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Doppler Tissue Imaging-Derived Left Ventricular Myocardial Performance Index and Cardiac Time Intervals in Chronic Hemodialysis Patient

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ABSTRACT

Background: Changes in the diastolic and systolic function of the LV are linked to end-stage renal disease (ESRD). For a wide range of clinical problems, tissue Doppler imaging (TDI) is regarded as an additional echocardiographic diagnostic tool.

Objective: This study aimed to assess left ventricular (LV) time intervals and the myocardial performance index in chronic HD patients using Doppler tissue imaging before and after HD sessions.

Methods: Fifty patients participated in this study with regular HD for at least six months, with good functioning arteriovenous (AV) fistula and aged >18 years old. Full history taking, clinical examination and blood tests were done. Conventional echocardiographic and TDI were recorded for all cases with assessing LV myocardial performance index (MPI) pre- and post-haemodialysis session

Results: Body weight, systolic and diastolic blood pressure, left ventricular end-diastolic and end-systolic diameters, ejection percent, E wave velocity, and E/A ratio were all much greater in pre-hemodialysis measurements than in post-hemodialysis measurements. On the other hand, parameters such as isovolumetric relaxation time, E wave deceleration time, and myocardial performance indices assessed by Doppler were notably increased after dialysis. No significant differences were observed in heart rate or in tissue Doppler-derived indices, including isovolumetric relaxation time (IVRT), isovolumetric contraction time (IVCT), and their calculated values, between the pre- and post-dialysis periods.

Conclusions: Essential hemodynamic and structural heart parameters were greatly decreased by HD. Standard flow LV MPI index measured from Doppler was impacted by hemodialysis. The LV MPI index produced from TDI was not, even though these major changes happened, the TDI-derived MPI was not affected.

Keywords: Chronic hemodialysis, Cardiac time intervals, Tissue Doppler imaging, End-stage renal disease.

INTRODUCTION

Globally, end-stage renal disease (ESRD) is becoming an increasingly significant issue. By 2030, the number of ESRD patients in need of renal replacement therapy—of which hemodialysis (HD) is still the most common may exceed 5 million [1].

Cardiovascular issues are typical in ESRD patients. Among the most common and clinically significant conditions are left ventricular hypertrophy (LVH) and abnormalities in the systolic and diastolic function of the LV and they greatly increase the high rates of disease and death in this population. Numerous contributory variables, including chronic anemia, volume overload, high parathyroid hormone levels, and persistent hypertension, frequently result in these cardiac anomalies [2].

The myocardial performance index (MPI), which is derived from tissue Doppler, offers a reliable and measurable way to assess both systolic and diastolic function during a single cardiac cycle. It has been shown to be useful in the diagnosis and prognosis of a number of heart disorders, including cardiac amyloidosis, anthracycline-induced cardiotoxicity, myocardial infarction, and dilated cardiomyopathy [3].

This study's goal was to evaluate the MPI and important cardiac time intervals before and after dialysis sessions in order to determine how sudden hemodynamic changes affect left ventricular function in patients receiving chronic hemodialysis.

METHODS

50 patients over the age of 18 who had been receiving regular HD for at least six months participated in this study.

Exclusion criteria: Patients with acute coronary syndrome, stroke, uncontrolled hypertension, active infection, pacemaker or other cardiac implanted electronic device, atrial fibrillation or other arrhythmias, anemia, and patients with temporary catheter or graft vascular access.

Every patient underwent clinical examination (general and vital signs), full history taking (name, age, sex, date of admission, chronology of symptoms, co-existing medical condition and family history), routine laboratory tests [serum creatinine, serum albumin, blood urea, blood urea nitrogen and complete blood count (CBC) using an automated analyzer].

Traditional echocardiography:

Trans-thoracic echocardiography (TTE) was performed for each patient using a GE Vivid I machine with TDI capability. The traditional TTE was performed in accordance with the American Society of Echocardiography's (ASE) recommendations [4]. To evaluate heart function, M-mode echocardiography was used to quantify the LV's end-systolic and end-diastolic diameters in the parasternal long-axis view. The left ventricular ejection fraction (LVEF) was calculated

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using M-mode method. Additionally, pulsed-wave Doppler was used to analyze mitral inflow parameters, such as peak velocities during early (E) and late (A) diastole and deceleration time (DT). The E/A ratio, MPI, isovolumetric contraction time (IVCT), and isovolumetric relaxation time (IVRT) were all calculated.

The subject was put in the left lateral decubitus posture and breathing regularly and spontaneously during each echocardiography and the examination was done before and after the HD session. Using tissue Doppler (TDI) imaging with pulsed wave, myocardial velocity profiles were produced from both apical two-chamber and four-chamber views. The anterior, inferior, lateral, and septal regions of the mitral annulus were the precise locations for the Doppler sample volume. Velocity curves obtained from these sites were used to assess IVCT, IVRT, and ejection time (ET), and their averages were then calculated. MPI was calculated by dividing the total of IVCT and IVRT by ET.

Ethical approval: Menoufia University Hospital's Ethical Committee gave its clearance for the study (7/2023CARD15). The patients gave their signed informed consent. The Declaration of Helsinki was adhered to during the research.

Statistical analysis

For analysis, SPSS version 26 (IBM Inc., Armonk, NY) was utilized. Quantitative data were summarized using means ± SD, and group differences were evaluated using t-test, Chi-square, or Fisher's exact tests. Pearson's correlation analysis between changes in MPI and variations in post-dialysis blood pressure and ultrafiltration volume was done. Significance level was considered by a p-value ≤ 0.05.

RESULTS

Our study included ESRD patients on regular HD, with mean age of 49.42 ± 13.25 with male predominance (58% of the cases).

Participants exhibited average body mass index (BMI) of 24.81 ± 5.27 and a standard height range of 1.68 ± 0.11 meter. A significant percentage of the cases exhibited a history of diabetes, hypertension, and dyslipidaemia, alongside a considerable incidence of smoking among individuals.

The initial laboratory assessments in ESRD patients demonstrated subnormal haemoglobin and haematocrit levels, signifying anaemia, whereas white blood cell and platelet counts remained within normal limits. Serum albumin levels were moderately diminished, implying possible nutritional or inflammatory issues (Table 1).

Table (1): General Demographics and Laboratory Investigations in the study group

Parameter	Category	ESRD (n=50)
Age (years)	Mean ± SD	49.42 ± 13.25
	Median (IQR)	48.00 (41.47-58.42)
Sex	Female	21 (42.0%)
	Male	29 (58.0%)
Height (m)	Mean ± SD	1.68 ± 0.11
	Median (IQR)	1.68 (1.57-1.77)
BMI (kg/m²)	Mean ± SD	24.81 ± 5.27
	Median (IQR)	23.77 (20.36-28.86)
Duration of HD (months)	Mean ± SD	75.16 ± 45.62
	Median (IQR)	62.35 (42.00-93.57)
Medical history	Diabetic	38 (76.0%)
	Hypertensive	42 (84.0%)
	Dyslipidemic	27 (54.0%)
	Smoker	41 (82.0%)
Baseline Laboratory Investigations in study cases		
Parameter	Category	ESRD (n=50)
Hemoglobin (Hb) (g/dL)	Mean ± SD	7.98 ± 1.60
Hematocrit (HCT) (%)	Mean ± SD	22.12 ± 5.54
White Blood Cells (WBCs) (×10³/µL)	Mean ± SD	8.37 ± 1.37
Platelets (PLT) (×10³/µL)	Mean ± SD	288.63 ± 34.54
Creatinine (mg/dL)	Mean ± SD	9.94 ± 2.71
Blood Urea Nitrogen (BUN) (mg/dL)	Mean ± SD	84.77 ± 4.67
Albumin (g/dL)	Mean ± SD	3.30 ± 0.74

ESRD: End-stage renal disease, data displayed as mean ± SD, **IQR:** Stands for interquartile range, **WBCs:** White blood cells, **PLT:** Platelets, **BUN:** Blood urea nitrogen, **HD:** Hemodialysis, **Hb:** Hemoglobin and **HCT:** Hematocrit.

The study demonstrated a notable decrease in body weight in post-HD than in pre-HD with a p-value < 0.001, implying that the weight alteration resulting from fluid evacuation during dialysis is considerable. The average ultrafiltrate volume in the ESRD group was around 1.9 litres. Regarding the heart rate, it remained relatively stable comparing pre-HD and post-HD. There was a significant reduction in systolic and diastolic blood pressure in post-HD than in pre-HD (p < 0.001) (Table 2).

Table (2): Change in body weight and vital signs in study cases

Parameter	Time	Mean ± SD	Median (IQR)	t	p
Weight (kg)	Pre-HD	69.64 ± 8.91	70.53 (55.00-84.00)	7.759	<0.001*
	Post-HD	62.55 ± 8.81	62.72 (46.00-80.00)		
Change in vital signs in study cases					
Parameter	Time	Mean ± SD	Median (IQR)	t	p
Heart Rate (HR) (bpm)	Pre-HD	73.84 ± 10.80	72.18 (56.00-95.00)	0.216	0.830
	Post-HD	74.06 ± 10.28	72.50 (57.00-99.00)		
Systolic Blood Pressure (SBP) (mmHg)	Pre-HD	144.77 ± 16.82	148.00 (111.00-169.00)	9.094	<0.001*
	Post-HD	125.71 ± 16.76	127.60 (95.00-154.00)		
Diastolic Blood Pressure (DBP) (mmHg)	Pre-HD	94.85 ± 16.24	97.57 (61.00-118.00)	7.894	<0.001*
	Post-HD	79.14 ± 16.58	81.87 (47.00-104.00)		

	ESRD (n=50)
Ultrafiltrate volume (Litre)	1.9 ± 0.92

ESRD: end-stage renal disease, **HR:** heart rate, **SBP:** systolic blood pressure, **DBP:** diastolic blood pressure, **IQR:** interquartile range. ***:** significant as P value ≤ 0.05

Regarding conventional echocardiography findings, important changes in cardiac function before and after HD were recorded. Several key parameters, including LVEDD, LVESD, LVEF, E wave and E/A ratio were significantly decreased post-HD than pre-HD (P value <0.001). While, the A wave (atrial filling) showed a slight decrease in post-HD, which was not statistically significant (p = 0.222). Other measures such as IVRT, EDT and IRT also displayed significant increase in post-HD than in pre-HD (p < 0.001, <0.001, 0.006*), however IVCT remained relatively unchanged (p = 0.107). Furthermore, parameters related to myocardial performance, including b showed significant decrease post-HD (p < 0.001). (a - b)/b (MPI)) showed significant increase post-HD (p < 0.001). The tissue Doppler parameters showed that there were no statistically significant differences between pre-HD and post-HD values. For instance, the tissue Doppler IVRT' increased slightly in post-HD than in pre-HD (p = 0.234), and the IVCT' decreased in post-HD than in pre-HD (p = 0.137). Similarly, the myocardial velocities a' and b' showed minimal non-significant changes (a', p = 0.212; and b', p = 0.229) in pre-HD or in post-HD. Additionally, the difference between a' and b' (a' - b') and the derived MPI ((a' - b')/b') did not exhibit significant alterations (p = 0.102 and p = 0.413 respectively) (Table 3).

Table (3): characteristics of tissue and conventional Doppler echocardiography in research cases

Conventional echocardiography parameters					
Parameter	Time	Mean ± SD	Median (IQR)	t	p
(LVEDD) (mm)	Pre-HD	4.80 ± 0.42	4.76 (4.10-5.70)	4.195	<0.001*
	Post-HD	4.58 ± 0.49	4.59 (3.70-5.40)		
(LVESD) (mm)	Pre-HD	3.02 ± 0.71	3.01 (1.30-4.40)	5.469	<0.001*
	Post-HD	2.61 ± 0.71	2.70 (1.00-3.80)		
(LVEF) (%)	Pre-HD	61.56 ± 6.06	60.75 (50.00-74.00)	3.641	<0.001*
	Post-HD	58.33 ± 5.99	58.00 (48.00-72.00)		
E wave (m/sec)	Pre-HD	0.88 ± 0.23	0.92 (0.49-1.18)	6.510	<0.001*
	Post-HD	0.69 ± 0.24	0.67 (0.23-1.06)		
A wave (m/sec)	Pre-HD	0.83 ± 0.22	0.82 (0.49-1.16)	1.238	0.222
	Post-HD	0.80 ± 0.23	0.80 (0.45-1.14)		
E/A Ratio	Pre-HD	1.03 ± 0.02	1.03 (1.00-1.07)	13.372	<0.001*
	Post-HD	0.80 ± 0.12	0.81 (0.47-0.95)		
Deceleration Time (DT) (msec)	Pre-HD	224.25 ± 41.65	216.31 (161.00-299.00)	6.510	<0.001*
	Post-HD	256.16 ± 40.09	260.26 (184.00-315.00)		
(IVRT) (msec)	Pre-HD	89.47 ± 13.51	86.11 (71.00-117.00)	7.279	<0.001*
	Post-HD	104.39 ± 15.63	106.50 (79.00-131.00)		
(IVCT) (msec)	Pre-HD	72.12 ± 20.09	77.03 (31.00-105.00)	1.641	0.107
	Post-HD	75.46 ± 19.30	79.50 (33.00-107.00)		
b (msec)	Pre-HD	272.40 ± 17.70	275.40 (216.30-299.70)	8.372	<0.001*
	Post-HD	222.13 ± 40.66	228.20 (77.40-258.70)		
a - b (msec)	Pre-HD	165.11 ± 17.62	167.11 (119.70-200.70)	1.182	0.243
	Post-HD	158.20 ± 39.61	164.96 (17.80-199.80)		
(a - b)/b [MPI] (ratio)	Pre-HD	0.54 ± 0.09	0.55 (0.40-0.70)	3.635	<0.001*
	Post-HD	0.64 ± 0.14	0.63 (0.30-0.90)		
tissue doppler parameters in study cases					
Parameter	Time	Mean ± SD	Median (IQR)	t	p
Tissue Doppler IVRT' (ms)	Pre-HD	88.79 ± 7.51	89.48 (71.01-101.04)	1.206	0.234
	Post-HD	90.88 ± 9.55	92.28 (74.16-107.46)		
Tissue Doppler IVCT' (ms)	Pre-HD	46.96 ± 8.55	46.31 (29.93-64.37)	1.512	0.137
	Post-HD	44.48 ± 9.20	44.37 (19.45-65.59)		
Tissue Doppler a' (ms)	Pre-HD	407.61 ± 17.52	409.67 (357.50-447.56)	1.265	0.212
	Post-HD	411.73 ± 16.17	412.21 (364.33-434.41)		
Tissue Doppler b' (ms)	Pre-HD	269.14 ± 10.55	268.14 (248.01-288.05)	1.218	0.229
	Post-HD	266.83 ± 9.59	266.60 (253.10-290.20)		
Tissue Doppler a' - b' (ms)	Pre-HD	140.29 ± 8.45	140.89 (119.26-164.25)	1.666	0.102
	Post-HD	143.63 ± 10.42	143.42 (120.63-160.90)		
Tissue Doppler (a' − b')/b' [MPI'] (ratio)	Pre-HD	0.52 ± 0.03	0.53 (0.47-0.58)	0.825	0.413
	Post-HD	0.53 ± 0.02	0.53 (0.47-0.58)		

DT: deceleration time, **LVEF:** left ventricular ejection fraction, **LVEDD:** left ventricular end diastolic diameter, **LVESD:** left ventricular end systolic diameter, Ejection time (ET), isovolumic relaxation time (IRT), and isovolumic contraction time (ICT) added up to the interval "a" between the stoppage and the start of transmitral flow. The LV outflow ET occurred during interval "b." EDT stands for E deceleration time, **IVRT** for isovolumetric relaxation time, **LVEF** for left ventricular ejection fraction, **EDT** for peak early diastolic and late diastolic mitral inflow velocities, **IVCT:** isovolumetric contraction time, **MPI:** myocardial performance index, **a′:** the time interval from the end to the onset of the mitral annular velocity pattern during diastole, **b′:** the duration of the systolic myocardial velocity wave, **IQR:** interquartile range. ***:** significant as P value ≤ 0.05.

Changes in TD-MPI in the studied group were not correlated with the ultrafiltration volume. Also, post-TD-MPI were not correlated with changes in systolic blood pressure (r = -0.035, P = 0.810), diastolic blood pressure (r = -0.059, P = 0.687) and ultrafiltration volume (r = -0.251, P = 0.078) (Table 4 & figure 1).

Table (4): Correlation between post Tissue Doppler MPI' ((a' − b')/b') and changes in BP and ultrafiltration volume:

	Pearson Correlation Coefficient (r value)	P-Value
Ultrafiltration volume	-0.251	0.078
Change in (SBP) (mmHg)	-0.035	0.810
Change in (DBP) (mmHg)	-0.059	0.687

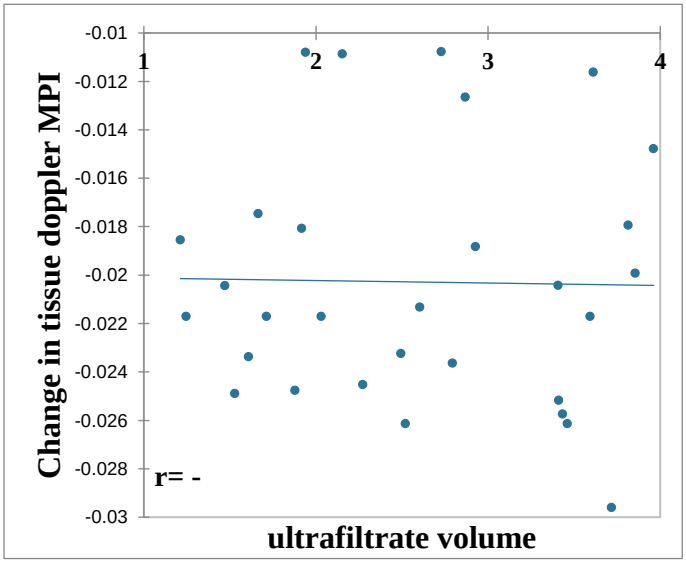

Figure (1): Correlation between change in tissue Doppler MPI and ultrafiltrate volume of the ESRD patients.

DISCUSSION

Anemia, arteriovenous fistula (AVF) flow, uremic toxicity, myocardial fibrosis, and chronic volume and pressure overload are some of the processes by which end-stage renal disease (ESRD) significantly compromises left ventricular (LV) structure and mechanics. These stressors result in increased LV mass index, changed geometry, and either concentric or eccentric LV hypertrophy (LVH) [5].

In the current study, LVEDD was substantially lower after HD than it was before HD (P value <0.05). Compared to before HD, LVESD and E-wave were considerably lower after HD.

IVRT was much higher after hemodialysis than it was before HD. The difference between LVEF before and after HD was negligible. Between before and after HD, there was no discernible difference in DT or IVCT. Following HD, the MPI significantly increased, indicating changes in overall heart efficiency. There was no discernible difference in IVRT′, IVCT′ and MPI′ between pre- and post-HD, suggesting that cardiac tissue mobility was preserved.

Because pulsed Doppler assesses blood flow velocities, which are more influenced by loading conditions (preload and afterload) and technical issues like valve timing and sample volume placement, pulsed Doppler-derived MPI is typically less accurate than tissue Doppler-derived MPI. On the other hand, DTI MPI's methodological approach is responsible for its independence from preload [6]. To measure the velocities of myocardial motion, particularly during the contraction (systole) and relaxation (diastole) stages of the cardiac cycle, DTI uses tissue Doppler imaging. By concentrating on the heart muscle's actual contractile and relaxation capabilities rather than the volume status or filling pressures that characterize preload, this method captures the intrinsic features of myocardial performance. As a result, DTI MPI combines the diastolic and systolic phases into a single index that represents the overall function of the heart without being impacted by the amount of blood returning to it [7].

According to **Mostafa *et al.*** [8] following HD, heart rate rose and LVEDD considerably improved, resulting in shorter diastolic length and R-R intervals ($p < 0.001$). The IVRT and EF% did not alter, suggesting that systolic function was unaffected. The dilatation of the left ventricle was the most common geometric anomaly. Early diastolic velocity (E) and the E/A ratio decreased after HD, indicating a reduction in diastolic function, although late diastolic velocity (A) remained constant.

According to **Ouali *et al.*** [9] there was no discernible change in the LV Tei Index following HD. According to **Koga and colleagues** [10], only those who lost more than 1.5 kg of weight showed significant changes in the Tei index before and after HD. Although the Tissue Doppler Echo-Tei and Pulsed Doppler Echo-Tei indices are both preload-dependent indicators, the effect of HD on the tissue Doppler Tei index varies when HD removes a significant amount of fluid. This is distinct from our findings because, although the average filtration capacity in our cohort was 1.9 kg, the statistical analysis did not reveal a significant link between the groups' doppler and tissue doppler assessed Tie index.

According to **Said *et al.*** [11], the LV cavity dimensions of the two study groups (twelve healthy controls who were matched for age and gender and ESRD patients who were scheduled for haemodialysis) for the first time were similar. However, the ESRD group's LV wall thickness was noticeably higher. Even though the two study groups' LVEFs were comparable, the ESRD group's MPI-LV was noticeably greater, suggesting that ESRD patients had impaired LV function.

The impact of heart-rate variations and HD-related volume decrease on the LV MPI by traditional PWD and

MPI using TDI in adult ESRD patients was examined by **Ozdemir *et al.*** [12] in a newly published study. They demonstrated how preload and heart-rate variations affected traditional PWD-derived MPI. Nevertheless, preload and heart-rate variations had no effect on the LV MPI determined by TDI. **Su *et al.*** [13] used MPI with TDI to assess the global right and left ventricular performance in adult uremia patients. Their patients' MPI values were higher, their ET was shorter, and their mean IVRT and IVCT were longer [13].

LIMITATIONS: Instead of employing invasive assessment instruments, we rely on the patient's weight as a gauge of their fluid state in ESRD. The sample size was somewhat modest.

CONCLUSIONS

While the left ventricular (LV) myocardial performance index (MPI) derived from tissue Doppler imaging (TDI) showed no statistically significant changes after hemodialysis, the procedure induced marked hemodynamic and structural alterations — including reductions in blood pressure and LV dimensions, as well as changes in diastolic function — which were associated with an apparent improvement in the conventional Doppler-derived MPI.

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REFERENCES

1. **Kolbrink B, Schüssel K, von Samson-Himmelstjerna F *et al.* (2023):** Patient-focused outcomes after initiation of dialysis for ESRD: mortality, hospitalization and functional impairment. Nephrol. Dial. Transplant., 38 (11): 2528-2536.
2. **Echefu G, Stowe I, Burka S *et al.* (2023):** Pathophysiological concepts and screening of cardiovascular disease in dialysis patients. Front. Nephrol., 3: 1198560.
3. **Goroshi M, Chand D (2016):** Myocardial Performance Index (Tei Index): A simple tool to identify cardiac dysfunction in patients with diabetes mellitus. Indian Heart J., 68 (1): 83-87.
4. **Mitchell C, Rahko P, Blauwet L *et al.* (2019):** Guidelines for performing a comprehensive transthoracic echocardiographic examination in adults: Recommendations from the American Society of Echocardiography. J. Am. Soc. Echocardiogr., 32 (1): 1-64.
5. **London G (2002):** Left ventricular alterations and end-stage renal disease. Nephrol. Dial. Transplant., 17 (1): 29-36.
6. **Dandel M (2024):** Monitoring of the right ventricular responses to pressure overload: prognostic value and usefulness of echocardiography for clinical decision-making. Cardiovasc. Diagn. Ther., 14 (1): 193-222.
7. **Omar A, Botero D, Caraballo J *et al.* (2022):** Tissue Doppler derived biphasic velocities during the pre and post-ejection phases: patterns, concordance and hemodynamic significance in health and disease. Cardiovasc. Ultrasound, 20 (1): 17.
8. **Mostafa F, Sad I, Elshamaa M *et al.* (2018):** Evaluation of left ventricular function by standard and tissue Doppler echocardiography in pediatric hemodialysis patients: correlation with brain natriuretic peptide. Arch. Med. Sci. Atheroscler. Dis., 3: 18-28.
9. **Ouali S, Abroug S, Neffeti E *et al.* (2009):** Influence of acute preload reduction on left ventricular function indices in pediatric end-stage renal disease: echocardiographic study before and after dialysis. Arch. Med. Sci. Atheroscler. Dis., 59: 14-19.
10. **Koga S, Ikeda S, Matsunaga K *et al.* (2003):** Hemodialysis-induced changes in Doppler echocardiographic parameters of left ventricular systolic and diastolic performance including the Tei index. Clin. Nephrol., 59 (3): 180-185.
11. **Said K, Hassan M, Baligh E *et al.* (2012):** Analysis of ventricular performance in new dialysis patients with end-stage renal disease using tissue Doppler imaging. J. Echocardiogr., 10 (4): 1054-1059.
12. **Özdemir K, Balci S, Duzenli M *et al.* (2007):** Influence of preload and heart rate on myocardial performance index assessed by Doppler and tissue Doppler echocardiography. Int. J. Clin. Cardiol., 30 (8): 342-348.

    Su Y, Wu N, Tian J (2006): Assessment of overall cardiac function using tissue Doppler-derived myocardial performance index in uremic patients. J. Med. Ultrasound, 25 (6): 1563-1569.