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Evaluation of right ventricle functions in acute pulmonary thromboembolism using tissue Doppler imaging

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ABSTRACT

Aims: Right ventricular (RV) systolic and diastolic functions are impaired in a significant proportion of patients with acute pulmonary thromboembolism (PTE). In these cases, knowledge of RV function is of great importance both in the diagnosis and in the choice of treatment. Our aim was to evaluate RV systolic and diastolic functions by standard pulse Doppler and tissue Doppler imaging (TDI) in normotensive patients with PTE without hemodynamic disturbances.

Methods: A total of 48 subjects, including 28 acute PTE patients (14 M, 14 F) with a mean age of 41 ± 13 years and 20 healthy subjects (10 M, 10 F) with a mean age of 40 ± 9 years, were included in our study. At the level of the tricuspid and mitral valve cusps, pulse Doppler echocardiography evaluated diastolic filling parameters. With the TDI technique, the diastolic function of the RV lateral wall and septum were analyzed in segments in the apical four-cavity image. Diastolic early and late velocities (e', a'), e'/a' ratio, e'dt, isovolumetric relaxation time (IVRT), systolic velocity (s'), and systolic duration (s' duration) were evaluated by TDI.

Results: Among the RV standard Doppler parameters, a significant decrease in E velocity and E/A ratio and a significant increase in A velocity were observed compared to the control group (p=0.042; p=0.002; p=0.001, respectively). A non-significant prolongation in E'dt was detected. RV ejection fraction was significantly lower in PTE patients compared to the control group (51.1% vs. 69.7%) (p=0.001). TDI was used to look at the RV systolic function, and it was found that all segments had higher systolic (Sa-m) velocities than the control group. However, systolic velocities in patients with DHB in the RV were found to be lower in the annular regions and RV-free walls. Increased s' velocities were observed in annular regions and RV-free walls. However, no statistical significance was found in s' velocity values.

Conclusion: RV systolic and diastolic functions may be impaired in normotensive patients with PTE without hemodynamic disturbances.

Keywords: Acute pulmonary embolism, tissue Doppler Imaging, right ventricular diastolic function

INTRODUCTION

Acute pulmonary thromboembolism (PTE) is not always an easily diagnosed disease due to its non-specific clinical manifestations. Since the right ventricle (RV) is affected in a significant proportion of PTE cases, knowledge of RV systolic and diastolic function is of great importance in diagnosis, selection of treatment, and prediction of prognosis.[1-6]

Echocardiography is widely used in the evaluation of RV function. Because the RV has a trabecular structure and complex geometry, two-dimensional echocardiographic images are sometimes inadequate and make evaluation more difficult.[7]

Although invasive methods are considered the gold standard for the evaluation of RV diastolic function, a practical and noninvasive method such as echocardiographic examination is also widely used.[8] It has become an increasingly widely used method because it is noninvasive, harmless, inexpensive, easily applicable, and reproducible.[9] Diastolic function assessment by pulse wave Doppler echocardiography has limitations because it is affected by some factors, such as systolic loading conditions.[9]

Tissue Doppler Imaging (TDI) can overcome various limitations of the conventional pulse wave Doppler method.[9,10] There are several studies evaluating RV systolic and diastolic functions by TDI in normal subjects and different pathologic conditions.[11-13] Evaluation of RV functions by TDI in patients with PTE may provide additional information about the severity of PTE and guide both diagnosis and treatment.

The aim of our study was to evaluate RV systolic and diastolic functions by standard pulse Doppler and TDI in normotensive patients with PTE without hemodynamic disturbances.

METHODS

After institutional approval, this thesis study was conducted in the echocardiography laboratory of the cardiology outpatient clinic, Erciyes University, Faculty of Medicine, between November 2001 and September 2002. The study was conducted as a prospective, cross -sectional and single -centered study. The study looked at 48 people: 28 with acute PTE (14 men and 14 women) with an average age of 41 ± 13 years, and 20 healthy people (10 men and 10 women) with an average age of 40 ± 9 years. They were all hospitalized in the chest diseases service and the gynecology and obstetrics service and were sent to the echocardiography laboratory for transthoracic echocardiography before or during the diagnosis.

Diagnosis

- High probability on V/Q scintigraphy + high clinical suspicion and/or DVT detected on lower extremity venous Doppler,
- Moderate probability + high clinical suspicion on V/Q scintigraphy and/or DVT detected on lower extremity venous Doppler,
- Patients with PTE findings on spiral thorax CT + high clinical suspicion and/or DVT detected on a lower extremity venous Doppler were considered as PTE.

Exclusion criteria: Patients with poor echocardiographic image quality, Patients with clinical onset of PTE of more than seven days, Patients with acute disease leading to hemodynamic disturbance, Patients with arrhythmia (rhythm other than sinus rhythm), Patients with severe valvular disease (moderate to severe stenosis and insufficiency), patients with artificial valves, Patients with a previous myocardial infarction or coronary bypass surgery, Patients with a known history of CAD or findings compatible with CAD on ECG, patients with regional wall motion abnormality in the left V on echocardiography, patients with right V wall thickness over 6 mm, patients with COPD, chronic renal failure, diabetes mellitus, history of alcohol and drug use, patients with psychiatric illness, patients with hypertension (blood pressure >140/90 mmHg), patients over 65 years of age.

Echocardiographic Examination

The procedure was done with a Vingmed System V (Vingmed GE System 5, Horten, Norway) echocardiography device with a 2.5 MHz transducer while the patients were breathing normally and lying on their left side with their legs bent over them. This was done after five minutes of rest. Two-dimensional, M-mode, pulse wave Doppler, color Doppler, and pulse wave tissue Doppler examinations were performed through standard windows as recommended by the American Society of Echocardiography. Heart rate and blood pressure (BP) were measured every five minutes during the procedure.

M-Mode, 2-Dimensional, Color Doppler and Standard Doppler Echocardiographic Examinations

Simpson's method was used for RV EF measurement in apical four-cavity imaging. Areas were calculated by determining endocardial border tracings at end-diastole and end-systole. On apical four-chamber imaging, RV and LV widths were measured from the basal septum to the widest part of the LV and RV lateral wall endocardium at the end of diastole. The RV wall motion abnormality was assessed as previously recommended.[4] Measurement of diastolic indices for the RV was performed as for the LV. The measurements were performed during the apnea period after deep expiration, as recommended by Zoghbi et al.[14] Pulmonary flow velocity and pulmonary flow acceleration time (PAcT) (m/sec) were measured. Pulmonary artery pressure was also calculated as previously described by Mahan et al.[15]

Tissue Doppler Echocardiographic Examination

Recordings were obtained using pulsed-wave tissue Doppler format with apical four-cavity imaging for long-axis velocities and short-axis imaging for circular velocities. Long-axis velocities were obtained by placing the pulse wave sample volume (5mm) at the tricuspid lateral annulus, free wall mid- and apical regions, and septal annulus, mid- and apical regions. All Doppler measurements were performed by taking the mean values of five consecutive cardiac cycles during calm respiration. From these images, the systolic (s') wave velocity, early (e'), and late (a') diastolic wave velocities of the annulus were measured. From the time intervals of these waves, e'deseleration time (e'dt), isovolumetric relaxation (IVRT), and duration of the systolic wave (s'duration) were measured. For s' duration, the time between the beginning and end of the s' wave was measured. For IVRT measured by tissue Doppler, the time between the end of the s' wave and the beginning of the e'wave was measured.

Statistical Analysis

Statistical analyses were performed using the "SPSS 10.0 for Windows" software package. Numerical data were given as the mean ± standard deviation. Pearson's method of bivariate correlation analysis was used to analyze the relationships between variables. An independent T test (unpaired T test) was used for the comparison of two independent groups, and an ANOVA test (Tukey test for post hoc comparisons) was used for the comparison of three independent groups. The error level α was taken as 0.05. Values with a $P<0.05$ were considered significant.

RESULTS

A total of 48 individuals, including 28 patients (14 M; 14 F) with a mean age of 41 ± 13 years and 20 controls (10 M; 10 F) with a mean age of 40 ± 9 years, were included in the study. The baseline clinical characteristics of the acute PTE and control groups are shown in **Table 1**.

Table 1. Comparison of baseline clinical features between PTE and control group

		Patient Group n=28	Control Group n=20	p value
Age (years)		41 ± 13 (19-65)	40 ± 9 (25-60)	NS
Gender	Male	14 (37 ± 3)	10 (38 ± 2)	NS
	Female	14 (43 ± 3)	10 (42 ± 3)	NS
Systolic Blood Pressure (mmHg)		121 ± 14	123 ± 11	NS
Diastolic Blood Pressure (mmHg)		68 ± 12	74 ± 10	NS
Average Blood Pressure (mmHg)		86 ± 11	90 ± 10	NS
Pulse (beats/min)		86 ± 10	75 ± 8	0.001*
Hemoglobin (g/dl):		13.1±2.4	12.8±2	NS
Blood glucose (mg/dl)		106±59	99±48	NS
Creatinine (mg/dl)		1.0±0.2	0.8±0.2	NS

* Statistically significant; NS; not statistically significant

While the pulse rate was significantly higher in the patient group (p=0.001), other variables were similar in both groups. Information about the underlying clinical conditions is detailed in **Table 2**.

Table 2. General characteristics of PTE patients

Risk factors for PTE	%, n
DVT	%53.5 (15)
Previous trauma/surgery	%57 (16)
Birth control pill use (n=14)	%7.14 (1)
Diseases related to hemostasis	%7.14 (2)
Symptoms	
Presyncope	%14
Side pain	%96
Palpitation	%61
Dyspnea	%96
hemoptysis	%29
Average symptom duration	4.2 ± 1.8 days
ECG findings	
Sinus rhythm: %	%100 (28)
Sinusal tachycardia: (heart rate 90/min □)	%54 (15)
Incomplete or complete right bundle branch block: %	%25 (7)
Right axle deviation: %	%14 (4)
S1Q3T3 pattern: %	%25 (7)
V1-3 abnormal repolarization: %	%14 (4)
Normal ECG (heart rate 90↓)	%25 (7)

RV EF measured by Simpson's method was significantly lower in the PTE group compared to the control group (51.1% vs. 69.7%), (p=0.001). There was a significant increase in the RV end-diastolic diameter obtained in the apical four-window image in the PTE group compared to the control group (p=0.003). This increase was greater in patients with RV wall motion abnormalities (50.6 mm vs. 39.5 mm). PAB values calculated from PAcT were also significantly increased in the patient group compared to the control group (p=0.014).

When RV standard pulse Doppler parameters obtained through the tricuspid valve were analyzed, a significant decrease in E-wave velocity was found in the patient group (p=0.042). The wave velocity was also significantly increased (p=0.002). The E/A value obtained by comparing the ratio of these two waves to each other showed a significant decrease in the patient group (p=0.001). Standard pulse Doppler flow parameters obtained from transtricuspid flow in the PTE and control groups are shown in **Table 3**.

Table 3. Transtricuspid diastolic flow patterns with standard pulse Doppler Echocardiography

Triküspid	Patient	Control Group n=20	p value
E	0.52 ± 0.09	0.57 ± 0.07	0.042*
A	0.53 ± 0.15	0.42 ± 0.06	0.002*
E/A	1.07 ± 0.38	1.38 ± 0.15	0.001*
Edt	175 ± 81	149 ± 52	0.21

* Statistically significant

The results obtained by the tissue Doppler method in the patient and control groups are shown in **Table 4**. In patients with PTE, s′ wave velocity increased in the lateral and septal annulus, but this increase was not statistically significant (p=0.805, p=0.265, respectively). e′ values were significant in the lateral annulus (p=0.023), septal annulus (p=0.129), and e′ values decreased in the PTE group, but this decrease was not statistically significant. In the patient group, lateral annulus and septal annulus were statistically significant in a′ values (p=0.023, p=0.047, respectively). Although there was a decrease in e′/a′ ratios in the patient group, it was not statistically significant (p >0.05). The s′ durations of the segments were found to be significantly shorter in the PTE group compared to the control group in the lateral and septal segments (p=0.001). IVRT values were prolonged in both annuli, but not statistically significant (p>0.05).

Table 4. Right Ventricular Septal and Lateral Annulus tissue Doppler echocardiography findings

		Patient n=28	Control n=20	p
RV lateral annulus	**s′**	0.138 ± 0.036	0.136 ± 0.027	0.805
	e′	0.123 ± 0.045	0.151 ± 0.035	**0.023***
	a′	0.159 ± 0.07	0.129 ± 0.02	**0.038***
	e′/a′	0.98 ± 0.61	1.170 ± 0.31	0.111
	e′dt	136.0 ± 42.1	120.7 ± 57.1	0.315
	s′ time	241.8 ± 34	287.5 ± 35.6	**0.001***
	IRT	57 ± 27	52.7 ± 31.7	0.624
RV septal annulus	**s′**	0.0925 ± 0.026	0.0855 ± 0.1	0.265
	e′	0.101 ± 0.035	0.113 ± 0.020	0.129
	a′	0.110 ± 0.04	0.09 ± 0.017	**0.047**
	e′/a′	1.06 ± 0.62	1.26 ± 0.32	0.089
	Edt	127.5 ± 39.4	121.78 ± 47.9	0.066
	s′ tine	240.7 ± 41.2	291.5 ± 28.7	**0.001***
	IRT	63.1 ± 43.1	62.5 ± 34.0	0.956

RV; Right ventricul DT; Deceleration time IRT; Isovolumetric relaxation time

DISCUSSION

In our study, we demonstrated that systolic and diastolic functions were affected in PTE patients with normal blood pressure, even if hemodynamic deterioration was not observed. We evaluated these results in accordance with the literature.

Many changes in lung and heart function occur in PTE. Pulmonary vascular resistance and RV afterload increase with occlusion of the pulmonary arteries and the release of vasoconstrictor factors. In a significant proportion of PTE cases, RV function deteriorates in direct proportion to the severity of the embolism, with a reported rate of 50% in some series.[6,16,17] The presence of signs of right ventricular overload in PTE is associated with a poor prognosis, and the evaluation of RV function is very important.[1-6] Pulse wave Doppler echocardiography has been used for many years as a noninvasive test for the evaluation of diastolic function.[8,9] However, this method has some limitations and is affected by heart rate changes and different loading conditions, and may normalize with the progression of diastolic dysfunction.[9] Previous studies have reported that RV dysfunction was not observed in approximately 40% of normotensive patients presenting with acute PTE.[4,18] Impaired RV function and hemodynamic instability were reported to be the most decisive findings in in-hospital mortality, with a mortality rate of 25%.[4,19,20] Goldhaber et al. reported that RV hypokinesia was observed in approximately half of the patients with PTE.[18] In our study, we found RV hypokinesia less frequently, which may be due to the fact that we excluded patients with underlying cardiac and pulmonary disease, so RV systolic dysfunction may have been observed less frequently. We also found significant RV diastolic dysfunction in the patient group.

Although hemodynamically unstable RV dysfunction is associated with increased mortality, PTE cases with RV dysfunction evaluated by echocardiography alone have not been found to have increased mortality.21 However, TDI RV myocardial velocities predict an increased risk of death up to 1 year after the event. TDI has been shown to be a very useful technique for quantitative assessment of LV diastolic and systolic function and is more sensitive for the early detection of functional myocardial abnormalities.[11]

We obtained similar findings in our patients with acute increases in RV afterload. Several mechanisms may be involved in the deterioration of RV diastolic function; RV function may be impaired directly due to the amount of increase in RV afterload. At the same time, RV ischemia, which is thought to occur due to the increase in arterial load, may affect diastolic functions. They have shown that pressure load has an important role in RV diastolic dysfunction.[22] They reported that early diastolic RV relaxation was significantly impaired in acute pressure overload due to RV dilatation and hypoxia and that this prolongation in relaxation was less in patients with chronic pressure overload than in acute cases.

A lot of things can go wrong when trying to figure out how well the RV is working, including the patient's age and heart rate, the LV's ejection fraction, and things that have to do with the Doppler scan.[5,6] A study by Caso et al.[13] looked at COPD patients who fit this model. They found that the RV lateral annulus TDI e'/a' ratio was low and IVRT was significantly higher with or without pulmonary hypertension. As an indicator of RV diastolic dysfunction, we observed decreased RV lateral wall TDI e′ velocities and e′/a′ ratio, increased a′ velocities, and prolonged IVRT intervals.

We think that TDI, as a new method that can relatively overcome the limitations of standard pulse Doppler, can be used as a suitable method for the evaluation of patients with PTE. In our study, we observed that systolic and diastolic functions were affected in PTE patients with normal blood pressure, even if hemodynamic deterioration was not observed.

Limitations

This study has some limitations. First of all, relatively few patients were included, and it was a single-center, retrospective study. Patients' echocardiography was performed only during the first hospitalization to the hospital. Follow-up echocardiographies were not performed in the hospital and after discharge. Examinations such as Strain Echocardiography and magnetic resonance imaging, which are relatively new imaging methods, were not performed on the patients in our study group. We could not include the drugs used in the study population in the analyses. Pulmonary angiography was not used as the gold standard in the diagnosis of PTE. Coronary artery disease could not be excluded angiographically. Simpson's method, which we use for RV ejection fraction, may not be as accurate as the gold standard method of invasive measurements. The presence of trabeculations and the inability to clearly select the RV endocardium may have impacted our two-dimensional echocardiographic measurements. The difficulty in obtaining measurements from apical regions with TDI may have affected our results.

CONCLUSION

As a result, cardiovascular autonomic neuropathy (CAN) is a common and severe complication of diabetes that can lead to hemodynamic instability during anesthesia. HRV is a new test that is more sensitive than the standard reflex test and detects cardiac autonomic dysfunction earlier. In this study, the hemodynamic effects during anesthesia induction and intubation were compared between type 2 diabetic and nondiabetic patients. Etomidate administration resulted in minimal hemodynamic changes while maintaining hemodynamic stability by preserving sympathetic outflow and autonomic reflexes in diabetic patients. The study concluded that etomidate may be a suitable option for anesthesia induction in diabetic patients with CAN. Furthermore, we feel that HRV evaluated at rest may not be adequate for detecting autonomic neuropathy in some instances.

ETHICAL DECLARATIONS

Ethics Committee Approval: "Evaluation of right ventricle functions in acute pulmonary thromboembolism using Tissue Doppler Imaging" was derived from the thesis study conducted in 2001. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Informed Consent: All patients signed and free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declared that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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