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Ratio of Peak Early to Late Diastolic Filling Velocity of Transmitral Flow is Predictive of Right Ventricular Diastolic Abnormality in Untreated Hypertensive Patients

Shun-Yi Hsu[1], Chih-Jen Liu[1], Shan-Hung Chang[2], Hsin-Hua Chou[1]*

[1]*Department of Cardiology, Buddhist Tzu Chi General Hospital, Taipei Branch, Taipei, Taiwan*
[2]*Second Section of Cardiology, Department of Internal Medicine, Chang Gung Memorial Hospital, Taoyuan, Taiwan*

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Abstract

Objective: Impaired right ventricular (RV) diastolic function in hypertensive patients has been observed with pulsed wave tissue Doppler imaging (TDI). However, it is unclear whether TDI should be used to assess RV diastolic function for all hypertensive patients, regardless of their transtricuspid flow patterns. Moreover, the predictors of TDI-derived RV diastolic function abnormality in these patients are not well known.
Materials and Methods: Thirty untreated hypertensive patients underwent standard Doppler echocardiography and pulsed wave TDI. They were divided into two groups based on RV diastolic filling patterns: group A (n=22) with a transtricuspid flow early diastolic filling velocity (E)/late diastolic filling velocity (A) ratio of >1 and group B (n=8) with a transtricuspid flow E/A ratio of <1. Systolic and diastolic indices of both ventricles were compared between the two groups.
Results: There were no significant differences in the baseline characteristics and standard Doppler echocardiographic measurements between the two study groups. Among the TDI parameters compared, only the RV regional relaxation time (RT_m) was significantly longer in group B than in group A (50.4±33.1 ms *vs.* 20.8±22.0 ms, respectively; p=0.009). A similar proportion of patients with TDI-derived RV diastolic dysfunction was observed in both groups (86.4% in group A *vs.* 87.5% in group B; p=1.000). Stepwise, forward multivariate analysis revealed that the only independent correlate of TDI-derived indices of RV diastolic function was the transmitral flow E/A ratio. This ratio was positively correlated with the ratio of tricuspid annular peak early diastolic (E_m) to late diastolic (A_m) velocity and negatively correlated with RV RT_m ($p<0.01$ for both).
Conclusion: In this study, the transmitral flow peak E/A ratio showed the best correlation with TDI-derived RV diastolic function indices. Assessment of RV diastolic function using pulsed-wave TDI in hypertensive patients is valuable if an inverted transmitral flow E/A ratio is detected with conventional Doppler echocardiography. [*Tzu Chi Med J* 2009;21(1):59–65]

*Corresponding author. Department of Cardiology, Buddhist Tzu Chi General Hospital, Taipei Branch, 289, Jianguo Road, Taipei, Taiwan.
E-mail address: shunyi57@tzuchi.com.tw

1. Introduction

The prevalence of systemic hypertension in the Western world is approximately 25% (1) and its association with cardiovascular disease is well established. If left untreated, systemic hypertension may lead to progressive myocardial hypertrophy and left ventricular (LV) diastolic dysfunction (2–4), both of which are responsible for the development of heart failure in hypertensive patients. In contrast to LV performance, there have been only a few published reports on right ventricular (RV) performance, particularly its diastolic function, in hypertensive patients (5,6). Echocardiography is the most common noninvasive modality used to assess RV diastolic function by means of transtricuspid flow velocity measurements (7,8). However, the parameters derived from conventional Doppler echocardiography may be affected by heart rate, ventricular compliance, and loading conditions (8). The recent introduction of tissue Doppler imaging (TDI) has provided a unique method for evaluating global and regional myocardial function in both ventricles (9–12). Compared with conventional echocardiography, TDI is relatively load-independent and also offers the potential to investigate RV function with better accuracy and reproducibility (13–15). Recently, studies that used TDI to evaluate RV diastolic function in systemic hypertensive patients have shown that, in the absence of systolic dysfunction, TDI-derived measurements of RV diastolic function are impaired (16,17). However, TDI is not routinely performed in clinical practice. It is unclear whether TDI should be used to assess RV diastolic function in all hypertensive patients, regardless of their transtricuspid flow patterns. Moreover, information about the predictors of TDI-derived RV diastolic function abnormalities in these patients is currently lacking.

In this study, we used conventional Doppler echocardiography and TDI to compare various well-established echocardiographic parameters in untreated hypertensive patients with different tricuspid inflow patterns. We also investigated the predictors of TDI-derived RV diastolic function abnormalities.

2. Materials and methods

2.1. *Study population*

The study comprised 30 patients with untreated systemic hypertension of various durations. Hypertension was defined as a mean systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg measured on three separate occasions before the patient underwent echocardiography. Clinical histories and baseline laboratory data were collected for each patient. Diabetes mellitus was defined as a history of hyperglycemia requiring previous or ongoing pharmacological therapy. Hyperlipidemia was defined as a fasting total cholesterol level > 200 mg/dL and/or a triglyceride level > 150 mg/dL, or current treatment with lipid lowering agents. The durations of hypertension were recorded based on the patients' self-reported medical histories. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Patients were free of coronary artery disease (angina and/or ECG signs of ischemia, and regional wall motion abnormalities determined by two-dimensional echocardiography), valvular heart disease, symptomatic heart failure, atrial fibrillation, chronic lung disease, and pulmonary arterial hypertension. The study protocol was approved by the institutional review board, and informed consent was obtained from all patients.

2.2. *Procedures*

Standard Doppler echocardiography and TDI were performed with the participants in the partial left lateral decubitus position, using Philip SONOS 7500 (Angilent Technologies, Andover, MA, USA) equipped with a phased array transducer of variable frequency (2.5–4.0 MHz) and TDI technology. Pulsed-wave Doppler echocardiographic and tissue Doppler tracings were obtained with the patients maintaining shallow respirations or end-expiratory apnea and the measurements were recorded on magneto-optical disks for subsequent analysis. All measurements were performed by the same experienced echocardiologist.

M-mode presentation in the parasternal long-axis view was used to determine the ventricular dimensions and septal and LV posterior wall thickness according to the recommendations of the American Society of Echocardiography. The left ventricular ejection fraction (LVEF) was calculated using Teichholz's formula. The left ventricular mass (LVM) was calculated according to Penn convention (18) and indexed for body height$^{2.7}$ (19). Tricuspid annular plane systolic excursion (TAPSE) was used as an index of RV global systolic function and calculated as previously described (20). Pulsed-wave Doppler measurements of LV and RV inflow were performed in the apical four-chamber view, with the sample volume placed between the tips of the mitral and tricuspid valves, respectively. The ultrasound beam was kept parallel to the direction of the blood flow as much as possible. The following parameters of global LV and RV filling were measured: peak early diastolic filling (E) and atrial phase filling (A) velocities (cm/s), E/A ratio, and E wave deceleration time (ms). LV isovolumic relaxation time (ms) was measured as the time interval between the end of systolic outflow and the onset of transmitral E wave by placing the sample volume between the LV outflow tract and mitral valve (7).

TDI was performed using transducer frequencies of 2.5–4.0 MHz, adjusting the Nyquist limit to 15–20 cm/s, and using the minimal optimal gain setting. The apical four-chamber view was used for all quantitative assessments and the incidence angle between the Doppler beam and longitudinal wall motion of both the ventricles was minimized as much as possible. A 5.2-mm pulsed Doppler sample volume was placed at the level of the septal mitral annulus and lateral tricuspid annulus, respectively. The tissue Doppler pattern is characterized by a positive systolic wave (S_m) and two negative diastolic waves, namely, the early diastolic (E_m) and atrial contraction (A_m) waves (Fig. 1). The following systolic indices of both ventricles were obtained: myocardial peak velocity of S_m (cm/s), myocardial pre-contraction time (PCT_m, the time from the onset of electrocardiogram QRS to the beginning of S_m, in milliseconds), and contraction time (CT_m, the time from the beginning to the end of S_m, in milliseconds). When evaluating the peak systolic velocity, we ignored the initial peak that occurred during isovolumic contraction. The measured diastolic indices of both ventricles included peak velocities of E_m and A_m (cm/s), E_m/A_m ratio, and relaxation time (RT_m, the time interval between the end of S_m and the onset of E_m). A tissue Doppler-derived E_m/A_m ratio of <1 and prolonged RT_m were regarded as measurements of global ventricular diastolic function [10,16, 17]. A mean of three consecutive cycles was used to calculate all conventional Doppler and TDI parameters. All measured time intervals were corrected for heart rate. The derived index, mitral E/E_m ratio, which can reliably reflect the presence of elevated LV filling pressure [10], was also determined.

2.3. *Assessment of reproducibility*

Intraobserver and interobserver reproducibilities were measured in 10 randomly selected patients. The latter involved a second observer who was unaware of the initial results. The percentage variability was derived as the absolute difference between the two sets of observations divided by the mean of the observations.

2.4. *Statistical methods*

The data were entered in Excel and analyzed using Stata statistical software version 8.0 (Stata Corp., College Park, TX, USA). Continuous data are presented as mean ± standard deviation (SD) and compared with Student's *t* test. Categorical variables are expressed as percentages and compared using Pearson's χ^2 test. Univariate correlations between individual variables were analyzed based on Pearson's method.

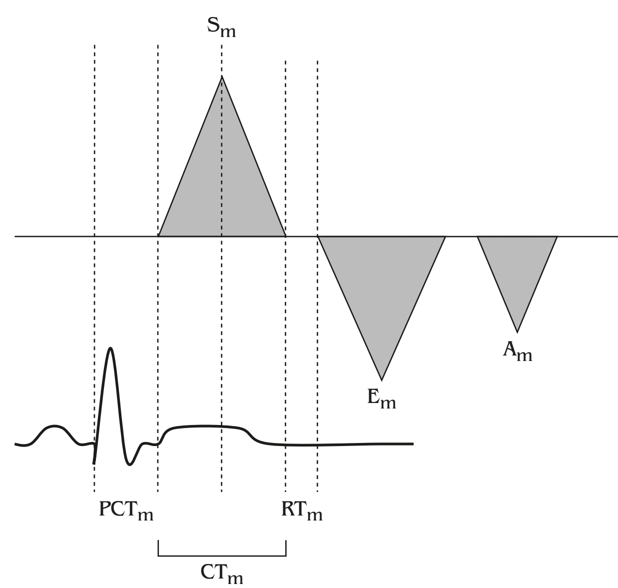

Fig. 1 — Scheme of a normal tissue Doppler pattern from the mitral and tricuspid annuli, characterized by a myocardial systolic wave (S_m), early diastolic wave (E_m) and late diastolic wave (A_m). Systolic and diastolic time intervals may be measured as described in the *Materials and methods*. PCT_m = myocardial pre-contraction time; CT_m = myocardial contraction time; RT_m = myocardial relaxation time.

Stepwise, forward multiple regression analysis was used to identify the independent predictors of both RV RT_m and the tricuspid annular E_m/A_m ratio. A p value of <0.05 was considered statistically significant.

3. Results

3.1. *Characteristics of the study population*

The 30 hypertensive patients were divided into two groups according to the RV filling patterns measured by conventional Doppler echocardiography: group A ($n=22$) with a transtricuspid flow E/A ratio of >1 and group B ($n=8$) with a transtricuspid E/A ratio of <1. The baseline characteristics of the patients in both groups are listed in Table 1. The patients in group B tended to be older than those in group A ($p=0.060$). No intergroup differences existed with regard to BMI, duration of hypertension, blood pressure, or the proportion of patients with diabetes mellitus and dyslipidemia.

3.2. *Standard Doppler echocardiographic analysis*

A comparison of the results of conventional two-dimensional and Doppler echocardiographic analyses

Table 1 — Baseline characteristics*

Variable	Group A (n=22)	Group B (n=8)	p
Age (yr)	49±12	58±10	0.060
Male	12 (54.6)	4 (50)	1.000
BMI (kg/m^2)	25.3±4.7	27.5±4.1	0.262
Duration of hypertension (yr)	4.5±4.3	7.4±5.4	0.147
Diabetes mellitus	2 (9.1)	1 (12.5)	1.000
Hyperlipidemia	11 (50)	6 (75)	0.407
SBP (mmHg)	163±22	163±15	0.965
DBP (mmHg)	94±15	83±9	0.070

*Data are presented as mean±standard deviation or n (%) of patients. BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure.

Table 2 — Conventional two-dimensional and Doppler echocardiographic analyses*

Variable	Group A (n=22)	Group B (n=8)	p
IVS (mm)	12.7±3.1	13.0±3.3	0.808
PWT (mm)	9.9±1.6	9.8±1.7	0.840
LVEDD (mm)	48.4±4.9	46.8±5.2	0.432
LVESD (mm)	29.1±4.8	25.0±3.8	0.037
LV mass index (g/m$^{2.7}$)	55.9±15.0	56.5±14.7	0.924
LVEF (%)	70.3±7.2	77.8±3.1	0.010
RVEDD (mm)	27.4±4.8	28.7±5.4	0.516
TAPSE (mm)	22.6±3.3	22.9±3.1	0.888
LV inflow			
Peak E velocity (cm/s)	78.2±21.6	71.1±14.3	0.399
Peak A velocity (cm/s)	83.7±23.7	90.2±13.7	0.474
Peak E/A ratio	0.98±0.31	0.80±0.14	0.124
DT (ms)	238.1±60.9	234.8±36.2	0.884
IVRT (ms)	92.5±14.7	92.1±20.1	0.961
RV inflow			
Peak E velocity (cm/s)	55.7±10.1	53.5±9.3	0.595
Peak A velocity (cm/s)	39.2±6.9	61.0±8.9	0.000
DT (ms)	254.6±42.4	228.9±32.7	0.132

*Data are presented as mean±standard deviation. LV = left ventricular; RV = right ventricular; IVS = thickness of interventricular septum; PWT = thickness of LV posterior wall; LVEDD = LV end-diastolic dimension; LVESD = LV end-systolic dimension; LVEF = LV ejection fraction; RVEDD = RV end-diastolic dimension; TAPSE = tricuspid annular plane systolic excursion; E = early diastolic filling; A = atrial filling; DT = deceleration time; IVRT = isovolumic relaxation time.

between the two groups is reported in Table 2. The dimensional parameters of both ventricles and TAPSE were similar between the two groups. Although group A had a lower mean LVEF than group B (70.3±7.2% *vs.* 77.8±3.1%, respectively; p=0.010), it was within the normal range. No difference was observed between the two groups with regard to the Doppler indices of LV inflow.

3.3. *Pulsed wave TDI analysis*

The TDI parameters of the two study groups are listed in Table 3. The regional LV and RV systolic indices, namely, the myocardial peak velocities of S_m, PCT_m, and CT_m were not significantly different between the two groups. Furthermore, no significant differences were observed for the majority of the TDI-derived LV diastolic measurements between the two study groups; however, the mitral annular E_m/A_m ratio was borderline significantly lower in group B than in group A (0.52±0.15 *vs.* 0.78±0.36, respectively; p=0.057). All patients in group B presented with a mitral annular E_m/A_m ratio <1, while only 77% of patients in group A presented with this ratio. However, the difference did not reach statistical significance (p=0.287). Among the TDI-derived indices of RV diastolic function, only RV RT_m was significantly longer in group B than in group A (50.4±33.1 ms *vs.* 20.8±22.0 ms, respectively; p=0.009); no significant differences were found between the two groups for the other diastolic measurements, including the tricuspid annular E_m/A_m ratio. Of the 26 patients (87%) with RV diastolic dysfunction, as indicated by the tricuspid annular E_m/A_m ratio <1, 19 were in group A (86.4%) and seven in group B (87.5%) (p=1.000). If conventional Doppler echocardiography alone was used to evaluate RV diastolic function, only 31% of the 26 patients with TDI-derived RV diastolic abnormalities could be identified. In univariate analysis (Table 4), RV RT_m was positively correlated with age (r=0.49, p=0.006) and negatively correlated with the transmitral flow E/A ratio (r=–0.54, p=0.002), transtricuspid flow E/A ratio (r=–0.46, p=0.011), and mitral annular E_m/A_m ratio (r=–0.45, p=0.012). The tricuspid

Table 3 — Pulsed-wave tissue Doppler analyses*

Variable	Group A (n=22)	Group B (n=8)	p
Septal mitral annulus			
E_m peak velocity (cm/s)	7.0±2.4	5.5±1.6	0.120
A_m peak velocity (cm/s)	9.8±2.5	10.9±3.3	0.318
Peak E_m/A_m ratio	0.78±0.36	0.52±0.15	0.057
Peak E/E_m ratio	12.3±5.8	13.7±4.8	0.568
S_m peak velocity (cm/s)	7.5±1.7	8.3±3.1	0.379
RT_m (ms)	68.6±21.3	74.0±27.6	0.574
PCT_m (ms)	103.4±15.5	105.0±29.2	0.843
CT_m (ms)	321.3±17.8	324.0±24.8	0.745
Peak E_m/A_m ratio <1	17 (77.2)	8 (100)	0.287
Tricuspid annulus			
E_m peak velocity (cm/s)	10.5±3.0	10.2±2.1	0.782
A_m peak velocity (cm/s)	13.2±3.7	15.7±3.5	0.101
Peak E_m/A_m ratio	0.84±0.28	0.67±0.20	0.138
S_m peak velocity (cm/s)	12.0±2.2	14.1±2.8	0.042
RT_m (ms)	20.8±22.0	50.4±33.1	0.009
PCT_m (ms)	104.5±19.1	101.8±23.3	0.741
CT_m (ms)	324.1±23.4	320.1±51.6	0.772
Peak E_m/A_m ratio <1	19 (86.4)	7 (87.5)	1.000

*Data are presented as mean±standard deviation or n (%). E_m = early diastolic wave; A_m = atrial contraction wave; E = early diastolic filling; S_m = systolic wave; RT_m = regional myocardial relaxation time; PCT_m = myocardial pre-contraction time; CT_m = myocardial contraction time.

Table 4 — Univariate correlation of RV relaxation time and tricuspid annular E_m/A_m ratio with clinical and echocardiographic parameters

	RV RT_m		Tricuspid annular E_m/A_m	
	r	*p*	*r*	*p*
Age	0.49	0.006	–0.55	0.002
Systolic blood pressure	0.35	0.057	–0.17	0.370
LV mass index	0.20	0.290	–0.05	0.776
Body mass index	0.18	0.334	–0.04	0.822
Mitral flow E/A ratio	–0.54	0.002	0.62	0.0003
Tricuspid flow E/A ratio	–0.46	0.011	0.49	0.006
DT of mitral E wave	0.29	0.129	–0.43	0.018
LV IVRT	0.07	0.713	0.23	0.230
Mitral annular peak E_m/A_m ratio	–0.45	0.012	0.46	0.011
Mitral annular peak E/E_m ratio	0.28	0.135	–0.16	0.413
LV RT_m	0.03	0.857	0.14	0.451
RVEDD	0.07	0.701	–0.13	0.481

RV = right ventricular; RT_m = regional myocardial relaxation time; E_m = early diastolic wave; A_m = atrial contraction wave; LV = left ventricular; E = early diastolic filling; A = atrial filling; DT = deceleration time; IVRT = isovolumic relaxation time; RVEDD = RV end-diastolic dimension.

annular E_m/A_m ratio was positively correlated with the transtricuspid flow E/A ratio (r=0.49, p=0.006), transmitral flow E/A ratio (r=0.62, p=0.0003) and mitral annular E_m/A_m ratio (r=0.46, p=0.011), and negatively correlated with age (r=–0.55, p=0.002) and the mitral E wave deceleration time (r=–0.43, p=0.018). After adjusting for potential determinants in Table 4 using stepwise forward multivariate analysis, only the transmitral flow E/A ratio was found to be independently correlated with both RV RT_m and tricuspid annular E_m/A_m ratio (R^2=0.29, standard error (SE)=15.8 ms, p=0.002 and R^2=0.38, SE=0.14, p=0.0003, respectively).

The interobserver and intraobserver reproducibilities are shown in Table 5. Small differences were observed among all Doppler variables.

Table 5 — Reproducibility of conventional Doppler and tissue Doppler imaging measurements

	Intraobserver error (%)	Interobserver error (%)
Mitral inflow E	0.1±0.1	0.8±0.6
Mitral inflow A	0.1±1.3	0.2±1.8
Mitral inflow DT	4.2±4.6	6.6±4.2
LV IVRT	1.0±0.1	7.1±0.4
Tricuspid inflow E	0.5±0.0	2.1±0.4
Tricuspid inflow A	0.7±0.2	0.2±0.7
Tricuspid inflow DT	7.8±6.2	6.9±5.5
Septal mitral annulus		
E_m peak velocity	1.3±0.0	2.5±1.3
A_m peak velocity	2.6±0.9	4.3±0.9
S_m peak velocity	1.2±1.2	1.2±3.6
RT_m	4.8±1.1	7.0±2.0
CT_m	0.0±0.2	1.2±0.2
PCT_m	2.4±1.8	1.4±1.2
Tricuspid annulus		
E_m peak velocity	2.0±4.0	7.1±1.0
A_m peak velocity	3.5±2.8	1.4±2.1
S_m peak velocity	0±1.7	1.7±1.7
RT_m	7±10.4	10.9±2.5
CT_m	0.2±1.1	0.4±0.2
PCT_m	2.7±3.4	3.7±2.4

E = early diastolic filling; A = atrial filling; DT = deceleration time; LV IVRT = left ventricular isovolumic relaxation time; E_m = early diastolic wave; A_m = atrial contraction wave; S_m = systolic wave; RT_m = regional myocardial relaxation time; CT_m = myocardial contraction time; PCT_m = myocardial pre-contraction time.

4. Discussion

Our results demonstrated that there were no significant differences in most of the LV and RV echocardiographic parameters between hypertensive patients with different tricuspid inflow patterns. The proportion of patients with abnormal RV diastolic function, as indicated by reversal of the tricuspid annular E_m/A_m ratio, was similar between patients with normal and inverted transtricuspid flow E/A ratios. This finding indicate that RV diastolic function in hypertensive patients cannot be reliably evaluated based on conventional Doppler RV filling patterns alone, which here identified only 31% patients with RV diastolic dysfunction in our study. Furthermore, the only independent correlate of the TDI-derived RV diastolic parameters (RV RT_m and tricuspid annular E_m/A_m ratio) was the transmitral flow E/A ratio. This implies that evaluating RV diastolic function by TDI in hypertensive patients is valuable if an inverted transmitral flow E/A ratio is detected using conventional Doppler echocardiography, even in those patients with a "normal" transtricuspid flow pattern.

4.1. *RV diastolic function in systemic hypertension*

Arterial systemic hypertension may lead to impaired LV diastolic and systolic function due to increased afterload (3,4) as well as changes in LV geometry and structure producing LV remodeling and hypertrophy (2,4). The right ventricle might also be affected by these processes (6). Previous studies have shown that RV free wall thickening develops in patients with hypertension (6,21), and RV diastolic dysfunction has been observed in these patients (5,6,16,17). The majority of previous reports have indicated that RV diastolic filling is closely related to the corresponding LV filling parameters and RV free wall thickness (5,6,16,22). These findings support the notion that ventricular interdependence and RV hypertrophy play major roles in RV performance in patients with hypertension (6,16,23). Although the clinical significance of RV diastolic dysfunction in hypertensive patients is not well known, the assessment of RV performance may be an additional indicator for the course of hypertensive cardiovascular disease (6).

4.2. *Evaluation of RV diastolic function in systemic hypertension*

In the past, assessment of RV function mostly relied on the thermodilution technique during right heart catheterization, radionuclide ventriculography, and nuclear magnetic resonance imaging. All of these techniques are relatively expensive, time consuming, and are not widely available. The advent of echocardiography provided a noninvasive approach for the rapid determination of both RV systolic and diastolic function. Initially, Doppler RV filling parameters, namely, transtricuspid flow peak E, A velocities and the E/A ratio, reflected the diastolic filling characteristics of RV (7,8). Most previous studies that used conventional Doppler echocardiography to assess RV diastolic function in systemic hypertension showed that the mean values of the transtricuspid flow E/A ratio were significantly different between hypertensive patients and normal controls, but there was significant overlap of these data (5,6,17,22). Recently, the clinical application of TDI has allowed online measurement of the velocities of tricuspid annular motion to assess systolic and diastolic RV function in various cardiac diseases, including systemic hypertension (15–17,24,25). The RT_m of RV and the tricuspid annular peak velocity of E_m determined by TDI are markers of ventricular relaxation, and the peak velocity of A_m reflects atrial activity (15,16). A tissue Doppler-derived tricuspid annular E_m/A_m ratio <1 indicates impaired ventricular compliance (16). Several studies that used TDI for analysis of RV diastolic function in patients with hypertension have demonstrated that the majority of RV diastolic indices are altered in these patients (16,17). Nevertheless, the frequency of involvement of RV diastolic function in hypertensive patients remains unclear. In the present study, 86.7% of the untreated hypertensive patients had TDI-derived evidence of RV diastolic dysfunction, and this was evenly distributed between patients with normal and inverted transtricuspid flow E/A ratios (86.4% *vs.* 87.5%, respectively; $p=1.000$). This observation implies that an abnormal RV filling pattern alone, as expressed by an inverted transtricuspid flow E/A ratio, cannot provide unequivocal evidence of RV diastolic dysfunction in hypertensive patients. Although the TDI-derived tricuspid annular E_m/A_m ratio has been suggested as a more appropriate measure of global RV diastolic function (15,16,24,25), it is not routinely performed in daily practice in echocardiographic studies because of time constraints or lack of facilities. One practical problem from the clinical viewpoint is how to select eligible patients for TDI analysis of RV diastolic function. In this study, we evaluated the clinical and echocardiographic predictors of TDI-derived RV diastolic indices (RV RT_m and tricuspid annulus E_m/A_m ratio) in a group of untreated hypertensive patients, and demonstrated for the first time that both indices are independently correlated with the transmitral flow E/A ratio, which is readily obtained and is most commonly used in clinical practice. In other words, the use of TDI to evaluate RV diastolic function in hypertensive patients is valuable if an inverted mitral E/A ratio is detected using the conventional Doppler method. The possible explanation for this correlation might be attributed to a functional interaction of ventricular passive diastolic properties, which suggests that both ventricles are influenced by the same factors (6,16). However, this finding should be verified in future analyses with a larger sample size. The tricuspid annular E_m/A_m ratio has been reported to be strongly related to the homologous mitral annular E_m/A_m ratio in hypertensive patients and normal controls, even after adjusting for clinical and echo confounders (16). However, we did not observe similar findings in multiple regression analysis. This discrepancy might be attributed to different study populations and, possibly, to the comparatively small sample size used in our study.

4.3. *Study limitations*

The present study has several limitations. First, this study included a relatively small number of patients with untreated systemic hypertension. Therefore, whether the same conclusion might be extrapolated to patients with mild or well-controlled hypertension is not known. More extensive studies incorporating patients with the full range of hypertension might yield different results. Second, comparatively standard techniques such as RV catheterization and/or sine magnetic resonance imaging were lacking. It might be more appropriate to compare TDI findings with a gold standard technique to confirm their accuracy. Third, there was no control group in the present study. However, comparison between hypertensive patients and normal controls was not the purpose of the study.

5. Conclusions

An abnormal RV diastolic filling pattern, as expressed by an inverted transtricuspid flow E/A ratio, is unreliable for evaluating RV diastolic function in untreated hypertensive patients. The best independent predictor of TDI-derived RV diastolic function abnormality in these patients is the transmitral flow peak E/A ratio. Assessment of RV diastolic function with pulsed-wave TDI in hypertensive patients is valuable if an abnormal transmitral flow peak E/A ratio is detected on conventional Doppler echocardiography despite a "normal" RV diastolic filling pattern.

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