Real-Time Ultrasound Elastographic Features and Color Doppler imaging of Mitral Valve Prolapse

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Abstract

Purpose: To investigate the elasticity of ocular structures in patients with mitral valve prolapse (MVP)

Methods: This prospective study included a total of 35 patients with MVP (study group) and 35 healthy volunteers (control group). The elastography value of the ratio of orbital fat- sclera (ROF/S) was measured with real-time US elastography. For each eye, central retinal artery (CRA), posterior ciliary artery (PCA), and ophthalmic artery (OA) were evaluated, respectively. All examinations were performed by the same physician.

Results: The mean ages of the patients in the study and the control groups were 31.77 ± 11.40 years, and 30.65 ± 7.45 years, respectively (P =0.511). Mean ROF/S were 1.95 ± 0.81 and 1.37 ± 1.06 (P=0.001) in the study groups and control, respectively. The mean RI of the OA was 0.67 ± 0.05 in the control group, 0.67 ±0.05 (0.55; 0.87) in study group. The mean RI of the PCA was 0.66 ± 0.05 in the control group, 0.68 ±0.06 in study group. . The mean RI of the CRA was 0.66 ± 0.05 in the control group, 0.66 ±0.06 in study group. The RI value was not a significant difference between control and study group ($p > 0.05$).

Conclusion: Scleral elasticity was significantly increased in MVP patients. These could be related to ocular pathologies such as glacouma, kerataconus in MVP.

Introduction

Mitral valve prolapse is a common valvular disease, seen in 2–6% of cases, characterized by the bulging of one or both mitral leaves into the left atrium more than 2 mm above the plane of the mitral annulus during systole, due to progressive myxomatous degeneration of the mitral valve leaflets and chorda tendinea.[1]

Kerataconus is associated with most of ocular manifestations described in MVP.[2, 3] In some studies,retinal vascular occlusion, retinal emboli and glacuoma are also releated with MVP.[4–6]

Real-time elastography (RTE) performed in the differential diagnosis of tumour, inflammation, and normal tissue is a relatively new imaging technique that provides a noninvasive and painless assessment of tissue stiffness and elasticity.[7] Ultrasound elastography show changed elasticity of tissues resulting from from radiofrequency signals during externally applied compression–relaxation cycles.[8] The Color Doppler Imaging (CDI) also is a non-invasive and painless technique that used to evaluted of blood flow velocity.[9] Assessment of blood flow and the retrobulbar vascular paramaters (central retinal artery, posterior ciliary artery, and ophthalmic artery) have been researched with CDI in many studies.[10]

In this study, we aimed to evaluate the ocular elasticity and retrobulbar vascular properties in patients with MVP by comparing them with the stiffness in the eyes of age and sex-matched healthy controls using ocular real-time ultrasound elastography and doppler ultrasonography.

Methods

Study Population and Design

This cross-sectional study was conducted at the Ophthalmology, Cardiology and Radiology Departments of Bursa City Training and Research Hospital. The study followed the tenets of the Declaration of Helsinki and was approved by the local ethics committee. Written informed consent was obtained from all participants.

Measurements of transthoracic echocardiography

All procedures of transthoracic echocardiography using a 1–5 MHz transducer (Vivid 7, GE Vingmed Sound Horten, Norway) were performed by the cardiologist. All volunteers were investigated using parasternal long-axis and short-axis approaches and apical four- and two-chamber views in supine and left lateral positions. According to the suggestions of the American Society of Echocardiography primary MVP was diagnosed when at least 1 mitral leaflet was prolapsed into the left atrium and passed the mitral annulus by at least 2 mm along the parasternal long axis during the systolic phase.[11]

Ocular ultrasound elastography measurement

Freehand RTE measurement was carried out with a high frequency linear probe (13–15 MHz) on a Hitachi Arietta 65 ultrasound machine (Hitachi Aloka Medical, Ltd,Japan) by the same radiologist (EKT) experienced on B-scan USG and elastography.

The all ocular measurements (CRA, PCA, and OA) were assessed in the same direction as the blood flow with in an angle (< 60°). The measurements have been carried out by the same experienced radiologist (EKT) and the method was previously described.[12, 13] The peak systolic velocity (PSV) and the end-diastolic velocity (EDV) values were recorded for each artery. Then, the vascular resistance index (RI) was calculated (RI: PSV – EDV/PSV).

After assessment of orbit with conventional USG, the probe was put onto the lids of the patient and elastography was carried out with the existing elasto software. Elasticity images were obtained by moving the probe continuously and obtaining compression and relaxation waveforms. After 8–10 compression and relaxation cycles, the elastographic examination was finalized, and strain rate measurements were acquired. We performed at a relatively slow speed, very gentle compression/release 3 to 5 times in intervals of 1 to 2 seconds and repeated measurements. At least 10 attempted elastography examinations were made for each eye until the color displayed in the region of interest (ROI) was completely stable to allow reliable measurement results. The strain images were put over gray-scale images in a color layout: red(largest strain,softest tissue), green(mean strain, intermediate tissue) and blue (lowest strain; hardest tissue). The ratio of orbital fat to sclera (S) was measured according to the semi-quantitative evaluation of the elastographic images. The region of interest (ROI) of the sclera was drawn, and the corresponding ROI in the adjacent normal fatty tissue was later drawn as a control for the

measuring ROF/S (ratio of orbital fat- sclera) (Fig. 1). The analyzed region in the sclera was the same dimension for all subjects and it was placed at a fixed distance from the surface. Higher elastography ratio values indicated stiffer tissue, while lower elastography ratio values showed increased elasticity. The image analyses were performed by the same radiologist who carried out the US examinations. All measurements were acquired in the supine position. All images were obtained from both eyes of both groups.

Exclusion Criteria

Patients who had a history of significant ocular disease, IOP readings greater than 21 mm Hg, glaucoma, ocular trauma, or tumor, ocular inflammatory disease, history of uveitis, retinal disease, diabetes, hypertension were excluded. diabetes,

Statistical Analysis

All statistical analyses were applied using SPSS version 26 software (SPSS Inc., Chicago, IL, USA). The conformity to normal distribution of each continuous variable was assessed using the Kolmogorov-Smirnov test. The Chi-square test were used to analyze the categorical variables between the groups. An independent *t* test was used to compare variables. A value of $p < 0.05$ was accepted as statistically significant.

Results

Demographic characteristics

This study included 70 eyes of 35 patients with MVP as the study group and 70 eyes of 35 healthy subjects as the control group. The mean age was 31.77 ± 11.40 years in the study group and 30.65 ± 7.45 years in the control group. There was no statistically significant difference between the two groups in respect of mean age ($P = 0.511$). The female-to-male ratio was 20:15 in the study group and 20:15 in the control group, with no significant difference between the groups ($P > 0.05$). The mean values of age,and gender distribution in the study group and the control group are summarized in Table 1.

Table 1
Characteristics of Patients

	Study Group	Control Group	*P*
Age	31.77 ± 11.40	30.65 ± 7.45	0.511[a]
Gender(F-M)	20 – 15	20 – 15	1.00[b]
[a] Independent samples t test, [b] Chi-square test			

Results of the Results of US elastography

The mean ROF/S was 1.95 ± 0.81 in the study group, 1.37 ± 1.06 in the control group (p = 0.001). The mean ROF/S was significantly higher in the study group than the control group. The mean RI of the OA was 0.67 ± 0.05 in the control group, 0.67 ± 0.05 (0.55; 0.87) in study group. The mean RI of the PCA was 0.66 ± 0.05 in the control group, 0.68 ± 0.06 in study group. The mean RI of the CRA was 0.66 ± 0.05 in the control group, 0.66 ± 0.06 in study group. The RI value was not a significant difference between control and study group ($p > 0.05$). The RTE and CDI measurements of both control and study are summarized in Table 2.

Table 2
The Comparison of the Ratio of Sclera to Orbital Fat and retrobulbar hemodynamics measurements between study and control groups.

	Study Group	Control Group	p[a]
ROF/S	1.95 ± 0.81	1.37 ± 1.06	0.001
Ophthalmic artery			
RI	0.67 ± 0.05	0.67 ± 0.05	0.975
PSV (cm/s)	17.30 ± 9.53	20.60 ± 8.79	0.051
EDV (cm/s)	5.69 ± 4.01	6.62 ± 3.20	0.171
Posterior ciliary arteries			
RI	0.68 ± 0.06	0.66 ± 0.05	0.069
PSV (cm/s)	18.04 ± 8.59	23.50 ± 9.36	0.001
EDV (cm/s)	5.67 ± 3.28	7.98 ± 3.72	< 0.001
Central retinal artery			
RI	0.66 ± 0.06	0.66 ± 0.05	0.978
PSV (cm/s)	19.66 ± 8.60	26.17 ± 9.13	0.004
EDV (cm/s)	5.80 ± 2.52	8.53 ± 3.41	< 0.001
[a] Independent samples *t* test			
RI; resistance index, PSV; peak systolic velocity, EDV; end-diastolic velocity,			

Discussion

Our study evaluated the blood flow rates of retrobulbar vascular structures

and elasticity of the eye in MVP patients. The results indicated that MVP patients had higher ROF/S values compared with the healthy participants. In the comparison of the MVP patients with a control group, statistically significant differences were found in the EDV, and PSV values of the PCA and CRA. A significant relationship was releated with ocular elasticity. MVP may occur as a result of various pathological mechanisms involving any of the functional components of the mitral valve apparatus. Primary MVP, which is seen as a result of valvular collagen disruption and myxomatous infiltration, is the prominent condition among them. MVP may be familial, sporadic, non-syndromic, or part of a well-defined syndrome of heritable connective tissue disorders, such as Marfan syndrome, Ehlers-Danlos syndrome, polycystic kidney disease among others.[14]

Patients with primary MVP have excessive connective tissue, which causes thickening of the spongiosa layer due to the excess of dermatan sulfate, which is a glycosaminoglycan. This condition weakens the structure of the mitral leaflets and adjacent tissues, resulting in elongation of the chordae tendineae.[6]

Ocular involvement can potentially lead to vision threatening disease. MVP can be associated with ophthalmological diseases such as keratoconus (KC), glaucoma, chronic progressive external ophthalmoplegia, and retinal artery embolism.[15]

According to the literature information some studies showing a relationship between MVP and ocular involvement. Duru et al.[2] reported thinning of Bowman layer in the inferior half of the cornea in patients with MVP.Lichter et al. found 22.2% keratoconus patients with MVP. Akcay et al.[15] reported that KC prevalence is higher than control individuals in MVP patients and the biomechanical properties of the cornea are altered in patients with MVP.

Chiang SJ et al.[6] reported that MVP is a significant predictor for the development of Open angle glaucoma, after adjusting for possible confounding factors. In MVP, the disease duration induces scleral tissue alterations which can lead to scleral destruction. Thus can be related with ocular involvement in MVP disease.

Previous studies have demonstrated the elastographic characteristics of ocular tissue

Ünal et al.[16] investaged the optic nerve head (ONH) characteristics in patients with primary open angle glaucoma (POAG) using real-time elastography. They found that human scleral rigidity of POAG patients was greater than the control eyes. Agladioglu et al.[17] reported the correlation between primary open angle glaucoma and ocular elasticity in adults and demonstrated that anterior vitreous/posterior vitreous strain ratio increases in glaucoma patients. Kazemi et al.[18] found that ocular rigidity was significantly lower in glaucomatous eyes than control eyes.

In addition to these associated with ophthalmological diseases, involvement of retinal vasculer manifestations retinal embolizm and retinal vascular occlusive disorders.

Previous studies have reported abnormal elastic properties of the vascular systems in MVP. Kardesoglu et al. found that the aortic stiffness index was increased.[19] Erolu et al.[1] reported that increased elasticty

of the aorta in childhood.

To the best of our knowledge, our study is the first to compare the blood flow rates of retrobulbar vascular structures and elasticity of the eye at the same time in MVP patients. This study demonstrated that MVP patients has a statistically significant difference scleral elasticity. The mean ROF/S values were significantly increased in patients with MVP as compared to the control group. The results of this study showed a significant difference between the control, and MVP groups in respect of the EDV and PSV values of PCA, and CRA. From these results, it can be said that vascular extracellular matrix changing in the vessels feeding the eye. This histological alteration can cause the feeding of tissues will be impaired with a reduced flow and consequently more ocular complications will be seen such as retinal vascular occlusive disorders. Nevertheless, there is a need for further studies to evaluate the importance of early determination of ocular vascular damage in MVP with CDI and RTE.

Declarations

The authors have no conflict of interests to disclose.

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Figures

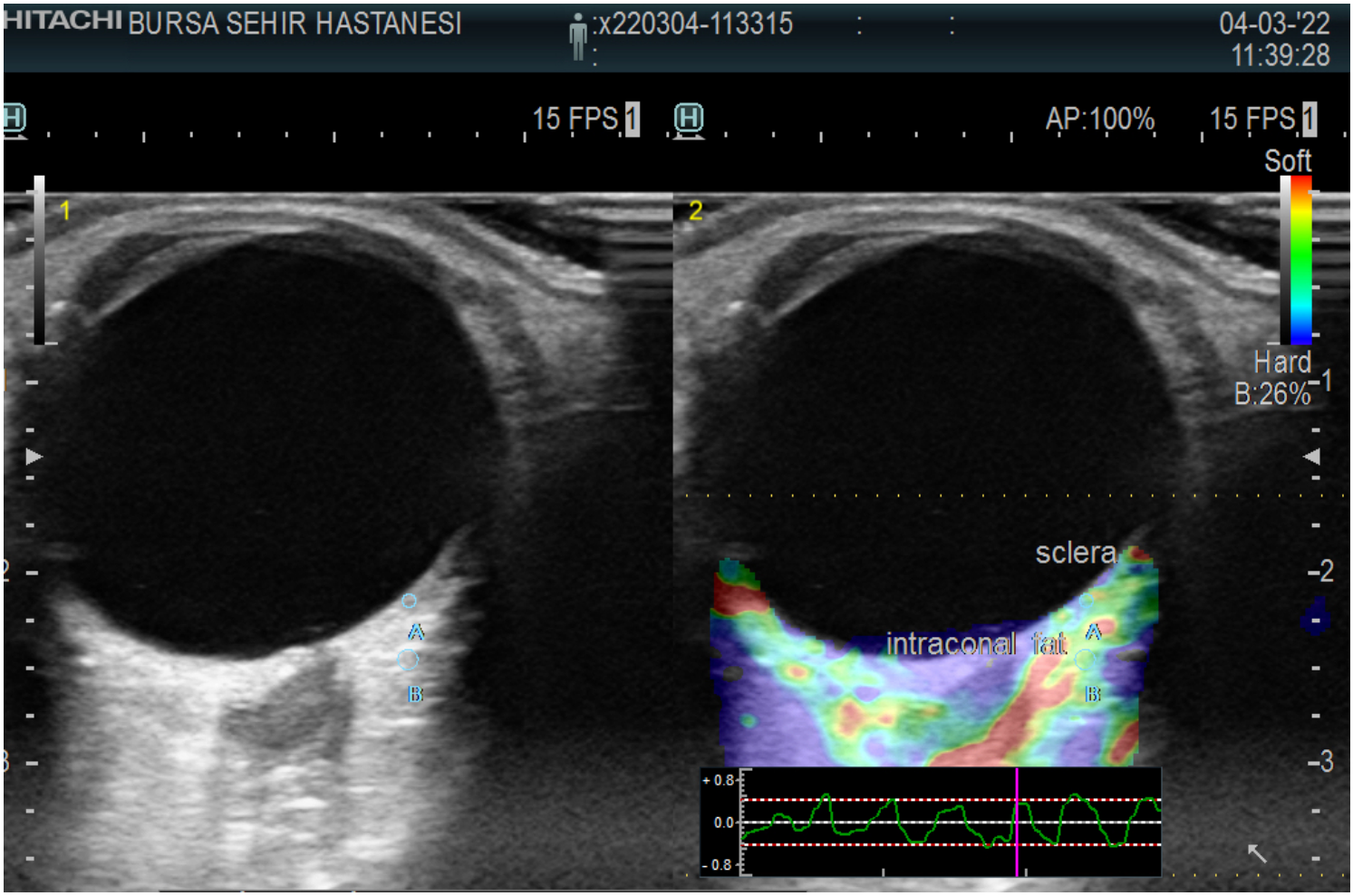

Figure 1

Legend not included with this version.