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Attenuation of ocular wall pulsation in eyes containing a gas bubble after vitrectomy

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Abstract

Purpose. To evaluate the effect of an intraocular gas bubble on ocular wall pulsation.

Methods. Eight patients that underwent vitrectomy with intraocular gas injection for various reasons were studied. Ocular pulsation was evaluated in a semi-quantitative way by means of Goldman applanation tonometry in both eyes before and after the operation. Vitreous cavity gas fill in the operated eye was estimated by means of indirect ophthalmoscopy and was correlated with ocular pulsation. The follow up lasted until the gas totally disappeared.

Results. Ocular pulsation disappeared postoperatively in the operated eye and gradually reappeared when the gas fill diminished. Pulsation returned to preoperative level when the gas disappeared from the vitreous cavity. A negative statistical correlation between ocular pulsation and gas fill could be documented.

Conclusion. The compressible nature of the intraocular gas bubble results in absorption of the vascular pulsation and prevents its transfer to the ocular wall. This leads to attenuation or even cancellation of ocular wall pulsation when a gas bubble exists within the eye.

Keywords: vitreoretinal surgery; ocular pulsation; gas; blood flow; hemodynamics

Introduction

Ocular wall pulsation is the result of the pulsatile blood inflow to the eye. The incoming bolus of blood results in a slight expansion of the eye that is detected as ocular pulsation, synchronous with the heart rate.[1,2] Ocular pulsation becomes possible because the eyeball behaves as an elastic system. In normal conditions the structure that determines the elasticity of the eyeball is the eye wall (choroid, cornea and mainly sclera); most of the structures that comprise the interior of the eye such as vitreous, aqueous and lens are incompressible and not elastic.[3] In many vitreoretinal procedures, however, air or other gases are injected into the vitreous cavity and remain there postoperatively for various amounts of time. In these situations, the elastic characteristics of the eye change dramatically, as gases are highly compressible. In the current study, we evaluated the effect that the presence of intraocular gas has on the pulsatility of eyes after vitrectomy.

Methods

Patients in this study were operated upon in the University Eye Clinic of Heraklion between September and December 2000. Corneal pulsation was evaluated by means of Goldman applanation tonometry on eyes which received an intraocular gas injection as part of a vitreoretinal procedure. During classic applanation tonometry the movement of the semicircles was evaluated and graded as absent (0), slight (1), obvious (2) and prominent (3). In total, 8 patients were included in the study. All of them exhibited preoperative pulsation grade 3 in both eyes. Preoperative diagnosis, operation performed, and gas used in the study individuals are listed in Table 1. Two patients received air and the rest C3F8.

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Table 1. Demographic and clinical characteristics of the study patients. (ERM = epiretinal membrane; VH = vitreous hemorrhage; RD = retinal detachment; MH = macular hole; PPV = pars plana vitrectomy)

Patient characteristics					
Initials	Sex	Age	Diagnosis	Operation	Gas used
TE	F	63	ERM	PPV	c3f8
KK	F	60	VH	PPV	air
NV	M	60	trauma	PPV	air
HS	F	55	RD	PPV	c3f8
PA	F	59	MH	PPV	c3f8
DP	F	62	MH	PPV	c3f8
HN	M	63	MH	PPV	c3f8
GU	F	62	RD	PPV	c3f8

During the postoperative follow-up, mean intraocular pressure (IOP) and magnitude of ocular pulsation in both eyes were recorded. The gas fill in the operated eye was also recorded as a percentage of vitreous cavity volume. The size of the gas bubble was estimated using indirect ophthalmoscopy with the patient in a sitting position and his pupils dilated. Follow up lasted until the gas had totally disappeared. Statistical analysis was used to determine the correlation between the grade of ocular pulsation and gas fill as well as the correlation between ocular pulsation and the IOP at certain study points. Because data were not normally distributed both percent gas fill and pulsation strength were transformed using a log(base 10) transformation. In order to avoid the log(10) of zero an "1" was added to all data points. A log(base 10) transformation was also applied to IOP data. All subsequent analyses are based on log transformed values. Calculation of correlation coefficients and linear regression analysis was performed using Microsoft Excel 98 (Microsoft Corporation, 1995–1998) and Microcal^{TM} Origin, version 6.0 (Microcal Software Inc, Northampton, MA, 1991–1999).

Results

Ocular wall pulsation was totally canceled in all operated eyes immediately after surgery. Wall pulsation gradually reappeared as gas fill diminished. All eyes regained the preoperative pulsation amplitude after the intraocular bubble disappeared (Fig. 1). Statistical analysis showed a negative linear correlation between ocular pulsation and gas fill (correlation coefficient = –0.9); the relation of the two parameters was statistically significant ($p = 0.012$) (Fig. 2). The ocular pulsation of the fellow eyes did not show significant change through out the study period. The IOP variation in the operated eyes is shown in Figure 3. No significant correlation could be found between ocular pulsation and IOP (correlation coefficient = –0.16); the relation of the two parameters was not statistically significant ($p = 0.74$).

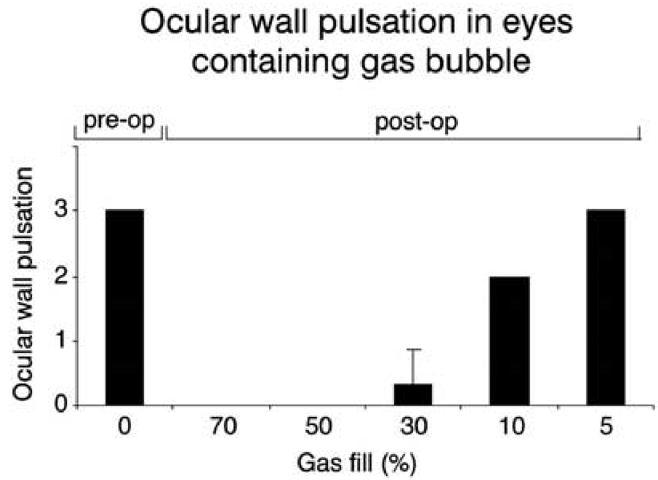

Figure 1. Eye wall pulsation disappeared in all eyes postoperatively. Minimal pulsation or absence of pulsation was detected as long as the gas fill was over 30%. After that point pulsation gradually returned to preoperative levels. An arbitrary grading for pulsation was used where 0 = absence of pulsation, 1 = slight pulsation, 2 = obvious pulsation and 3 = prominent pulsation. Data on x-axis are displayed in chronological order: before the operation there was no gas into the eye (fill 0%); immediately after the operation the fill was maximum and diminished gradually.

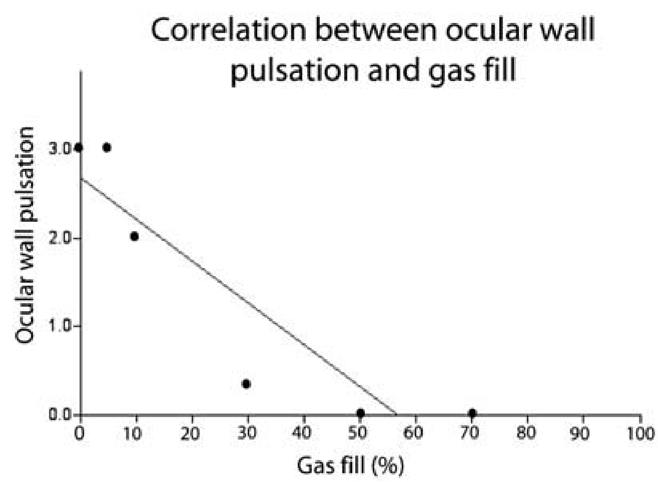

Figure 2. A negative correlation between ocular wall pulsation and gas fill was revealed (correlation coefficient = –0.9). The log(10) of the measured values was used for both x and y axes. The formula of the linear fit was Log(pulse) = 0.73–0.38*Log (GasFill%).

Discussion

Our study shows that the presence of a gas bubble in the vitreous cavity results in a dramatic change of the pulsatile behavior of the eye wall. The ocular wall pulsation

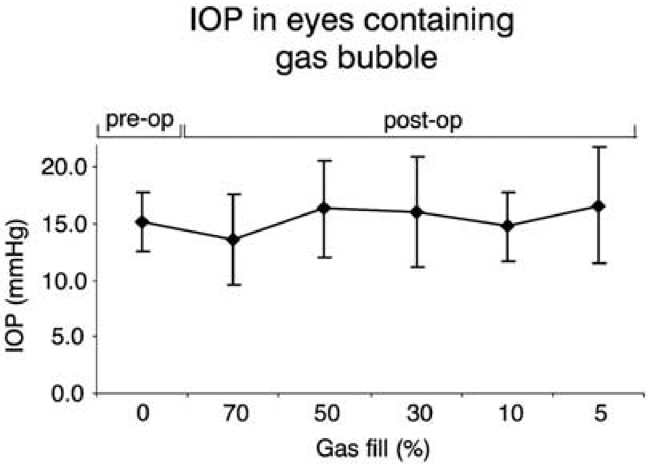

Figure 3. Intraocular pressure showed small variation during the follow-up period. No correlation could be found between IOP and gas fill. Data on x-axis are displayed in chronological order: before the operation there was no gas into the eye (fill 0%); immediately after the operation the fill was maximum and diminished gradually.

was canceled or significantly reduced and the reduction showed a negative correlation with the intraocular gas fill.

Under normal conditions ocular elasticity is one of the main determinants of ocular wall pulsation.[2,4] For the same volume of blood inflow and the same total eyeball volume the surface of an eye with a very rigid sclera will expand less compared to an eye with an elastic sclera. In eyes containing gas, the bubble, because of its highly compressible nature, becomes an important determinant of eyeball elasticity. In our study, when sufficient volume of gas was present in the vitreous cavity the vascular pulsation was absorbed by the gas bubble and no pulsation was transmitted to the ocular wall. With smaller amounts of gas fill, the bubble absorbed part of the pulsation while the rest appeared as ocular wall pulsation.

Scleral elasticity is considered a significant parameter of the haemodynamic status of the eye.[5,6] In Friedman's vascular hypothesis of AMD pathogenesis, reduced scleral elasticity is proposed as the reason for increased resistance to blood inflow, associated with an elevated intravascular pressure; this, in combination with endothelial growth factors and a break in a calcified Bruch membrane is suggested as the cause of choroidal neovascularization.[7] Within the framework of this vascular model the "pressure absorbent" action of an intraocular bubble, documented in this study, might compensate for the reduced scleral elasticity. This would mean that in cases with increased scleral rigidity, putatively at high risk of developing AMD, the presence of an intraocular bubble might have a protective haemodynamic effect reducing the resistance to blood inflow. In future research color Doppler ultrasonography or laser Doppler flowmetry could be used to evaluate the haemodynamic effect of an intraocular gas bubble in eyes before and after vitrectomy.

The operating principle of most devices that use tonometric methods to measure the pulsatile ocular blood flow takes advantage of the ocular pulsation. These devices measure the IOP variation during the cardiac cycle and use this variation to determine the pulsatile blood flow.[2–4,8] This principle assumes that the interior of the eye is incompressible and the incoming bolus of blood increases both the volume of fluid content of the eye and the intraocular pressure.[9] While this is true under normal conditions, the findings of our study indicate that it is not true for eyes containing a gas bubble. In an eye containing a gas bubble the incoming bolus of blood will compress the gas bubble. Thus a certain increase of the volume of the fluid content may be accomplished without a change of the total volume of the eye and without any change of the intraocular pressure. This will lead to diminished or absent pulsation of the eyewall. In such an eye, the variation in IOP during the cardiac cycle will be also diminished or absent leading to the conclusion that the pulsatile inflow is diminished or absent. Such a conclusion may be misleading, as in this condition the vascular pulsation exists but it is not transmitted to the ocular wall as the bubble "absorbs" it. Occasionally, when asked, patients will describe the pulsation of the gas bubble inside their operated eye. Perkins, in his work concerning ocular pulse, pointed out the significance of small air bubbles within the tonometric system he used for recording the ocular pulse; he suggested that the presence of these small air bubbles resulted most likely in underestimation of the pulse amplitude.[2] For these reasons we believe that tonometric methods to measure the pulsatile blood flow should not be used in eyes containing gas bubbles.

The changes in ocular pulsation observed in our study showed no significant correlation with mean IOP. Laser interferometry studies have revealed a significant effect of mean IOP changes on fundus pulsation in the macula and the optic disc.[10] In our study, however, the mean IOP remained within normal range and showed a variation during the follow-up that was too small to account for the significant reduction in ocular pulsation postoperatively.

In this study, we used the pulse-induced changes in diameter of applanation during applanation tonometry as a way to measure the ocular pulsation. This method is easy to apply but yields only semi-quantitative information. Similarly, a semi-quantitative method was used for estimation of the intraocular gas fill. Although our measurements were sufficient for establishing the negative correlation between pulsatility and gas fill they did not permit an accurate correlation of the intraocular gas volume with the exact amplitude of ocular pulsation. This could be accomplished in future studies by the utilization of a more accurate method of quantitating ocular pulsation, such as continuous monitoring of intraocular pressure by means of OBF or the use of a pneumatonometer in pulse mode; similarly, the intraocular gas volume may be estimated using a B-scan ultrasound or magnetic resonance imaging.

In conclusion, this study revealed the impact of an intraocular gas bubble on ocular wall pulsatility and demonstrated the negative correlation between them. Our findings advocate for care during the interpretation of tonometric pulsatile blood flow readings in eyes containing gas. The possible haemodynamic effect of an intraocular gas bubble warrants further investigation.

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