The effect of postural changes (leg lifting) on tissue Doppler parameters in coronary artery disease

Koroner arter hastalığında bacak kaldırma ile sağlanan postüral değişikliğin doku Doppler parametreleri üzerine etkisi

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Objectives: We investigated the effect of increased preload through postural changes (leg lifting) on tissue Doppler parameters in patients with and without coronary artery disease (CAD).

Study design: The study included 42 patients who were scheduled for coronary angiography. All the patients underwent standard two-dimensional, color Doppler and tissue Doppler echocardiography before coronary angiography. Tissue Doppler imaging was performed from septal and lateral mitral annuluses at baseline and during 45º leg lifting followed by two-minute stabilization. Patients were grouped based on coronary angiography findings: those having stenosis greater than 70% were considered to have CAD and those with normal coronary arteries comprised the control group. Echocardiography measurements were compared between the two groups.

Results: Angiography showed normal coronary arteries or border irregularities in 22 patients and CAD in 20 patients. The two groups were similar with regard to demographic data and ejection fractions, except for male preponderance in the CAD group. Compared with the control group, patients with CAD exhibited a significantly lower isovolumic acceleration rate (IVA) at the lateral (p=0.007) and septal (p=0.03) mitral annuluses. In the control group, leg lifting resulted in increased systolic velocity (S) compared with baseline at the lateral (p=0.009) and septal (p=0.01) annuluses, whereas S wave augmentation was only significant at the septal annulus (p=0.009) in patients with CAD. No significant change was observed in IVA following leg lifting in both groups.

Conclusion: Preload alteration induced by leg lifting resulted in similar changes in tissue Doppler parameters in patients with and without CAD, except for blunted augmentation of S wave at the lateral annulus in CAD. Detection of decreased IVA at baseline may be a useful finding for CAD.

Key words: Blood flow velocity; coronary artery disease; echocardiography, Doppler; posture/physiology; ventricular function, left.

Amaç: Bu çalışmada koroner arter hastalığı (KAH) olan ve olmayan kişilerde postüral değişikliğe (bacak kaldırma) bağlı venöz dönüş artışının doku Doppler parametreleri üzerindeki etkileri araştırıldı.

Çalışma planı: Çalışmaya koroner anjiyografi planlanan 42 hasta alındı. Koroner anjiyografiden önce tüm hastalar standart ikiboyutlu renkli Doppler ve doku Doppler ekokardiyografi ile değerlendirildi. Doku Doppler ölçümleri hasta normal konumda iken ve bacak 45 derece kalkık durumda iki dakika bekletildikten sonra mitral annulusun septal ve lateral kenarlarından yapıldı. Hastalar koroner anjiyografi sonuçlarına göre iki gruba ayrıldı: %70'in üzerinde darlık saptananlar KAH hastası olarak kabul edilirken, koroner arterleri normal bulunanlar veya sadece kenar düzensizliği saptananlar kontrol grubunu oluşturdu. İki grubun ekokardiyografik ölçüm sonuçları karşılaştırıldı.

Bulgular: Koroner anjiyografide 22 hasta normal değerlendirilirken, 20 hastada KAH saptandı. Erkek hasta sayısının KAH grubunda anlamlı derecede fazla olması dışında, grupların demografik özellikleri ve ejeksiyon fraksiyonları benzer bulundu. Kontrol grubu ile karşılaştırıldığında, KAH grubunda izovolemik akselerasyon hızı (İAH) hem lateral (p=0.007) hem de septal (p=0.03) mitral annulusta anlamlı derecede düşük bulundu. Bacak kaldırma sonucunda kontrol grubundaki zirve sistolik hızda (S) başlangıca göre lateral (p=0.009) ve septal (p=0.01) mitral annulusta anlamlı artış görülürken, KAH grubunda artışın sadece septal annulusta anlamlı olduğu görüldü (p=0.009). İki grupta da bacak kaldırma sonrası İAH'de anlamlı değişiklik olmadı.

Sonuç: Bacak kaldırma ile sağlanan venöz dönüş artışı KAH olan ve olmayan kişilerde, KAH'de lateral annulus S dalgası artışının baskılanması dışında, benzer doku Doppler değişikliklerine neden olmaktadır. Başlangıç İAH'sinde saptanan düşüklük KAH için yardımcı bir bulgu olabilir.

Anahtar sözcükler: Kan akım hızı; koroner arter hastalığı; ekokardiyografi, Doppler; postür/fizyoloji; ventrikül fonksiyonu, sol.

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Tissue Doppler echocardiography has been introduced as a useful tool for assessing systolic and diastolic myocardial function.[1-3] Tissue Doppler indices are considered relatively load-independent when compared with transmitral velocities.[4] However, further studies have shown that their usefulness is limited by both preload and afterload dependency.[5]

Myocardial acceleration during isovolumic contraction begins at the very onset of the left ventricular pressure rise and represents the earliest event in ventricular systole. The acceleration rate of the isovolumic contraction has been proposed as a load-independent parameter of ventricular contractility after being validated in animal studies.[6] However, data about the clinical significance of this parameter are limited.

The effect of postural changes on tissue Doppler indices in healthy hearts has been studied.[7] Increases in venous return have been demonstrated to enhance systolic function. Transmitral and diastolic mitral annular velocities are also influenced by an alteration in cardiac load in healthy subjects.[7,8] However, the response of tissue Doppler parameters to increased preload in patients with coronary artery disease (CAD) with preserved ejection fraction is not clear. This study aimed to assess the effect of postural changes on Doppler indices in patients with CAD with preserved systolic function and to determine tissue Doppler parameters that might be useful in identifying these patients.

PATIENTS AND METHODS

Study subjects. Forty-two patients with suspected CAD were recruited after obtaining informed consent from each patient. All the patients were scheduled for coronary angiography. All study protocols were performed in accordance with the Declaration of Helsinki. Exclusion criteria included the presence of the following: moderate to severe valvular heart disease, prior coronary artery surgery, ejection fraction of less than 40%, rhythm other than sinus rhythm, and chronic renal failure. Clinical variables and risk factors for CAD were recorded for each subject.

Study protocol. Transthoracic echocardiography was performed in all patients before coronary angiography. After obtaining baseline images, passive leg lifting was performed with the patient tilted into a 45° Trendelenburg position on a stretcher. Following a stabilization period for 2 min, echocardiographic measurements were repeated. All patients underwent standard two-dimensional, color Doppler and tissue Doppler echocardiography in the left lateral supine position at baseline and with their trunk turned on the left side during leg lifting.

Coronary angiography findings were reviewed by two independent investigators who were blinded to echocardiography data. Severity of coronary stenosis was evaluated using an automated computer-based system (quantitative coronary angiography). Patients having coronary artery stenosis greater than 70% were considered to have CAD. Patients with normal coronary arteries or coronary artery border irregularities comprised the control group. Subjects having isolated right coronary artery stenosis or distal coronary artery lesions were excluded from the analysis.

Image acquisition and analysis. Echocardiography was performed using an Acuson, Sequoia (Siemens, Mountain View, CA, USA) ultrasound system with a 3.5 MHz transducer. Images were obtained from standard parasternal and apical views, and all data were recorded to videotapes. For each image, three cardiac cycles were acquired at a frame rate of 60-70 Hz and measurements were obtained by averaging three cardiac cycles. Left ventricular end-diastolic volume, end-systolic volume, and ejection fraction (EF) were assessed using the modified biplane Simpson's equation. Transmitral velocities were recorded from the apical four-chamber view by placing the sample volume at the tips of the mitral leaflets. Peak velocity for early filling (E), atrial contraction (A), and deceleration time for E wave were measured. Pulse-wave Doppler images of the left ventricular outflow tract were recorded, and left ventricular ejection time was measured. Myocardial performance index (Tei index) was calculated as the sum of isovolumic relaxation time and isovolumic contraction time divided by the left ventricular ejection time. Using pulse-wave tissue Doppler, mitral annular velocities were recorded by placing the sample volume at septal and lateral mitral annuluses.[9,10] Peak systolic velocity (S), early (Ea) and late (Aa) diastolic velocities, and isovolumic contraction velocity (IVC) were measured for each annular side. The acceleration rate of the isovolumic contraction (IVA) was calculated as the peak IVC divided by the time interval from baseline to peak. All measurements were repeated after leg lifting. Total time duration for imaging was 40 to 45 min for each patient.

Statistical analyses. The results were expressed as means ± SD. Clinical characteristics of the two groups were compared with the chi-square test. Baseline echocardiographic parameters of the two groups were compared using the independent samples t-test.

Table 1. Baseline characteristics of the patients with and without coronary artery disease (CAD)

	Patients without CAD (n=22)			Patients with CAD (n=20)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (years)			59±11			59±9	0.9
Sex (males)	7	31.8		19	95.0		<0.001
Body surface area (m^2)			1.8±0.2			1.9±0.1	0.2
Heart rate (beat/min)			78±12			85±15	0.3
Systolic blood pressure (mmHg)			155±29			151±28	0.1
Diastolic blood pressure (mmHg)			84±18			78±12	0.2
Hypertension	15	68.2		9	45.0		0.1
Diabetes mellitus	9	40.9		4	20.0		0.2
Smoking	5	22.7		13	65.0		0.02
Dyslipidemia	12	54.6		16	80.0		0.1
Coronary artery lesions	-						
1-vessel disease				4	20.0		
2-vessel disease				7	35.0		
3-vessel disease				9	45.0		

Data obtained before and after leg lifting were compared with the paired sample t-test. A *p* value of less than 0.05 was considered statistically significant. All analyses were performed using the SPSS software (Statistical Package for Social Sciences, version 11.0, SPSS Inc, Chicago, Ill, USA).

RESULTS

Coronary angiography demonstrated normal coronary arteries or noncritical coronary artery stenosis in 22 patients. Twenty patients had CAD. The mean ages of the patients were similar in the control and CAD groups (59±11 years *vs* 59±9 years; p>0.05). Baseline characteristics of the patients and distribution of coronary artery lesions are summarized in Table 1. Six patients had a history of myocardial infarction in the CAD group.

Two-dimensional and conventional Doppler measurements. There was no difference with respect to end-diastolic volume between the two groups. Patients with CAD exhibited a greater end-systolic volume, and lower EF (Table 2). Eight patients with CAD had regional wall motion abnormalities. Baseline transmitral Doppler measurements and myocardial per-

Table 2. Two-dimensional, conventional Doppler and tissue Doppler parameters at baseline

	Patients without CAD (Mean±SD)	Patients with CAD (Mean±SD)	*p*
Left ventricular			
Ejection fraction (%)	56±6	51±8	0.03
End-diastolic volume (ml)	92±28	107±34	0.1
End-systolic volume (ml)	41±17	55±24	0.03
Early transmitral velocity (E) (cm/sec)	70±15	63±9	0.1
Late transmitral velocity (cm/sec)	88±15	85±11	0.5
Deceleration time (msec)	191±33	205±43	0.2
Isovolumic relaxation time (msec)	105±19	102±13	0.5
Myocardial performance index	0.54±0.1	0.58±0.1	0.1
Lateral mitral annulus			
Systolic annular velocity (cm/sec)	14.7±5.1	15.5±5.2	0.6
Early diastolic annular velocity (Ea) (cm/sec)	14.8±3.7	14.2±3.4	0.6
Late diastolic annular velocity (cm/sec)	18.0±6.0	20.1±5.9	0.3
E/Ea	4.8±1.2	4.7±1.3	0.8
Isovolumic acceleration rate (m/sec^2)	5.8±0.5	4.8±1.0	0.007
Septal mitral annulus			
Systolic annular velocity (cm/sec)	12.3±3.3	12.5±3.8	0.9
Early diastolic annular velocity (Ea) (cm/sec)	13.6±4.7	11.0±2.4	0.03
Late diastolic annular velocity (cm/sec)	17.1±4.5	17.1±5.2	0.8
E/Ea	5.9±1.8	5.8±1.2	0.7
Isovolumic acceleration rate (m/sec^2)	5.9±1.3	4.4±1.1	0.03

Table 3. Transmitral Doppler parameters before and after leg lifting

	Patients without CAD			Patients with CAD		
	Before	After	*p*	Before	After	*p*
Early transmitral velocity (E) (cm/sec)	70±15	78±17	0.002	63±9	74±11	<0.001
Late transmitral velocity (A) (cm/sec)	88±15	95±24	0.6	85±11	88±14	0.2
E/A	0.79±0.2	0.83±0.2	0.1	0.74±0.2	0.83±0.2	0.02
Deceleration time (msec)	191±33	179±40	0.04	205±43	184±40	0.02
Isovolumic relaxation time (msec)	105±19	100±19	0.1	102±13	100±14	0.6
Myocardial performance index	0.54±0.1	0.48±0.1	0.003	0.58±0.1	0.54±0.1	0.04

formance index were similar in the two groups. After leg lifting, E wave velocity demonstrated a significant increase in both groups (70±15 to 78±17 cm/sec in the normal group, p=0.002; 63±9 to 74±11 cm/sec in the CAD group; p<0.001), but changes in A wave velocity were not significant (Table 3). Deceleration time of E wave decreased in both groups after leg lifting (191±33 to 179±40 msec, p=0.04 in the normal group; 205±43 to 184±40 msec, p=0.02 in the CAD group). Myocardial performance index improved significantly in both groups following leg lifting (Table 3).

Tissue Doppler measurements. No significant differences were observed between the two groups with regard to S wave velocities at the lateral and septal annuluses (p>0.05; Table 2). Patients with CAD had a significantly lower IVA at both annular sides (for lateral annulus, p=0.007; for septal annulus, p=0.03; Table 2, Fig. 1). Leg lifting resulted in significant increases in Ea, Aa, and S waves at the septal and lateral annuluses in the control group. In patients with CAD, septal annular velocities increased significantly after leg lifting; however; increase in S wave velocity at the lateral annulus was not significant. After leg lifting, changes in IVA at both annular sides were not significant and the ratio of E/Ea remained unchanged in both groups (Table 4).

DISCUSSION

The present study demonstrates that leg lifting results in increased venous return leading to alterations in both transmitral and tissue Doppler parameters in subjects with normal coronary arteries and patients with CAD. Augmentation of systolic function due to increased preload may be impaired in patients with CAD, which can be determined by an unaltered S wave velocity at the lateral mitral annulus after leg lifting. The acceleration rate during isovolumic contraction may be used as a parameter to identify patients with CAD in a subset of patients with suspected CAD and preserved systolic function.

Tissue Doppler velocities are useful parameters for assessing both systolic and diastolic function of the left ventricle (LV).[11] Peak systolic mitral annular velocity has been shown to correlate with LV EF and positive dP/dt.[12] At baseline, we found similar S wave velocities in patients with CAD and in patients with normal coronary arteries. This observation is consistent with the data of Yamada et al.[12] who found no significant difference with respect to S velocity between patients with ischemic heart disease and the control group, provided that their EF was similar. Plewka et al.[13] also demonstrated that S velocity was similar in patients with ischemic and nonischemic

Table 4. Tissue Doppler parameters of lateral and septal mitral annuluses before and after leg lifting

	Patients without CAD			Patients with CAD		
	Before	After	*p*	Before	After	*p*
Lateral mitral annulus						
Systolic annular velocity (cm/sec)	14.7±5.1	16.7±4.7	0.009	15.5±5.2	17.0±5.1	0.1
Early diastolic annular velocity (Ea) (cm/sec)	14.8±3.7	16.4±3.4	0.006	14.2±3.4	16.4±4.3	0.01
Late diastolic annular velocity (cm/sec)	18.0±6.0	20.5±6.7	0.02	20.1±5.9	21.3±7.6	0.3
E/Ea	4.8±1.2	4.9±1.1	0.8	4.7±1.3	4.8±1.1	0.9
Isovolumic acceleration rate (m/sec^2)	5.8±0.5	5.7±1.4	0.8	4.8±1.0	4.6±1.1	0.7
Septal mitral annulus						
Systolic annular velocity (cm/sec)	12.3±3.3	14.0±3.9	0.01	12.5±3.8	15.3±5.3	0.009
Early diastolic annular velocity (Ea) (cm/sec)	13.6±4.7	15.4±5.3	0.01	11.0±2.4	14.1±4.1	0.001
Late diastolic annular velocity (cm/sec)	17.1±4.5	19.0±6.0	0.02	17.1±5.2	19.8±7.0	0.02
E/Ea	5.9±1.8	5.6±1.5	0.8	5.8±1.2	5.5±1.5	0.7
Isovolumic acceleration rate (m/sec^2)	5.9±1.3	5.9±1.9	0.9	4.4±1.1	5.2±1.3	0.2

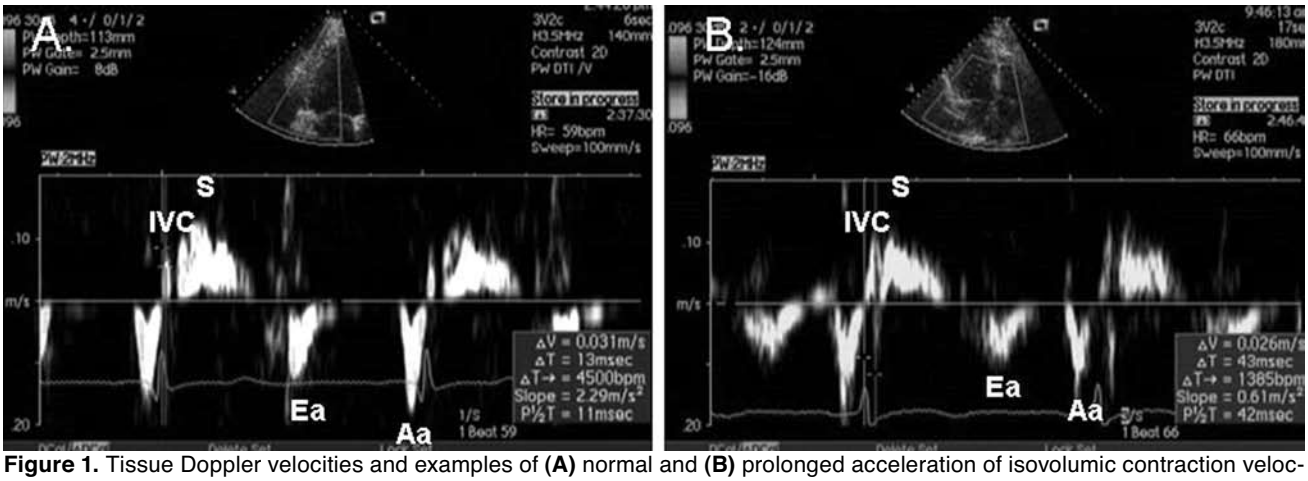

Figure 1. Tissue Doppler velocities and examples of **(A)** normal and **(B)** prolonged acceleration of isovolumic contraction velocity. Note **(A)** the steep rise (13 msec) in IVC in a patient with normal coronary arteries and **(B)** delayed acceleration (43 msec) in a patient with coronary artery disease. IVC: Velocity of isovolumic contraction wave; S: Systolic annular velocity; Ea: Early diastolic annular velocity; Aa: Late diastolic annular velocity.

cardiomyopathy. It is a challenge to identify ischemic myocardial segments in the setting of preserved EF and regional LV systolic function. Myocardial strain imaging traditionally obtained with tissue Doppler and recently with speckle tracking two-dimensional echocardiography may be useful in the assessment of ischemic myocardium. Unlike tissue velocity measurements, strain measurements are specific for the region of interest and therefore are not affected by cardiac tethering and translation. However, these techniques are still technically challenging and probably not ready for routine clinical use.[14]

In our study, increased preload caused by leg lifting resulted in augmentation of systolic function as reflected by increased S velocity and improved myocardial performance index in the control group. Although patients with CAD exhibited similar changes in septal wall S velocity and myocardial performance index, improvement in lateral wall S velocity did not reach statistical significance following leg lifting, suggesting a slightly blunted contractile reserve in resting ischemia in response to increased preload. To identify these patients, either myocardial strain imaging or stress echocardiography incorporated into tissue Doppler imaging should be used to discriminate myocardial segments with resting ischemia.

The isovolumic acceleration rate during the contraction phase has recently become a matter of interest to measure myocardial contractility. In an animal model, Vogel et al.[6] showed that IVA correlated well with the invasive measures of LV pressure and that it was load-independent. However, data on the clinical use of IVA are limited. In contrast to experimental studies, Andersen et al.[15] reported that IVA was influenced by load alterations in young, healthy individuals. Ruan et al.[10] reported that, as measurements of LV function during the ejection phase, S velocity was a more accurate predictor than the IVA to identify patients with an EF of less than 45%, and IVA might be valuable in examining LV function during the isovolumic contraction phase. In our study, baseline S velocities were similar in patients with and without CAD, whereas IVA was significantly lower in patients with CAD. Ischemia may influence LV contractility during the isovolumic contraction phase, and IVA may be useful in identifying patients with resting ischemia. Our results support the findings of Shimizu et al.[16] who showed in an open-chest pig study that constriction of the left anterior descending coronary artery resulted in a lower IVA of the LV free wall without changing S velocity. In our study, enhancement of the venous return associated with leg lifting caused no significant changes in IVA in both groups. Although there is controversy about the load-independency of IVA in the literature, our results are consistent with experimental data suggesting that IVA is preload independent.[6,15,17]

Tissue Doppler imaging has been widely used to assess the diastolic properties of the LV.[1,18,19] Although tissue Doppler velocities are relatively load independent compared with transmitral Doppler velocities, Ea has been shown to be influenced by changes in preload, particularly when relaxation is normal.[5] On the other hand, Aa is mostly determined by the parameters of left atrial function.[5] We observed increases in E and Ea velocities following leg lifting in both groups. The increase in Ea velocity and shortening of the deceleration time suggest accelerated relaxation as

opposed to increased filling pressures since the E/Ea ratio remained unchanged.

Study Limitations. Our study has several limitations. We did not perform invasive pressure measurements to demonstrate increased contractility and accelerated relaxation. We did not use conductance catheters during coronary angiography. Echocardiographic examination and left heart catheterization were not performed simultaneously. Nonetheless, our aim was to determine the influence of preload alterations on echocardiographic parameters, which are more relevant in routine patient care. No other maneuvers other than leg lifting were used to alter preload. Therefore, further studies using different methodologies including administration of nitroglycerine, volume loading, or invasive techniques (e.g. inferior vena cava constriction) may be necessary to verify our results. The small number of our study subjects may be considered another limitation, but some reports on healthy individuals also had similar number of subjects.[7,15] Another limitation is that, even though EFs of the two groups were in normal range, patients with CAD had a significantly lower EF than the control group. However, S wave velocities at baseline were similar in the two groups, so changes in tissue Doppler parameters in response to leg lifting were comparable. Our study groups were not similar with respect to sex and there was a significant male preponderance in the CAD group. Due to the small number of patients, sex adjusted analysis could not be conducted.

In conclusion, increased preload induced by leg lifting affects both conventional transmitral and tissue Doppler parameters in normal subjects and in patients with CAD. Except for the S wave at the lateral mitral annulus, tissue Doppler indices demonstrated similar changes in response to load alteration induced by leg lifting in both groups, with preserved EF. Enhancement of systolic function may be depressed in patients with CAD based on lateral wall annular systolic velocity. Isovolumic acceleration rate which was significantly lower in patients with CAD may be a useful, preload-independent parameter to identify these patients; however, further studies in a broader population are warranted.

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