Color Doppler imaging of the ophthalmic artery in patients with chronic heart failure

Ultrassonografia Doppler em cores da artéria oftálmica em pacientes com insuficiência cardíaca crônica

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ABSTRACT

Purpose: To evaluate the ophthalmic artery hemodynamics in patients with chronic heart failure.

Methods: Doppler parameters of ophthalmic artery of 18 patients with chronic heart failure in different stages of the disease were compared with 21 healthy volunteers (control group). These parameters were also correlated with echocardiographic assessments and clinical cardiologic status.

Results: Mean diastolic velocity was 5.14 ± 2.4 cm/s in the chronic heart failure group and 7.44 ± 3.5 cm/s in the control group (p=0.007). Mean resistance index of the ophthalmic artery was 0.76 ± 0.08 in the chronic heart failure group and 0.70 ± 0.08 in the control group (p=0.04). Mean systolic velocity of the ophthalmic artery was 22.03 ± 7.7 cm/s in the chronic heart failure group and 25.32 ± 9.2 cm/s in the control group (p=0.24). There was a negative correlation between the resistance index of the ophthalmic artery and systemic blood pressure of patients with chronic heart failure (r= -0.47, p=0.007). Diastolic velocity of the ophthalmic artery correlated positively with systemic blood pressure (r=0.44, p=0.02).

Conclusion: Lower diastolic velocity and higher resistance index were observed in the ophthalmic artery of chronic heart failure patients when compared to the control group, which probably reflects the presence of orbital vasoconstriction in response to low cardiac output. Therefore, the influence of these findings on the structure and function of the optic nerve head deserves investigation.

Keywords: Echocardiography, Doppler, color; Blood flow velocity; Heart failure; Chronic disease; Intraocular pressure; Ophthalmic artery

RESUMO

Objetivo: *Avaliar o fluxo sanguíneo da artéria oftálmica em pacientes com insuficiência cardíaca crônica.*

Métodos: *Parâmetros da ultrassonografia Doppler em cores da artéria oftálmica de 18 pacientes com insuficiência cardíaca crônica em diferentes estágios da doença foram comparados com 21 voluntários saudáveis (grupo controle). Estes parâmetros foram também correlacionados com avaliação ecocardiográfica e quadro clínico cardiológico.*

Resultados: *A média da velocidade diastólica foi 5,14 ± 2,4 cm/s no grupo insuficiência cardíaca crônica e 7,44 ± 3,5 cm/s no grupo controle (p=0,007). O índice de resistência da artéria oftálmica foi de 0,76 ± 0,08 no grupo insuficiência cardíaca crônica e 0,70 ± 0,08 no grupo controle (p=0,04). A média de velocidade sistólica da artéria oftálmica foi 22,03 ± 7,7 cm/s no grupo insuficiência cardíaca crônica e 25,32 ± 9,2 cm/s no grupo controle (p=0,24). A pressão arterial sistêmica dos pacientes com insuficiência cardíaca crônica correlacionou-se negativamente com o índice de resistência da artéria oftálmica (r=-0,47, p=0,007) e positivamente com a velocidade diastólica da artéria oftálmica (r=0,44, p=0,02).*

Conclusão: *Velocidade diastólica mais baixa e índice de resistência mais alto foram observados na artéria oftálmica de pacientes com insuficiência cardíaca crônica quando comparados ao grupo controle, o que provavelmente reflete a presença de vasoconstrição orbital em resposta ao baixo débito cardíaco. Portanto, a influência desses achados sobre a estrutura e função da cabeça do nervo óptico merece ser investigada.*

Descritores: *Ecocardiografia Doppler em cores; Velocidade do fluxo sanguíneo; Insuficiência cardíaca; Doença crônica; Pressão intraocular; Artéria oftálmica*

INTRODUCTION

Ocular blood flow may be affected in some ocular diseases, including glaucoma. Glaucoma is a progressive optic neuropathy that presents as a distinct appearance of the optic disc and visual field loss, being the leading cause of irreversible blindness worldwide[1-4]. The vascular theory describing the mechanism of glaucoma considers the optic neuropathy as a consequence of insufficient blood perfusion due to either increased intraocular pressure or other risk factors which may lead to a reduction in the ocular blood flow[2]. Several studies have demonstrated that the reduction of the optic nerve head perfusion is associated with glaucoma[2,5-8]. The Barbados Eye Study found a higher incidence of glaucoma in patients with lower systolic blood pressure and lower ocular perfusion pressure[9]. Several studies have shown that patients with large fluctuations in blood pressure at night present a higher risk for glaucoma progression[10-12]. In the Ocular Hypertension Treatment Study, previous history of heart disease was a risk factor for the development of glaucoma[13]. Additional evidence suggesting the importance of blood flow on the pathogenesis of glaucoma comes from reports of glaucomatous-like optic nerve and visual field damage secondary to transient hemodynamic shock[14].

Chronic heart failure (CHF) is a serious and common condition, in which an abnormality of cardiac function is responsible for a failure of the heart to pump blood at a rate commensurate with the requirements of the metabolizing tissues[15]. A complex neurohormonal system is involved in an attempt to compensate heart failure, aiming to guarantee a suitable perfusion of the tissues[16]. However, studies indicate that the cerebral blood flow may be reduced in these patients[17-23]. The blood flow of the ophthalmic artery during heart failure and its possible role in the pathogenesis of glaucoma has not yet been investigated. The color Doppler imaging is a non-invasive, fast and easy access ultrasound technique, used in ophthalmology practice to measure the blood flow velocity of the orbital vessels[1-3,17-25]. The purpose of this study was to evaluate the blood flow of the ophthalmic artery in patients with chronic heart failure using color Doppler imaging.

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METHODS

A cross-sectional study was carried out. Patients with heart failure symptoms and left ventricle ejection fraction bellow 55% documented by echocardiography were recruited from the outpatient cardiomyopathy and heart failure clinic of a tertiary care university hospital. Non-cardiopathic volunteers were included as a control group. The study was approved by the Institutional Review Board and followed the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects prior to the study and after an explanation of the nature and possible consequences of the study.

Heart failure cases or control subjects under 18 years of age, patients with prior history of significant ocular disease, ocular trauma or ocular surgery, chronic corticosteroid usage (topical or systemic), secondary glaucoma, dense media opacities, retinal disease, heart transplantation, stroke or any other neurological diseases were not included in the study.

The blood pressure readings for systolic and diastolic blood pressure were obtained after the participant was seated for 10 minutes. The mean arterial blood pressure was calculated according to the formula: mean arterial blood pressure=2/3*diastolic blood pressure + 1/3*systolic blood pressure. The mean ocular perfusion pressure was calculated as: mean ocular perfusion pressure=2/3*mean arterial blood pressure - intraocular pressure[5].

Color Doppler imaging and ophthalmologic evaluation

The ophthalmic artery blood flow velocity was measured by transpalpebral Doppler ultrasound (EnVisor - Philips Medical Systems, Bothell, WA, USA), with a linear high frequency transducer (10 MHz). The evaluated parameters were: systolic velocity, diastolic velocity and resistance index. Two radiologists examined both eyes of all subjects.

Patients were examined in the supine position, with their heads inclined at a 30° angle. The transducer was covered in gel and gently placed externally upon the eyelid, avoiding excessive pressure. The flow velocity was measured at the medial proximal point of the ophthalmic artery using a wall filter of 100 Hz and sample of 0.12 mm. Doppler insonation angle was adjusted between 0 and 40°. If the ophthalmic artery was not detected within 5 minutes, the examination was aborted in order to minimize ocular exposure to the ultrasound.

Once the waveforms of the ophthalmic artery were obtained, the values of systolic velocity, diastolic velocity and resistance index were calculated using the automatic algorithm of the machine (Figure 1). Three measurements were taken from all patients by each radiologist, and the mean value was considered for the analysis.

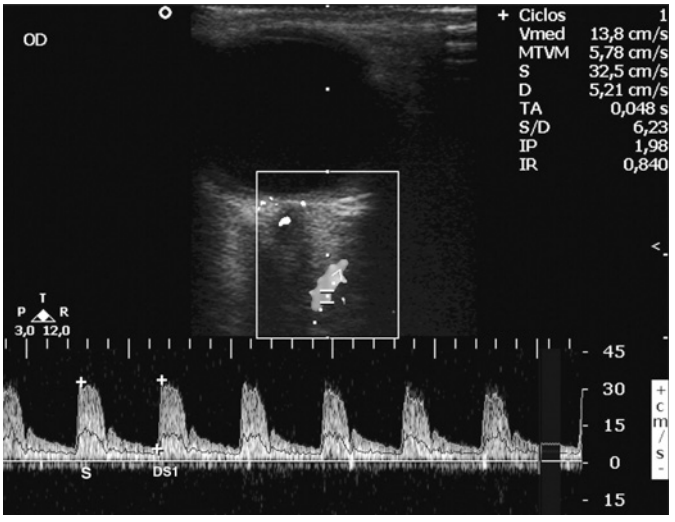

Figure 1. Velocity waveform (bottom) of the ophthalmic artery from a patient with chronic heart failure.

All subjects underwent a comprehensive ophthalmological examination including best-corrected visual acuity, slit-lamp examination, Goldmann applanation tonometry and fundoscopy. Tonometry was performed within 30 minutes after the arterial blood pressure measurement. All examinations were performed between 9 a.m. and 11 a.m.

Statistical analysis

The correlations between the color Doppler ultrasound indices and left ventricle ejection fraction, functional classification (New York Heart Association - NYHA) and the measurements of blood pressure were calculated using the Spearman correlation test. To take into account the correlation between both eyes of the same individual, generalized estimating equation was used to compare the mean values between the groups. It was calculated that at least 36 eyes in each group were needed to have 90% power to detect a 0.1 difference in the resistance index between the groups, considering a standard deviation of 0.1, an intracluster correlation between both eyes of the same individual of 0.58, a design effect of 1.58 and a significance level of 0.05. Results are expressed as mean ± standard deviation (SD), and $P<0.05$ was considered statistically significant.

RESULTS

Eighteen CHF patients and 21 control participants (non-cardiopathic volunteers) were included in the study. No age or gender differences were observed between the CHF patents and the controls (Table 1). The results of systolic velocity, diastolic velocity and resistance index of the ophthalmic artery are summarized in table 2. Mean diastolic velocity was lower (p=0.007) while mean resistance index was higher (p=0.04) in the CHF patients when compared to the control group. Mean systolic velocity was not statistically significant different between the two groups (p=0.24). Mean systemic arterial blood pressure was significantly lower in the CHF group (80.9 ± 11.0 mmHg) than in the control group

Table 1. Baseline characteristics of the chronic heart failure and control groups

	Chronic heart failure group (N=18)	Control group (N=21)
Age (years), mean ± SD	50.2 ± 11	50.4 ± 12
Male	67%	62%
Race		
White, N (%)	5 (28)	8 (39)
Black, N (%)	3 (17)	4 (17)
Mixed, N (%)	9 (50)	9 (44)
Asian, N (%)	1 (5)	
Heart failure etiology		
Chagas	39%	NA
Ischemic	22%	
Idiopatic	17%	
Others	22%	
Ejection fraction of LV	34% (14% to 45%)	NA
Functional class of the heart failure (NYHA)		
I	45%	NA
II	33%	
III	22%	
Medications		
Diuretics	100%	NA
β-Blockers	94%	
ACE inhibitors	94%	
Digoxin	11%	

ACE= angiotensin-converting enzyme; NYHA= New York Heart Association; LV= left ventricle; SD= standard deviation; NA= not applicable

(104.0 ± 10.3 mmHg). Ocular perfusion pressure was significantly lower in the CHF group (42.3 ± 6.9 mmHg) than in the control group (54.1 ± 7.8 mmHg).

Resistance index of the ophthalmic artery had a statistically significant negative correlation with the systemic systolic (r=-0.47; p=0.007) and diastolic arterial blood pressure (r=-0.56; p=0.001). Diastolic velocity of the ophthalmic artery had a positive correlation with the systolic (r=0.37; p=0.04) and diastolic arterial blood pressure (r=0.44; 0=0.02). There were no statistically significant correlations between the Doppler parameters and the cardiologic evaluation (ejection fraction and functional class) of the heart failure patients (Table 3).

DISCUSSION

This study evaluated the ophthalmic artery blood flow in patients with heart failure. No similar study was found in the literature regarding this form of evaluation. Low cardiac output is associated with compensatory mechanisms of peripheral vasoconstriction in attempt to maintain satisfactory blood pressure and minimum perfusion to critical tissues such as the heart and brain[17,26]. On the other hand, the excessive vasospasm/vasoconstriction of the ocular vessels may be related to a reduction in the perfusion and tissue death at the optic nerve head[6]. Therefore, patients with CHF could present hemodynamic alterations of the ocular microvasculature and a higher risk of developing glaucoma. The color Doppler imaging of the ophthalmic artery with the velocity waveform in function of the heart cycle offers important information regarding hemodynamic pathophysiology.

The finding that low diastolic blood pressure correlates with high resistance index and low diastolic velocity of the ophthalmic artery possibly reflects the pathophysiology of heart failure and the presence of orbital vasoconstriction in response to low cardiac output. No correlation was found between left ventricle ejection fraction and the Doppler parameters, which is not surprising, since studies examining cerebral circulation had already shown that left ventricle ejection fraction is not directly related to the measured blood flow to this tissue[18]. In contrast with this result, some reports have suggested that a cardiac output increase is of higher relevance than the increase in blood pressure to maintain the cerebral blood flow[19,23,27].

Regarding the heart failure functional classification, some studies have shown that the worsening of the functional class is related to low cerebral perfusion in patients with heart failure[18,19]. We observed no correlation between the heart failure functional classification (NYHA) and Doppler parameters of the ophthalmic artery. However, our experimental group is composed of outpatients (mostly functional classes I and II), unlike other studies involving patients with more uncontrolled disease (functional classes III and IV). Moreover, the findings of nuclear medicine and other techniques used in other studies, which assess flow rather than velocity, may not be comparable to the Doppler technique.

CHF patients had lower diastolic velocity and a higher resistance index in the ophthalmic artery when compared with the control group. Studies using color Doppler imaging found reduced systolic and diastolic velocity peaks, as well as, an increased resistance index in the retrobulbar vessels of patients with glaucoma in comparison with healthy subjects[2,3,5,8,24]. Velocimetric changes of the ophthalmic artery may be related to and even antedate the glaucomatous damage[2,3,5,8,24]. Therefore, it is possible that patients with CHF have a higher risk of developing normal tension glaucoma and the blood flow alterations may be related to its pathogenesis.

This study, however, presents a few limitations, such as the presence of heart disease at different stages and thus presents distinct risks of changes in the ocular microvasculature, which may have attenuated differences found between the groups. Moreover, despite the similarity of gender and age between the studied groups, other potential confounding factors were not controlled, such as carotid atherosclerosis and medication use. In addition, the color Doppler imaging simply measures velocities and not directly the blood flow.

CONCLUSION

This study demonstrated reduced diastolic velocity and increased resistance index in the ophthalmic artery of patients with heart failure. However, there was no correlation between the Doppler parameters of the ophthalmic artery, left ventricle ejection fraction and functional class. Systemic blood pressure may be a good clinical parameter in the determination of cardiac patients with a higher risk of developing ophthalmic vascular alterations. The results of this study suggest that heart failure could be a risk factor for low

Table 2. Hemodynamic parameters in chronic heart failure and control groups

	CHF group (N=18)	Control group (N=21)	P
Systemic systolic blood pressure (mmHg), mean ± SD	100.8 ± 12.3	127.14 ± 13.4	<0.001
Systemic diastolic blood pressure (mmHg), mean ± SD	71.0 ± 11.2	92.50 ± 9.6	<0.001
Mean arterial pressure (mmHg), mean ± SD	80.9 ± 11.0	104.00 ± 10.3	<0.001
Ocular perfusion pressure (mmHg), mean ± SD	42.3 ± 6.9	54.10 ± 7.8	<0.001
Color Doppler of the ophthalmic artery, mean ± SD			
Systolic velocity (cm/s)	22.03 ± 7.70	25.32 ± 9.20	0.240
Diastolic velocity (cm/s)	5.14 ± 2.40	7.44 ± 3.50	0.007
Resistance index	0.76 ± 0.08	0.70 ± 0.08	0.040

Table 3. Correlation between cardiologic evaluation and parameters of the Doppler of ophthalmic artery

	Functional class (NYHA)§		Ejection fraction of the left ventricle§		Systemic systolic blood pressure		Systemic diastolic blood pressure	
	r	P	*r*	P	*r*	P	*r*	P
SV	0.06	0.82	0.05	0.83	0.170	0.360	0.15	0.420
DV	0.28	0.29	0.10	0.70	0.367	0.040	0.44	0.020
RI	-0.41	0.09	-0.14	0.57	-0.470	0.007	-0.56	0.001

NYHA= New York Heart Association; SV= systolic velocity; DV= diastolic velocity; RI= resistance index
§= evaluated in heart failure patients; *r*= Spearman correlation coefficient

ocular perfusion, which is considered to be a risk factor for glaucoma according to current literature; moreover, this topic deserves attention and further investigation.

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