstitial Lung Disease to Evaluate Pulmonary Hypertension

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**Abstract**

**Aim:** We aimed to determine how accurately various measures of the PA, as viewed on HRCT, predict right heart catheterisation (RHC)-confirmed pulmonary hypertension.

**Methods:** The present study was conducted at Department of Radio Diagnosis, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India for one year and 500 patients were included in the study. Patients with a CT scan within 90 days of MRI and RHC were included. In order to meet inclusion criteria, a diagnostic quality CT pulmonary angiogram (CTPA) with a slice thickness of less than 5 mm was required.

**Results:** We included 500 scans from 500 patients; 300 (60%) had RHC-confirmed pulmonary hypertension, with mPAP ≥ 25 mmHg. Compared with the non-pulmonary hypertension group, the group with pulmonary hypertension had greater MPAD, RPAD, LPAD and PA: Ao in both respiratory cycles, whereas the PA angle was greater in the non-pulmonary hypertension group. In the subgroup with pulmonary hypertension, the median MPAD was 34.60 mm in inspiration and 34.65 mm in expiration, while in the non-pulmonary hypertension group it was 30.00 mm in inspiration and 30.50 mm in expiration. For the cohort as a whole, the areas under the receiver operating characteristic curves (AUCs) for inspiratory MPAD and inspiratory PA:Ao (for RHC-confirmed pulmonary hypertension defined as Mpap ≥ 25 mmHg) were 0.741 and 0.750, respectively. For the cohort as a whole, the cut-offs MPAD ≥ 32.5 mm and PA:Ao ≥ 0.94 yielded the most favourable diagnostic profiles.

**Conclusion:** Findings on HRCT may assist in the diagnosis of RHC-confirmed pulmonary hypertension. MPAD ≥ 29 mm had high sensitivity and PA:Ao ≥ 1.0 had high specificity. Compared with the entire cohort, MPAD had greater sensitivity in ILD and PA:Ao had higher specificity in COPD.

**Keywords:** Interstitial Lung Disease, Computed Tomography (CT) Scanning, Right Heart Catheterisation, Pulmonary Artery Diameter, Pulmonary Hypertension.

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## Introduction

Pulmonary hypertension (PH) is defined on right heart catheterisation (RHC), as a resting mean pulmonary artery pressure (mPAP) greater than or equal to 25 mmHg. [1,2] PH commonly complicates lung disease and chronic hypoxia, such as interstitial lung disease (ILD). When present in lung disease, PH is associated with a poor outcome. [3] CT is used to diagnose and phenotype suspected ILD, and is often part of the workup of patients with unexplained breathlessness and suspected PH. [4] Dilatation of the main pulmonary artery (PA) or major branch vessels has been identified as markers of the presence of PH and is often the first imaging finding to suggest the diagnosis. [5-9] As CT is commonly used in the investigation of patients with ILD, it would be useful to use the pulmonary arterial size to screen for the presence of pulmonary hypertension. Routine CT pulmonary angiography is performed without ECG gating. Pulmonary arterial size changes during the cardiac cycle. MRI is typically gated to the cardiac cycle and allows assessment of pulmonary arterial size at both systole and diastole. Some authors have suggested that in the presence of established lung fibrosis, the main PA diameter is not accurate for estimation of mean pulmonary arterial pressure as dilatation of the main PA develops in patients with pulmonary fibrosis in the absence of PH. [5,10]

Computed tomography (CT) chest scans have largely supplanted chest x-rays in patients with PH, partly due to its ability to detect thromboembolism in some cases, but also to identify any diffuse parenchymal lung diseases that may not be evident in 15% of chest x-rays. [11,12] With advances in CT technology and its wide availability, there have been attempts to address the utility of CT to predict the presence of PH. The pulmonary artery (PA) is a more compliant vessel than the systemic arterial system, and is thus more sensitive to changes in pressure and volume. As a result, an increase in mean pulmonary arterial pressure (MPAP) should correlate with pulmonary artery diameter. A variety of PA dimensions have been explored to see if there is any association with both the presence and severity of PH, including the PA diameter, the cross-sectional area, the ratio of the diameter to the bronchus, the ratio of the diameter to the pulmonary vein, the ratio of diameter to the aortic diameter, and multiple regression methods assessing dimension of the main and branching pulmonary arteries. [13-15]

We aimed to determine how accurately various measures of the PA, as viewed on HRCT, predict right heart catheterisation (RHC)-confirmed pulmonary hypertension.

## Materials and Methods

The present study was conducted at Department of Radio Diagnosis, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India for one year and 500 patients were included in the study. Patients with a CT scan within 90 days of MRI and RHC were included. In order to meet inclusion criteria, a diagnostic quality CT pulmonary angiogram (CTPA) with a slice thickness of less than 5 mm was required. Patients underwent systemic evaluation as part of their routine clinical workup, which included clinical review, multi-modality imaging and lung function testing.

### Radiographic evaluation

All patients underwent volumetric CT imaging on a multidetector row helical CT scanner (Siemens Definition AS+ or Siemens Sensation 64; Siemens, Forchheim, Germany) at full-inspiration and end-expiration. CT scans were reconstructed with a slice thickness of 0.75 mm. Scans were acquired at 50–200 mAs and 120 kV peak. Vessel dimensions were measured using mediastinal windows. A radiologist and pulmonologist decided on,

reviewed and practised the protocol for measurements: MPAD was measured at the widest portion of the main PA perpendicular to the wall abutting the Ao. The Ao was also measured at this level to establish PA:Ao. Left and right PA diameters (LPAD and RPAD, respectively) were measured at their widest points after the bifurcation. The angle between the main PA at the bifurcation (PA angle) was also measured. We used various cut-offs, including the conventional values MPAD ≥ 29 mm and PA:Ao ≥ 1.0, to assess diagnostic accuracy of HRCT measures for RHC-confirmed pulmonary hypertension. [16-18] All HRCT scans were reviewed by a pulmonologist (P.R.) blinded to the presence of pulmonary hypertension and results of the RHC. To assess the validity of measurements made by the pulmonologist, 50 randomly selected scans were also reviewed by a chest radiologist (A.O.) who was also blinded to the presence of pulmonary hypertension and results of the RHC.

### RHC hemodynamics

All pressure measurements were performed at end-expiration while patients were in the supine position and breathing spontaneously. We defined pulmonary hypertension as mean PA pressure (mPAP) ⩾25 mmHg. [19] In certain analyses, we used the newly proposed criterion (mPAP ⩾20 mmHg) from the 6th World Symposia on Pulmonary Hypertension. [20]

### Statistical analysis

Because data were not normally distributed, we report median values (interquartile range) for continuous variables. Differences between groups were evaluated using Chi-squared or Wilcoxon rank sum tests as appropriate. We used intraclass correlation and Bland–Altman analyses to assess inter-rater reliability and agreement between measurements made by the radiologist and pulmonologist. To assess the diagnostic performance of HRCT-derived measures for RHC-derived measures, we generated 2×2 contingency tables and calculated the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). We conducted separate analyses for subjects who had HRCT and RHC within 7, 14, 30 or 60 days of each other. Spearman correlation was used to examine associations between HRCT- and RHC-derived measures. We considered $p<0.05$ to represent statistical significance. All analyses were conducted using Stata version 11.

### Results

**Table 1: Demographic and clinical characteristics**

| | **Total n=500** | **Pulmonary hypertension group n=300** | **Non-pulmonary hypertension group n=200** | **p-value** |
|---|---|---|---|---|
| Age years | 70.01±15.15 | 71.09±15.67 | 70.96±14.54 | 0.760 |
| Male | 250 | 144 | 100 | 0.550 |
| Height cm | 168.00±14.50 | 167.10±14.20 | 169.00±14.99 | 0.180 |
| Weight kg | 83.00±30.71 | 84.37±30.46 | 78.47±29.99 | 0.002 |
| BMI kg·m−2 | 29.31±9.42 | 30.03±9.97 | 28.20±8.46 | <0.001 |
| **Smoking history** | | | | |
| Nonsmoker | 210 | 120 | 88 | 0.160 |
| Current smoker | 15 | 9 | 4 | |
| Ex-smoker | 275 | 171 | 108 | |
| **Underlying disease** | | | | |
| COPD | 200 | 72 | 36 | 0.033 |
| ILD | 190 | 108 | 80 | 0.384 |

| | | | | |
|---|---|---|---|---|
| Embolism | 30 | 18 | 16 | 0.432 |
| Heart disease | 280 | 180 | 100 | 0.010 |
| **Haemodynamics** | | | | |
| mPAP mmHg | 27±13 | 33±12 | 20±5 | <0.001 |
| CO (TD) L·min−1 | 4.69±1.93 | 4.60±2.06 | 4.80±1.80 | 0.065 |
| CO (Fick) L·min−1 | 4.60±1.75 | 4.59±1.81 | 4.65±1.63 | 0.458 |
| PVR (TD) WU | 3.02±2.69 | 4.09±3.28 | 2.11±1.11 | <0.001 |
| PVR (Fick) WU | 3.10±2.64 | 4.00±3.26 | 2.18±1.31 | <0.001 |
| RAP mmHg | 7±5 | 9±6 | 5±4 | <0.001 |
| PCWP mmHg | 12±6 | 14±7 | 10±5 | <0.001 |
| **Inspiratory HRCT median (IQR)** | | | | |
| MPAD mm | 32.75 (7.35) | 34.60 (7.10) | 30.00 (6.50) | <0.001 |
| PA:Ao | 0.95 (0.22) | 1.01 (0.23) | 0.87 (0.16) | <0.001 |
| RPAD mm | 25.95 (5.35) | 27.00 (4.90) | 24.30 (5.10) | <0.001 |
| LPAD mm | 25.20 (4.80) | 26.15 (4.50) | 24.10 (4.70) | <0.001 |
| PA angle deg | 84.45 (29.57) | 80.17 (28.83) | 90.67 (30.62) | <0.001 |
| **Expiratory HRCT median (IQR)** | | | | |
| MPAD mm | 32.80 (7.20) | 34.65 (7.05) | 30.50 (6.00) | <0.001 |
| PA:Ao | 0.94 (0.21) | 0.99 (0.22) | 0.86 (0.16) | <0.001 |
| RPAD mm | 25.50 (5.35) | 26.60 (5.00) | 23.80 (4.70) | <0.001 |
| LPAD mm | 25.60 (4.90) | 26.10 (4.90) | 24.20 (4.70) | <0.001 |
| PA angle deg | 94.44 (23.02) | 92.99 (22.46) | 98.56 (25.96) | <0.001 |

We included 500 scans from 500 patients; 300 (60%) had RHC-confirmed pulmonary hypertension, with mPAP ≥ 25 mmHg. Compared with the non-pulmonary hypertension group, the group with pulmonary hypertension had greater MPAD, RPAD, LPAD and PA:Ao in both respiratory cycles, whereas the PA angle was greater in the non-pulmonary hypertension group. In the subgroup with pulmonary hypertension, the median MPAD was 34.60 mm in inspiration and 34.65 mm in expiration, while in the non-pulmonary hypertension group it was 30.00 mm in inspiration and 30.50 mm in expiration.

**Table 2: Diagnostic performance of various high-resolution computed tomography-derived measures for pulmonary hypertension defined as mean pulmonary artery (PA) pressure ≥ 25 mmHg on right heart catheterisation for subgroups with chronic obstructive pulmonary disease (COPD) or interstitial lung disease (ILD)**

| | Subjects n | Sensitivity % | Specificity % | PPV | NPV |
|---|---|---|---|---|---|
| **COPD** | | | | | |
| **Inspiration** | | | | | |
| MPAD ≥ 29 mm | 200 | 88.17 | 41.86 | 0.77 | 0.62 |
| PA:Ao ≥ 1.0 | 200 | 50.54 | 88.37 | 0.90 | 0.45 |
| MPAD and PA:Ao | 200 | 50.54 | 88.37 | 0.90 | 0.45 |
| MPAD or PA:Ao | 200 | 88.17 | 41.86 | 0.77 | 0.62 |
| **Expiration** | | | | | |
| MPAD ≥ 29 mm | 195 | 90.11 | 37.50 | 0.77 | 0.63 |
| PA:Ao ≥ 1.0 | 195 | 50.55 | 85.00 | 0.88 | 0.43 |
| MPAD and PA:Ao | 195 | 49.45 | 85.00 | 0.88 | 0.43 |
| MPAD or PA:Ao | 195 | 91.21 | 37.50 | 0.77 | 0.65 |
| **ILD** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Inspiration** | | | | | |
| MPAD ≥ 29 mm | 190 | 91.24 | 37.76 | 0.67 | 0.76 |
| PA:Ao ≥ 1.0 | 190 | 52.55 | 80.61 | 0.79 | 0.55 |
| MPAD and PA:Ao | 190 | 50.36 | 84.69 | 0.82 | 0.55 |
| MPAD or PA:Ao | 190 | 93.43 | 33.67 | 0.66 | 0.79 |
| **Expiration** | | | | | |
| MPAD ≥ 29 mm | 185 | 91.97 | 32.98 | 0.67 | 0.74 |
| PA:Ao ≥ 1.0 | 185 | 45.99 | 78.72 | 0.76 | 0.50 |
| MPAD and PA:Ao | 185 | 45.99 | 79.79 | 0.77 | 0.50 |
| MPAD or PA:Ao | 185 | 91.97 | 31.91 | 0.66 | 0.73 |

For the cohort as a whole, the areas under the receiver operating characteristic curves (AUCs) for inspiratory MPAD and inspiratory PA:Ao (for RHC-confirmed pulmonary hypertension defined as Mpap ≥ 25 mmHg) were 0.741 and 0.750, respectively. For the cohort as a whole, the cut-offs MPAD ≥ 32.5 mm and PA:Ao ≥ 0.94 yielded the most favourable diagnostic profiles.

**Table 3: Spearman correlation coefficients showing the relationship between various high-resolution computed tomography-derived measures for pulmonary hypertension defined as mean pulmonary artery (PA) pressure ≥ 25 mmHg on right heart catheterization**

| | **Inspiration** | | | **Expiration** | | |
|---|---|---|---|---|---|---|
| | **All** | **ILD** | **COPD** | **All** | **ILD** | **COPD** |
| MPAD | 0.479 | 0.456 | 0.574 | 0.444 | 0.415 | 0.534 |
| RPAD | 0.335 | 0.295 | 0.462 | 0.327 | 0.327 | 0.327 |
| LPAD | 0.339 | 0.323 | 0. 405 | 0.273 | 0.254 | 0.183 |
| (RPAD+LPAD)/2 | 0.360 | 0.329 | 0.463 | 0.297 | 0.269 | 0.265 |
| PA:Ao | 0.507 | 0.489 | 0.579 | 0.488 | 0.461 | 0.564 |
| PA angle | −0.241 | −0.212 | −0.246 | −0.241 | −0.327 | −0.316 |

There were weak positive correlations between RHC-measured mPAP and inspiratory MPAD, RPAD, LPAD and (RPAD+LPAD)/2. There was moderate positive correlation between mPAP and PA:Ao. There was weak negative correlation between mPAP and the PA angle. In general, compared with inspiration, correlations were not as strong between mPAP and HRCT measurements taken in expiration. Compared with the ILD subgroup, in the subgroup with COPD, correlations were generally stronger between HRCT measures and mPAP.

## Discussion

Although there have been significant advances in the treatment of pulmonary hypertension (PH), there remains significant morbidity and mortality. [21-23] With increasingly more effective and safer pharmacological therapy for pulmonary arterial hypertension (PAH), outcomes may be improved by earlier detection of PH. [23] Screening algorithms have been proposed to facilitate the timely and accurate diagnosis of PH, utilizing a combination of echocardiographic, physiologic (lung function), and radiologic non-invasive techniques [24,25], before proceeding to a definitive right heart catheterization (RHC) for confirmation.

In a meta-analysis of 20 publications, CT-measured MPAD had a mean sensitivity of 79% and a mean specificity of 83% for identifying RHC-confirmed pulmonary hypertension, and PA:Ao had a mean sensitivity of 74% and a mean specificity of 81%. [7] On balance, in each study of

HRCT included in the meta-analysis, diagnostic performance of HRCT was not as good as standard CT or CTA, and our results suggest the same. [26]

A wide range of cut-off values for identifying RHC-confirmed pulmonary hypertension have been proposed for MPAD (from 25 to 38 mm) and PA:Ao (from 0.84 to 1.4).26 We elected to use the cut-offs proposed in the European Society of Cardiology/European Respiratory Society pulmonary hypertension guideline for our main analyses [18,27], but also ran analyses using a range of values, and found that alternative cut-off values performed better. We also conducted analyses for a lower threshold for mPAP (20 mmHg), as that may be adopted as the threshold for pulmonary hypertension in the future. [20] Reassuringly, on balance, results were similar whether we considered scans within 1 week or out to within 2 months of the RHC.

Results for the subgroups with COPD or ILD were similar to those for the cohort as a whole: MPAD was highly sensitive (>90% for the ILD subgroup) but poorly specific and PA:Ao was poorly sensitive but highly specific for each of the two subgroups. For subjects with COPD, cut-offs of MPAD 32.5 mm and PA:Ao 0.90 yielded the most favourable diagnostic profile. For subjects with ILD, cut-offs of MPAD 32.5 mm and PA:Ao 0.92 yielded the most favourable diagnostic profiles. Because HRCT is used most often in patients with ILD, we propose these as cut-offs values for these patients. Of course, our work will require validation. ALHAMAD et al. [28] found MPAD ≥ 25 mm had a sensitivity of 86%, a specificity of 41% and yielded the largest AUC (0.65) among 100 subjects with various forms of ILD. Among 34 subjects without ILD, including eight with COPD, they found MPAD ≥ 31.6 mm had a sensitivity of 47%, a specificity of 93% and yielded the largest AUC (0.73). [29]

## Conclusion

Measurements of the PA taken on HRCT scan may suggest the presence or absence of pulmonary hypertension; these measures may be highly sensitive (MPAD) or specific (PA:Ao), but not both. In ILD, the sensitivity of MPAD was higher, while in COPD, the specificity of PA:Ao was higher. Among patients in whom HRCT is performed, inspiratory measures for MPAD and PA:Ao may raise or lower the level of concern for pulmonary hypertension. A MPAD ≥ 32.5 mm in a patient with ILD or COPD has high sensitivity for RHC-confirmed pulmonary hypertension.

## References

1. Kiely DG, Elliot CA, Sabroe I, Condliffe R. Pulmonary hypertension: diagnosis and management. BMJ. 2013 Apr 16;346.
2. Galiè N, Humbert M, Vachiery JL, Gibbs S, Lang I, Torbicki A, et al. 2015 ESC/ ERS Guidelines for the diagnosis and treatment of pulmonary hypertension: The Joint Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS): Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC), International Society for Heart and Lung Transplantation (ISHLT). Eur Heart J. 2016; 37(1):67–119.
3. Hurdman J, Condliffe R, Elliot CA, Davies C, Hill C, Wild JM, Capener D, Sephton P, Hamilton N, Armstrong IJ, Billings C. ASPIRE registry: assessing the Spectrum of Pulmonary hypertension Identified at a REferral centre. European Respiratory Journal. 2012 Apr 1;39(4):945-55.
4. Rajaram S, Swift AJ, Condliffe R, Johns C, Elliot CA, Hill C, Davies C, Hurdman J, Sabroe I, Wild JM, Kiely DG. CT features of pulmonary arterial hypertension and its major subtypes: a systematic CT evaluation of 292

patients from the ASPIRE Registry. Thorax. 2015 Apr 1;70(4):382-7.
5. Devaraj A, Wells AU, Meister MG, Corte TJ, Hansell DM. The effect of diffuse pulmonary fibrosis on the reliability of CT signs of pulmonary hypertension. Radiology. 2008; 249(3): 1042–9.
6. Edwards PD, Bull RK, Coulden R. CT measurement of main pulmonary artery diameter. Br J Radiol. 1998; 71(850):1018–20.
7. Shen Y, Wan C, Tian P, Wu Y, Li X, Yang T, An J, Wang T, Chen L, Wen F. CT-base pulmonary artery measurement in the detection of pulmonary hypertension: a meta-analysis and systematic Review. Medicine. 2014 Dec;93(27).
8. Ng CS, Wells AU, Padley SP. A CT sign of chronic pulmonary arterial hypertension: the ratio of main pulmonary artery to aortic diameter. J Thorac Imaging. 1999; 14(4):270–8.
9. Kuriyama K, Gamsu G, Stern RG, Cann CE, Herfkens RJ, Brundage BH. CT-determined pulmonary artery diameters in predicting pulmonary hypertension. Invest Radiol. 1984; 19(1):16–22.
10. Alhamad EH, Al-Boukai AA, Al-Kassimi FA, Alfaleh HF, Alshamiri MQ, Alzeer AH, Al-Otair HA, Ibrahim GF, Shaik SA. Prediction of pulmonary hypertension in patients with or without interstitial lung disease: reliability of CT findings. Radiology. 2011 Sep;260(3):875-83.
11. Epler GR, McLoud TC, Gaensler EA, Mikus JP, Carrington CB. Normal chest roentgenograms in chronic diffuse infiltrative lung disease. New England Journal of Medicine. 1978 Apr 27;298(17):934-9.
12. Zompatori M, Bnà C, Poletti V, Spaggiari E, Ormitti F, Calabrò E, Tognini G, Sverzellati N. Diagnostic imaging of diffuse infiltrative disease of the lung. Respiration. 2004;71(1):4-19.
13. McGoon M, Gutterman D, Steen V, Barst R, McCrory DC, Fortin TA, Loyd JE. Screening, early detection, and diagnosis of pulmonary arterial hypertension: ACCP evidence-based clinical practice guidelines. Chest. 2004 Jul 1;126(1):14S-34S.
14. Chan AL, Juarez MM, Shelton DK, MacDonald T, Li CS, Lin TC, Albertson TE. Novel computed tomographic chest metrics to detect pulmonary hypertension. BMC medical imaging. 2011 Dec; 11:1-8.
15. Burger IA, Husmann L, Herzog BA, Buechel RR, Pazhenkottil AP, Ghadri JR, Nkoulou RN, Jenni R, Russi EW, Kaufmann PA. Main pulmonary artery diameter from attenuation correction CT scans in cardiac SPECT accurately predicts pulmonary hypertension. Journal of Nuclear Cardiology. 2011 Aug; 18:634-41.
16. Kuriyama K, Gamsu G, Stern RG, Cann CE, Herfkens RJ, Brundage Bh. CT-determined pulmonary artery diameters in predicting pulmonary hypertension. Investigative radiology. 1984 Jan 1;19 (1):16-22.
17. Tan RT, Kuzo R, Goodman LR, Siegel R, Haasler GR, Presberg KW. Utility of CT scan evaluation for predicting pulmonary hypertension in patients with parenchymal lung disease. Chest. 1998 May 1;113(5):1250-6.
18. Galiè N, Humbert M, Vachiery J-L, et al. 2015 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension. Eur Respir J 2015; 46: 903.
19. Hoeper MM, Bogaard HJ, Condliffe R, Frantz R, Khanna D, Kurzyna M, Langleben D, Manes A, Satoh T, Torres F, Wilkins MR. Definitions and diagnosis of pulmonary hypertension. Journal of the American College of Cardiology. 2013 Dec 24;62(25S): D4 2-50.
20. Galiè N, McLaughlin VV, Rubin LJ, Simonneau G. An overview of the 6th World Symposium on Pulmonary

Hypertension. European Respiratory Journal. 2019 Jan 1;53(1).
21. D'Alonzo GE, Barst RJ, Ayres SM, Bergofsky EH, Brundage BH, Detre KM, Fishman AP, Goldring RM, Groves BM, Kernis JT, Levy PS. Survival in patients with primary pulmonary hypertension: results from a national prospective registry. Annals of internal medicine. 1991 Sep 1;115(5): 343-9.
22. Benza RL, Miller DP, Barst RJ, Badesch DB, Frost AE, McGoon MD. An evaluation of long-term survival from time of diagnosis in pulmonary arterial hypertension from the REVEAL Registry. Chest. 2012 Aug 1;142(2):448-56.
23. Galiè N, Corris PA, Frost A, Girgis RE, Granton J, Jing ZC, Klepetko W, McGoon MD, McLaughlin VV, Preston IR, Rubin LJ. Updated treatment algorithm of pulmonary arterial hypertension. Journal of the American College of Cardiology. 2013 Dec 24;62(25S): D60-72.
24. Writing Committee Members, McLaughlin, V.V., Archer, S.L., Badesch, D.B., Barst, R.J., Farber, H.W., Lindner, J.R., Mathier, M.A., McGoon, M.D., Park, M.H. and Rosenson, R.S., ACCF/AHA 2009 expert consensus document on pulmonary hypertension: a report of the American College of Cardiology Foundation task force on expert consensus documents and the American Heart Association: developed in collaboration with the American College of Chest Physicians, American Thoracic Society, Inc., and the Pulmonary Hypertension Association. Circulation, 2009; 119(16): 2250-2294.
25. Galie, N., Hoeper, M.M., Humbert, M., Torbicki, A., Vachiery, J.L., Barbera, J.A., Beghetti, M., Corris, P., Gaine, S., Gibbs, J.S. and Gomez-Sanchez, M.A., Guidelines for the diagnosis and treatment of pulmonary hypertension: the Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS), endorsed by the International Society of Heart and Lung Transplantation (ISHLT). European heart journal. 2009; 30(20): 24: 93-2537.
26. Mahammedi A, Oshmyansky A, Hassoun PM, Thiemann DR, Siegelman SS. Pulmonary artery measurements in pulmonary hypertension: the role of computed tomography. Journal of thoracic imaging. 2013 Mar 1;28(2):96-103.
27. Hoeper MM, Bogaard HJ, Condliffe R, Frantz R, Khanna D, Kurzyna M, Langleben D, Manes A, Satoh T, Torres F, Wilkins MR. Definitions and diagnosis of pulmonary hypertension. Journal of the American College of Cardiology. 2013 Dec 24;62(25S): D4 2-50.
28. Alhamad EH, Al-Boukai AA, Al-Kassimi FA, Alfaleh HF, Alshamiri MQ, Alzeer AH, Al-Otair HA, Ibrahim GF, Shaik SA. Prediction of pulmonary hypertension in patients with or without interstitial lung disease: reliability of CT findings. Radiology. 2011 Sep;260(3):875-83.
29. Khan A., Tidman D. M. M., Shakir D. S., & Darmal D. I. Breast Cancer in Afghanistan: Issues, Barriers, and Incidence. Journal of Medical Research and Health Sciences. 2022; 5(8): 2125–2134.