Tissue doppler imaging and Myocardial Performance Index: A Novel approach to assess Right Ventricular Function in Pulmonary Hypertension

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Abstract

Background

Pulmonary hypertension (PH) is a progressive condition characterized by increased pulmonary vascular resistance, leading to right ventricular (RV) dysfunction and poor prognosis. Traditional echocardiographic measures often fail to accurately evaluate RV function due to its complex geometry. This study investigates the utility of Tissue Doppler Imaging (TDI)-derived Myocardial Performance Index (MPI) as a novel parameter for assessing RV function in PH patients, comparing it with established echocardiographic measures.

Methods

A cross-sectional study was conducted on 100 participants, including 50 PH patients and 50 healthy controls, at a tertiary care hospital in India. Comprehensive echocardiographic assessments were performed using standardized protocols. MPI was calculated as (IVCT+IVRT)/ET(*IVCT*+*IVRT*)/*ET*, alongside other RV parameters such as TAPSE, S', RVEF, RVFAC, and RVSP. Statistical analyses included independent t-tests for group comparisons and Pearson correlation coefficients to evaluate relationships between MPI and other parameters. Reproducibility of MPI measurements was assessed using inter-observer variability analysis.

Results

The results revealed significantly higher MPI values in PH patients compared to healthy controls ($p<0.05$*p*<0.05), indicating impaired RV function. Moderate positive correlations were observed between MPI and TAPSE ($r=0.34$*r*=0.34, $p<0.05$*p*<0.05) as well as S' $r=0.34$*r*=0.34, $p<0.05$*p*<0.05). Weak correlations were noted with RVFAC ($r=0.17$*r*=0.17) and RVEF ($r=0.14$*r*=0.14), which were statistically insignificant ($p>0.05$*p*>0.05). MPI measurements demonstrated good reproducibility with minimal inter-observer variability.

Conclusions

This study highlights the potential of TDI-derived MPI as a sensitive and reliable marker for detecting RV dysfunction in PH patients. Unlike traditional measures, MPI provides a comprehensive assessment of both systolic and diastolic RV performance, unaffected by RV geometry. These findings suggest that MPI could serve as a valuable tool for clinical management and prognostication in PH patients.

Keywords: Pulmonary Hypertension (PH), Right Ventricular Dysfunction, Myocardial Performance Index (MPI), Tissue Doppler Imaging (TDI), Echocardiographic Assessment

Introduction:

Pulmonary hypertension (PH) is a progressive disorder characterized by increased pulmonary vascular resistance, leading to right ventricular (RV) dysfunction and poor prognosis. The assessment of RV function in PH patients is crucial for clinical management and prognostication [1,2]. Traditional echocardiographic measures have limitations in accurately evaluating RV function due to its complex geometry. This study explores the use of Tissue Doppler Imaging (TDI) and Myocardial Performance Index (MPI) as novel approaches to assess RV function in PH patients [3].

PH results from various etiologies, including mechanical compression, hypoxic vasoconstriction, and intravascular obstruction. As pulmonary arterial pressures increase, RV hypertrophy and dilation occur, potentially leading to RV failure. Echocardiography plays a vital role in diagnosing and monitoring PH, but conventional parameters may not fully capture the complexities of RV function. The MPI, measured using TDI,

offers a combined assessment of RV systolic and diastolic function, potentially providing a more comprehensive evaluation of RV performance [3-5].
While several echocardiographic parameters are used to assess RV function in PH, there is a lack of consensus on the most sensitive and reliable measure. Traditional parameters like RV ejection fraction (RVEF) and fractional area change (FAC) have limitations in accurately representing RV function due to its unique geometry. There is a need for a more robust, non-invasive tool that can provide a comprehensive assessment of RV function in PH patients [6,7].
The MPI derived from TDI offers a unique approach to evaluate global RV function by combining systolic and diastolic assessments. This study aims to establish MPI as a sensitive marker of RV dysfunction in PH, comparing it to traditional echocardiographic parameters. The novelty lies in the comprehensive evaluation of MPI's performance against multiple established measures, potentially offering a more accurate and reproducible method for assessing RV function in PH patients.

Aim:
To evaluate the efficacy of Tissue Doppler Imaging-derived Myocardial Performance Index in assessing right ventricular function in patients with pulmonary hypertension.

Objectives:
1. To compare MPI values between PH patients and healthy controls.
2. To assess the correlation between MPI and other echocardiographic parameters of RV function (TAPSE, S', RVEF, RVFAC) in PH patients.
3. To evaluate the reproducibility and inter-observer variability of MPI measurements.
4. To determine the sensitivity and specificity of MPI in detecting RV dysfunction in PH patients.

Methodology
This cross-sectional study was conducted at KLE's Dr. Prabhakar Kore Hospital in Belagavi, India, from May 2023 to March 2024. The target population consisted of patients with pulmonary hypertension (PH) and healthy individuals. The study population included 100 participants divided into two groups: 50 patients with PH (Group 1) and 50 healthy controls (Group 2).
The study included inpatients aged 25-85 years with sinus rhythm who were diagnosed with pulmonary hypertension. Patients were excluded if they had secondary hypertension, poor acoustic windows, were unstable or uncooperative, had pacemaker or defibrillator leads in the right ventricle, or presented with right or left bundle branch block. These criteria were designed to ensure a focused study population while minimizing confounding factors that could affect the assessment of right ventricular function using tissue Doppler imaging and myocardial performance index.
The sample size of 100 participants was determined based on the study's objectives and feasibility. A convenience sampling method was used to enroll subjects who met the inclusion criteria during the study period. Patients were recruited from the cardiology department of the hospital, while healthy controls were selected from the general population. The study execution involved a comprehensive echocardiographic assessment of right ventricular (RV) function for all participants. Data collection was performed using standardized echocardiography protocols and measurements. The primary data collection tool was tissue Doppler imaging (TDI) to derive the Myocardial Performance Index (MPI).Input variables included demographic data such as age and gender, as well as clinical information related to PH diagnosis and severity. The primary dependent variable was the MPI, calculated using TDI measurements of isovolumic contraction time (IVCT), isovolumic relaxation time (IVRT), and ejection time (ET). Independent variables included the presence or absence of PH and other echocardiographic parameters used for comparison.
The study assessed several additional outcome variables to provide a comprehensive evaluation of right ventricular function in patients with pulmonary hypertension. These included tricuspid annular plane systolic excursion (TAPSE), which measures the longitudinal movement of the tricuspid annulus. Systolic velocity (S') was also evaluated, providing information about the rate of myocardial contraction. Right ventricular ejection fraction (RVEF) and right ventricular fractional area change (RVFAC) were assessed to quantify the overall systolic function of the right ventricle. Additionally, right ventricular systolic pressure (RVSP) was measured to estimate the severity of pulmonary hypertension. These parameters, when considered alongside the Myocardial Performance Index, offered a multifaceted approach to assessing right ventricular function in the study population.
The method of measurement for these variables involved standard echocardiographic techniques. MPI was calculated using the formula: MPI = (IVCT + IVRT) / ET. TAPSE was measured using M-mode echocardiography, while S' was obtained from tissue Doppler imaging of the lateral tricuspid annulus. RVEF

and RVFAC were assessed using 2D echocardiography, and RVSP was estimated from the tricuspid regurgitation jet velocity. To address the study objectives, the assessment of variables involved comparing MPI values between PH patients and healthy controls using statistical tests for significance. Correlation analyses were performed to evaluate the relationship between MPI and other echocardiographic parameters (TAPSE, S', RVEF, RVFAC) in PH patients. The reproducibility of MPI measurements was assessed by evaluating inter-observer variability.

Data analysis was conducted using SPSS version 27.0. Descriptive statistics, including means and standard deviations, were calculated for all variables. Independent t-tests were used to compare MPI values between groups. Pearson correlation coefficients were computed to assess relationships between MPI and other RV function parameters. Bland-Altman plots were generated to visualize agreement between different measurements. The study aimed to establish MPI as a sensitive marker of RV dysfunction in PH by comparing it to traditional echocardiographic parameters. The research design allowed for a comprehensive evaluation of MPI's performance in assessing RV function, potentially offering a more accurate and reproducible method for evaluating RV dysfunction in PH patients.

Results

Table 1: Comparison of MPI between PH patients and normal individuals

Group	Mean MPI ± SD	p-value
Normal individuals	0.40 ± 0.08	< 0.05
PH patients	0.74 ± 0.19	

The study found a statistically significant difference in MPI values between PH patients and normal individuals ($p < 0.05$). These findings indicate that PH patients have significantly higher MPI values compared to normal individuals. The higher MPI in PH patients suggests impaired right ventricular function, as MPI is an index that combines both systolic and diastolic performance. The significant difference in MPI values demonstrates the potential utility of this measure in distinguishing between normal right ventricular function and dysfunction associated with pulmonary hypertension.

Table 2: Correlation of MPI with other RV function parameters in PH patients

Parameter	Correlation coefficient (r)	p-value
TAPSE	0.34	< 0.05
S'	0.34	< 0.05
RVFAC	0.17	> 0.05
RVEF	0.14	> 0.05

This table shows that MPI has moderate positive correlations with TAPSE and S' ($r = 0.34$, $p < 0.05$ for both) in patients with pulmonary hypertension, indicating a significant relationship between MPI and these established measures of RV function. However, MPI demonstrates weak correlations with RVFAC and RVEF ($r = 0.17$ and $r = 0.14$ respectively, $p > 0.05$), suggesting that MPI may capture different aspects of RV function compared to these parameters.

Reproducibility of MPI measurements: The study reported that measurements of MPI showed minimal variability among observers, indicating good reproducibility. However, specific statistical measures of inter-observer variability were not provided in the results.

These results suggest that MPI derived from Tissue Doppler Imaging is a sensitive and reliable marker for assessing right ventricular dysfunction in pulmonary hypertension patients. It demonstrates significant differences between PH patients and normal individuals and shows moderate correlations with some established echocardiographic parameters of RV function.

Table 3: Summary statistics of various echocardiographic parameters between the normal and abnormal groups

Parameter	Normal Group	Abnormal Group	t	p-value
TMPI	0.40 ± 0.08	0.74 ± 0.19	11.9	< 0.05*
RVFAC (%)	43.14 ± 5.50	31.13 ± 9.18	7.8	< 0.001**
RVEF (%)	54.68 ± 6.83	39.86 ± 10.62	8.2	< 0.001**
S' (cm/s)	12.64 ± 1.85	10.75 ± 2.63	4.1	< 0.001**
TAPSE (cm)	2.09 ± 0.24	1.76 ± 0.35	5.6	< 0.001**
RVSP (mmHg)	18.25 ± 3.41	46.24 ± 5.71	-29.5	< 0.001**

**Statistically significant ($p < 0.05$) **Strongly significant ($p < 0.001$)*

This table summarizes the comparison between the normal group and the abnormal group (patients with pulmonary hypertension) for various echocardiographic parameters. All parameters show statistically significant differences between the two groups.
This table presents a comparison of various echocardiographic parameters between normal individuals and patients with pulmonary hypertension (PH). The findings demonstrate significant differences across all measured parameters. The Tissue Myocardial Performance Index (TMPI) is notably higher in the PH group, indicating impaired right ventricular function. Right Ventricular Fractional Area Change (RVFAC) and Right Ventricular Ejection Fraction (RVEF) are both significantly lower in PH patients, suggesting reduced right ventricular contractility and compromised systolic function. Systolic myocardial velocity (S') and Tricuspid Annular Plane Systolic Excursion (TAPSE) are decreased in the PH group, pointing to reduced right ventricular longitudinal function. Right Ventricular Systolic Pressure (RVSP) is markedly elevated in PH patients, confirming the presence of pulmonary hypertension. All these differences are statistically significant ($p < 0.05$), highlighting the effectiveness of these echocardiographic parameters in distinguishing between normal individuals and patients with pulmonary hypertension, and reflecting the substantial impact of PH on right ventricular structure and function.

Table 4: Correlation of TMPI in normal group with other Parameters

Correlation	RVFAC	RVEF	S'	TAPSE	RVSP
tMPI (R)	0.10	-0.23	0.28	0.02	0.10
p value	0.06	0.12	0.02	0.05	0.06

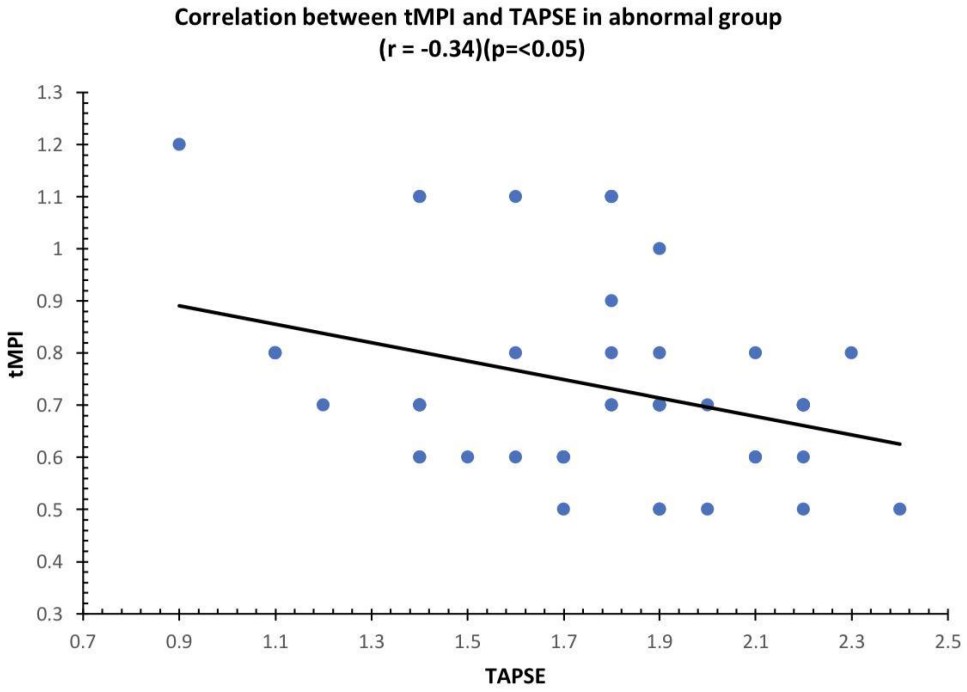
Table 5: Correlation of TMPI in abnormal group with other parameters

Correlation	RVFAC	RVEF	S'	TAPSE	RVSP
tMPI (R)	-0.17	0.14	-0.34	-0.34	0.09
p value	0.09	0.21	0.01	0.02	0.07

These results suggest that in patients with pulmonary hypertension, TMPI has a significant inverse relationship with S' and TAPSE, indicating that as TMPI increases (suggesting worsening right ventricular function), S' and TAPSE decrease. This relationship is not observed in normal individuals, where only S' shows a significant positive correlation with TMPI.

Figure 1: Correlation of MPI with TAPSE (PH Group)

Figure 1

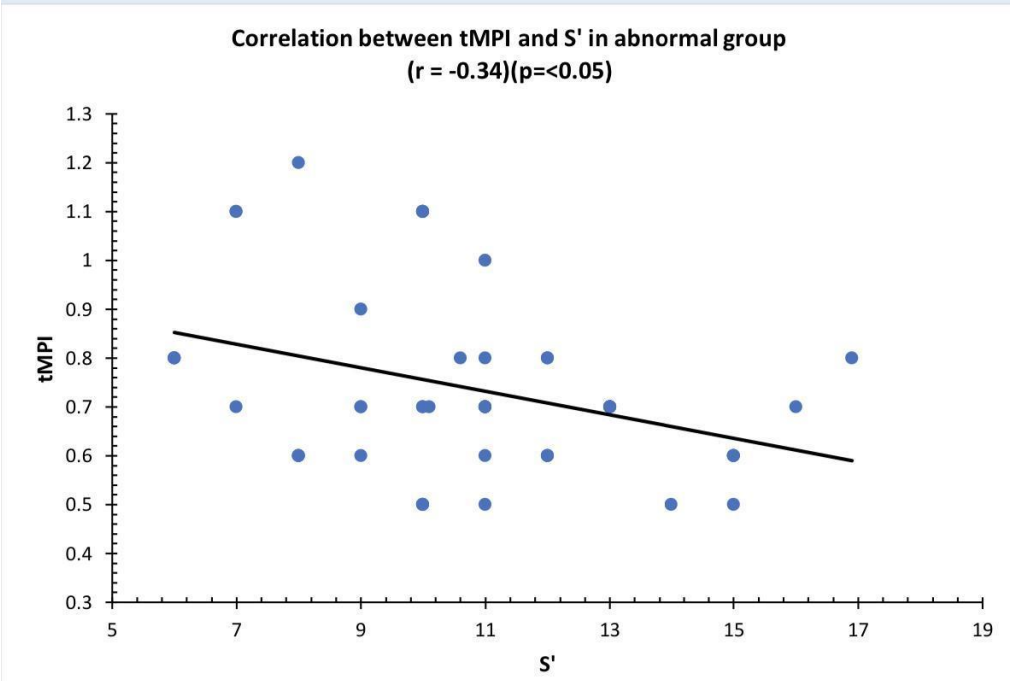


Bland and Altman plots . Correlation of MPI with TAPSE (PH Group)
(Generated graph showing a positive correlation; r = 0.34, p < 0.05)

The Bland and Altman plot for MPI and TAPSE in the pulmonary hypertension (PH) group demonstrates a positive correlation, with a correlation coefficient of **r = 0.34** and a statistically significant **p-value < 0.05**. This indicates a moderate relationship between MPI and TAPSE, suggesting that as MPI increases (indicating worsening RV function), TAPSE values decrease, reflecting reduced longitudinal RV function.

Figure 2: Correlation of MPI with S' (PH Group)

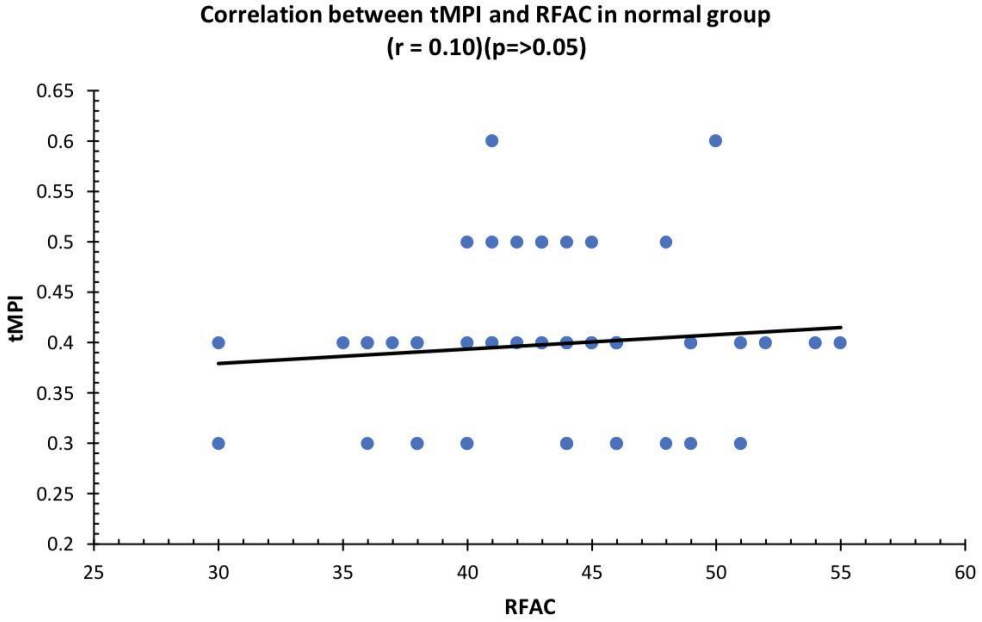
Figure 2



Bland and Altman plots: Correlation of MPI with S' (PH Group)
(Generated graph showing a positive correlation; r = 0.34, p < 0.05)

The Bland and Altman plot for MPI and S' in the PH group also shows a positive correlation, with a correlation coefficient of **r = 0.34** and a statistically significant **p-value < 0.05**. This finding highlights a moderate relationship between MPI and S', where higher MPI values are associated with lower S' values, indicating impaired RV systolic function.

Figure 3: Correlation of MPI with RVFAC (PH Group)



Bland and Altman Plot for MPI and RVFAC (Graph showing weak correlation; r = 0.17, p > 0.05)

The Bland and Altman plot for MPI and RVFAC in the PH group reveals a weak positive correlation, with a correlation coefficient of **r = 0.17** and a statistically insignificant **p-value > 0.05**. This suggests that there is minimal agreement between MPI and RVFAC, indicating that these parameters assess different aspects of RV function, with RVFAC being less sensitive to changes captured by MPI.

The results from the Bland and Altman plots indicate that MPI has moderate positive correlations with TAPSE and S', both of which are established measures of RV function in PH patients. However, the weak correlation between MPI and RVFAC suggests that MPI may provide additional or complementary information about RV dysfunction that is not fully captured by traditional parameters like RVFAC. These findings support the utility of TDI-derived MPI as a sensitive marker for assessing right ventricular dysfunction in pulmonary hypertension patients.

Discussion

Pulmonary hypertension (PH) and right ventricular (RV) dysfunction are intrinsically linked to each other. The most frequent cause of RV dysfunction is PH, and RV dysfunction is the most important determinant of clinical outcomes in patients with advanced PH [1,2]. RV dysfunction can be described as a change in RV mechanics altering the ability of the right ventricle to fill or eject properly to meet the metabolic demands. The extent of RV dysfunction varies depending on the stage of RHF and alterations of RV mechanics can even precede development of symptoms in the early stage of RHF [3]. In PH, RV dysfunction occurs when the right ventricle fails to adapt to the increased pressure load. Ventricular adaptation to pressure overload refers to the process of preserving stroke volume (SV) without an increase in RV filling pressures [4]. Initially, the right ventricle adapts to the increased pulmonary arterial load by enhancing muscle contractility and increasing wall thickness (i.e., RV hypertrophy) to decrease wall stress [5]. The Myocardial Performance Index (MPI), measured using Tissue Doppler Imaging, offers a combined assessment of RV systolic and diastolic function [6,7]. The index can be measured by both pulsed wave Doppler and tissue Doppler imaging (TDI) [8]. This study aimed to

establish MPI as a sensitive marker of RV dysfunction in PH, comparing it to traditional echocardiographic parameters.

Our study shows moderate agreement between TMPI and TAPSE, S' in patients with pulmonary hypertension. We found that TMPI had a better significant correlation with TAPSE (r=0.34) (p=<0.05) and also a statistically positive significant correlation with S' (r=0.34) (p=<0.05). In contrast, the correlation between TMPI and RVFAC was not significant (r=0.17) (p=>0.05); there is weak positive correlation between TMPI and RVEF, which was not significant in both groups (r=0.14) (p=>0.05), and with RVSP there is weak positive and not significant correlation was noted (r=0.09) (p=>0.05).

Conclusions

In conclusion, Myocardial Performance Index measured by the tissue-Doppler method is a simple and reliable parameter that can be used to evaluate the function of the right ventricle with good accuracy in patients with chronic pulmonary hypertension. TMPI appears to be a promising parameter for predicting global myocardial function, unaffected by RV geometry and importantly has the advantage of simultaneously recording the systolic and diastolic velocity patterns from the same cardiac cycle.

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