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Color Doppler imaging of the ophthalmic artery in glaucoma patients

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Introduction

For almost 300 years the term glaucoma meant elevated intraocular pressure. Detection of elevated pressure was essential for the diagnosis. Some turmoil arose when glaucomatous neuropathy was found in eyes with a normal pressure. Glaucoma became defined as the result of a synergism of many risk factors leading to optic neuropathy. Now the term glaucoma refers to a group of diseases that have in common a characteristic optic neuropathy with associated visual field loss for which elevated intraocular pressure (IOP) is one of primary risk factors. Glaucoma is a leading cause of blindness in the elderly population. Despite its prevalens, glaucoma remains a disease of unknown etiology and inadequate treatment [1]. The mechanisms of glaucomatous damage are still not fully understood. Nowadays vascular factors with or without an increase in IOP have been implicated in the development of glaucomatous damage. The mechanisms of their involvement, either as part of a generalized vascular disorder or as a purely localized disturbance, are still unclear [2].

There are many methods to quantify ocular hemodynamics. Invasive methods are indocyanine green angiography and oculo-oscilo-dynamography. Non invasive methods are: OBF System, bidirectional laser Doppler velosimetry, laser Doppler flowmetry, scanning laser ophthalmoscopy and color Doppler imaging. [3]

The color Doppler imaging (CDI) systems enable visualization of the ocular structures using ultrasound (B mode): Doppler sonographic quantification of frequency shifts with color-coded visualization of blood cell movements and pulse curves, and thus determination of blood flow velocities and vascular resistance parameters in the ophthalmic, short posterior ciliary, and central retinal arteries. Color-coded imaging of moving blood cells, changing their color intensity and positioning the measurement spot related to speed and direction of flow, allows the investigator to image a certain vessel and to position the measurement area for pulsed Doppler measurements accordingly [3]. Data are shown as graphs, peak systolic velocity (V_{max}) and end diastolic velocity (V_{diast}) are calculated by a computer. Moreover, pulsatily index PI (Gossling, 1974) for high resistivity systems is expressed like:

$$PI=V_{max} - V_{min}/V_{mean}.$$

Peripheral resistive index RI is given by

$$RI=V_{max} - V_{diast}/V_{max}$$

Deep in the orbit, the ophthalmic artery can be depicted, which usually enters the orbit temporal to the optic nerve and crosses over the nerve in the mid orbit. The blood flow velocities of the ophthalmic arteries after various authors are shown in Table 1.

Table 1. **The blood flow velocities of the ophthalmic arteries after various authors**

Reference	subjects	V_{max}	V_{dias}
10	187	37,3±6,8	8,3±2,8
11	72	31,6±9	8,2±3,7
12	40	31,4±4,2	-
13	20	41,3±3,4	9,5±2
14	20	28,7	-
15	206	38,8±8,6	12,0±3,1
16	60	45,1±7,7	11,9±3,4

The main objectives of our study was to evaluate retrobulbar hemodynamics in ophthalmic artery in primary open angle glaucoma and primary angle closure glaucoma compared with age and male matched controls.

Materials and methods

Clinical data were obtained during the ophthalmological examination of responders from international health and nutrition examination study MONICA (MONItoring of trends and determinants in CArdiovascular disease) in the Eye clinic of Kaunas Medical University Hospital from April 2001 till May 2002. Brachial artery blood pressures were measured using a blood pressure cuff and a stethoscope .The following eye examination was carried out: visual acuity, impression tonometry, biomicroscopy, fundus examination with Super Field lens Of the 1357 persons 35-64 years of age, who were examined in the MONICA, glaucoma was 15 (30 eyes). All of them were performed CDI, visual field examination, gonioskopy. Because glaucoma is multifactoial disease and usually is devided in two big anatomical subgroups - open angle and angle closure, in this study we separate all glaucoma patients in Primary Open Angle Glaucoma (POAG) patients (N=11) group and Primary Angle Closure Glaucoma (PACG) patients (N=4) group. There were 3 patients (5 eyes) after surgery in POAG patients group and all eyes excluded from the group. In PACG patients group all patients were after various types of surgery and laser treatment. Surgery types and laser treatment in this group are shown in Table 2. Only no operated eyes enrolled in POAG patient group (17 eyes) and all eyes enrolled in PACG patient group (8 eyes). The distribution of patients according glaucoma treatment

in POAG and PACG patient groups is shown in Table 3. To assess the results of patients with POAG and PACG a control groups of healthy persons was formed.

Dopplerography of ophthalmic artery was performed by means of the ultrasonic blood flow detector UDD – 03, developed on the bases of IBM PC 386 (Kaunas University of Technology), working in CDI mode for investigation of peripheral vessels. This instrument measures automatically V_{max} during systole, blood flow velocity at the end of diastole V_{diast}, PI (pulsatily index), RI (resistive index). The maximum measuring of depth – 35 mm, the frequency ultrasonic waves 8 MHz, intensivity of ultrasound < 15 mW/cm^2 . Standard method was used for this investigation [4]. Patients were investigated through the upper lid in a sitting position looking down to the nose. The Doppler curve of the normal blood flow in the ophthalmic artery of the healthy person is shown in Fig. 1.

Statisticl analysis was performed using "Microsoft Excel 2000", "Statistica 5.0".

Table 2. **Surgery types and laser treatment in PACG group**

Surgery or laser mode	Number of eyes
Trabeculectomy	2
Laser iridotomy (LIRT)	3
Laser trabeculoplasty (LTP) and LIRT	1
Without surgery and laser	2

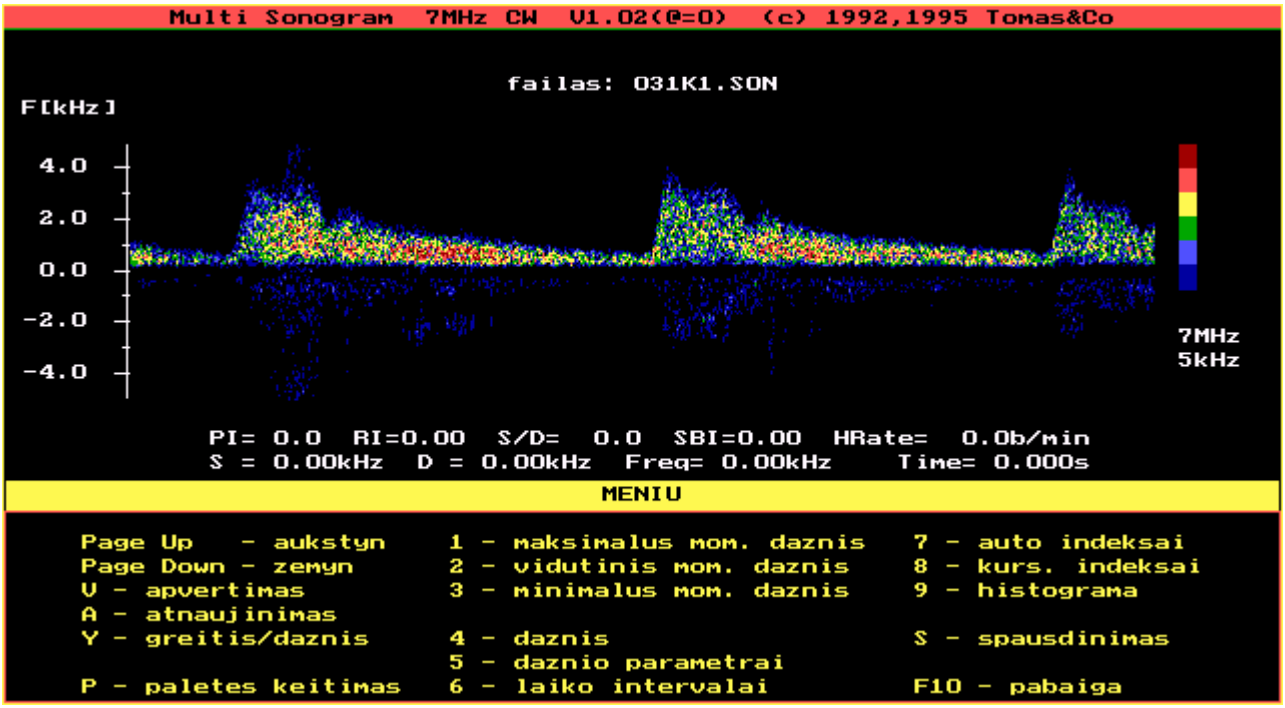

Fig. 1. **The Doppler curve of the normal blood flow in the ophthalmic artery of the healthy person**

Table 3. **The distribution of patients according glaucoma treatment in POAG and PACG patient groups**

Antiglaucoma drugs	POAG number of eyes	PACG number of eyes
Timolol 0,5% 2 times daily	7	2
Dorzolamide 2% and Timolol 0,5% 2times daily	8	0
Pilocarpine 2% 2 times daily	0	1
Pilocarpine 2% and Timolol 0,5% 2 times daily	0	2
Pilocarpine 2% and Timolol 0,5% 2 times daily and Latanoprost 0,005% 1 times daily	0	2
Clonidine 0,125% 3 times daily	2	0

Results

Both control groups of healthy persons were adjusted for age and male with POAG and PCAG patient groups. Main characteristics of study subjects are shown in Tables 4 and 5.

There were no significant differences between the POAG patients and healthy persons groups according to the age and sex. Systolic blood pressure of POAG patients was statistical significant ($p<0,05$) lower, than of healthy persons, but diastolic blood pressure was the same. Intraocular pressure (IOP) was statistically significant

(p<0,05) higher in the POAG group compared to normal controls. There were no significant differences between the PACG patients and healthy persons groups according to the age and sex. Systolic and diastolic blood pressure of PACG patients was the same as healthy persons. Intraocular pressure (IOP) was statistically significant (p<0,05) higher in PACG group compared to normal controls. Ophthalmic artery blood flow parameters of POAG and PACG patients and healthy persons are shown in Tables 6 and 7.

Table 4. **Main characteristics of study subjects (POAG group)**

Risk factors	POAG patients	Normal controls	p
Total N (%)	9(100%)	26(100%)	-
Male N (%)	5(56%)	14(54%)	-
Female N (%)	4(44%)	12(46%)	-
Age (X±SD)	55,1±7,4	55,2±6	NS
SBP (X±SD)	131,1±26	152,5±22,8	<0,05
DBP (X±SD)	81±14,8	89,8±15,1	NS
IOP (X±SD)	22,1±5,2	16±2,3	<0,05

Table 5. **Main characteristics of study subjects (PACG group)**

Risk factors	PCAG patients	Normal controls	p
Total N (%)	4(100%)	11(100%)	-
Male N (%)	1(25%)	3(27%)	-
Female N (%)	3(75%)	8(73%)	-
Age (X±SD)	62±3	60,6±2,1	NS
SBP (X±SD)	150±29,1	143,1±24,7	NS
DBP (X±SD)	85,5±10,1	86,9±14	NS
IOP (X±SD)	21,8±4,6	16,2±1,6	<0,05

Table 6. **Ophthalmic artery doplerography data mean average standard deviation of the POAG patients and persons of the control group**

Variable	POAG group N=17 eyes	Control group N=50 eyes	p
V_{max} (cm/s)	27,85±6,36	32,37±7,43	<0,05
V_{diast} (cm/s)	7,07±3	6,92±2,79	NS
RI	0,75±0,08	0,79±0,06	NS
PI	1,65±0,39	1,83±0,36	NS

Table 7**. Ophthalmic artery doplerography data mean average standard deviation of the PCAG patients and persons of the control group**

Variable	PACG group N=8 eyes	Control group N=22 eyes	p
V_{max} (cm/s)	20,3±6,3	26,8±7,9	<0,05
V_{diast} (cm/s)	6±2,7	6,6±3,2	NS
RI	0,7±0,18	0,77±0,07	NS
PI	1,6±0,3	1,8±0,4	NS

The average of the systolic blood flow velocity in ophthalmic artery of glaucoma patients (POAG and PACG) was statistical significant (p<0,05) lower than in ophthalmic artery of healthy persons. The peripheral resistive index RI in an ophthalmic artery of glaucoma patients (POAG and PACG) was lower than in an ophthalmic artery of healthy persons, but statistical not significant (p>0,05). The pulsatily index PI in an ophthalmic artery of glaucoma patients (POAG and PACG) was lower than in an ophthalmic artery of healthy persons, but statistical not significant (p>0,05) too. We did not find differences in a blood flow velocity at the end of diastole of the ophthalmic artery in glaucoma patients (POAG and PACG) and in control groups (p>0,05).

Discussion

Systemic hypertension is not consistently associated with glaucoma [4,5], so a low blood pressure is reported in different studies as an important risk factor for glaucoma [6, 7, 8]. In our study the systolic blood pressure was statistically significant lower in patients from the POAG group in comparison with healthy persons.

Most studies using color Doppler imaging reported a lower peak systolic velocity in ophthalmic artery of the POAG patients compared to healthy [17,18,19,20]. Some of them find increased resistivity indices in high and normal pressure glaucoma patients compared to normal subjects [17, 18, 19]. However some studies report RI is not statistically different between glaucomatous and healthy subjects [20]. Our study show only a peak systolic velocity lowering in an ophthalmic artery of the POAG patients too. There was very interesting study from Department of Ophthalmology Academic Medical Center, University of Amsterdam. In this study were analyzed a group of controls who were normal with regard to glaucoma, but who had the same type of systemic disease such as arterial hypertension, or conditions such as diabetes mellitus. These “normal” subjects were compared to a group of true glaucoma patients, who also had many systemic diseases. They found in the “normal’s” ophthalmic artery resistive index statistically significant greater than in high and normal pressure glaucoma patients ophthalmic artery. In summary, these results show that other factors, not necessarily related to glaucoma, may influence ocular blood flow findings, and therefore, that altered blood flow related parameters may not necessarily be associated with glaucomatous damage [3]. In our study, like this, normal controls were with arterial hypertension.

Although CDI provides only velocity information, it has several advantages over other techniques. It is noninvasive and easily repeatable, there is minimal patient cooperation necessary, and it can be used in patients with opaque optical media, where other techniques, requiring direct visualization of the fundus, fail.

Conclusions

1. The peak systolic blood flow velocity in ophthalmic artery of POAG patients was statistical significant (p<0,05) lower than in an ophthalmic artery of healthy persons.

2. The peak systolic blood flow velocity in an ophthalmic artery was significantly lower in the PACG patients compared to normal subjects.
3. Interpretation of CDI results must be done carefully.

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Glaukoma sergančiųjų akinės arterijos doplerografinis tyrimas

Reziumė

Tyrimų tikslas - įvertinti glaucoma sergančiųjų akinės arterijos hemodinamikos pokyčius.

Metodai: iš 1357 asmenų, kurie dalyvavo mokslinėje studijoje MONICA-4, buvo atrinkta 15 sergančių glaukoma, šie suskirstyti į atviro ir uždaro kampo glaukomos grupes, jiems atliktas doplerografinis akinės arterijos tyrimas ir vertinami hemodinamikos parametrai (maksimalus sistolinis, galinis diastolinis greičiai, pulsacijos ir periferinio pasipriešinimo indeksai). Kiekvienos grupės hemodinaminiai rodikliai palyginti su atitinkamo amžiaus kontrolinėmis grupėmis.

Rezultatai: nustatyta, kad sistolinis kraujo srovės greitis glaukoma (tiek atviro, tiek uždaro kampo) sergančiųjų akinėje arterijoje yra statistiškai patikimai ($p<0,05$) mažesnis nei kontrolinės grupės asmenų sveikose akyse. Kiti hemodinamikos parametrai akinėje arterijoje tiek sergančių glaukoma, tiek sveikų asmenų statistiškai patikimai nesiskyrė.

Išvada: ultragarsinis doplerinis akinės arterijos tyrimas gali teikti papildomos informacijos diagnozuojant glaukomą, nustatant prognozę bei pasirenkant gydymo taktiką.

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