Influence of change in body position on choroidal blood flow in normal subjects

P Kaeser, S Orgül, C Zawinka, G Reinhard, J Flammer

Aim: To compare subfoveal choroidal blood flow (ChBF) in sitting and supine positions in normal volunteers.

Methods: ChBF was measured with laser Doppler flowmetry in 22 healthy volunteers of mean (SD) age 24 (5) years. Six independent measurements of ChBF were obtained in one randomly selected eye of each subject while seated. The subjects then assumed a supine position for 30 minutes and a new series of six measurements was obtained. The mean values of the two series were calculated. Systemic brachial artery blood pressure and intraocular pressure were measured in the sitting and supine positions. Ocular perfusion pressure (OPP) was calculated based on formulae derived from ophthalmodynamometric studies. The influence of changing OPP during change in body posture on the change in ChBF was assessed by linear regression analysis.

Results: ChBF decreased by 6.6% (p = 0.0017) in the supine position. The estimated ophthalmic blood pressure in the supine position was adjusted to obtain a result of no change in OPP for no change in ChBF, yielding a mean decrease in the estimate of OPP of 6.7% (p = 0.0002). The necessary adjustment for the estimate of OPP in the supine position suggested a marked buffering of the change in perfusion pressure by the carotid system. The relative decrease in OPP correlated significantly with the relative decrease in ChBF (r^2 = 0.20; p = 0.036) with a slope for the regression line of 1.04.

Conclusions: The comparable degree of change in ChBF and OPP and the linear relationship between the two parameters suggest a passive response of the choroidal circulation to a change in posture. In contrast, the carotid system seems to control the gradient in perfusion pressure closely between the heart and its branches.
(IOP) below 20 mm Hg in both eyes, and no pathological findings on slit lamp examination and indirect fundoscopy.

**Experimental procedure**

Subjects were studied at least 2 hours after a light meal and were asked to refrain from alcohol and caffeine for 12 hours before the trial days, as well as to avoid heavy exercising or meals too rich in sugar and fat before the experimental day. A resting period of at least 30 minutes was scheduled for each subject. Stable baseline conditions were established, which were ensured by repeated measurements of blood pressure (Profilomat, Roche, Basel, Switzerland). After stabilisation of blood pressure, two measurements of SBP and DBP as well as heart rate (HR) were recorded and averaged. Immediately afterwards, IOP was determined with a handheld tonometer (Tonopen; Mentor, Norwell, MA, USA) after applying one drop of 0.4% benoxinate hydrochloride and staining the tear film with a strip of fluorescein sodium. The subjects were seated with the head stabilised in a slit lamp head rest. Care was taken to standardise the subject’s head position which was held constant throughout the recordings by aligning marks on the head rest with anatomical landmarks on the head. The subjects were asked to fixate the red light spot within the ocular and to adjust the focus by turning the ocular. The ocular-to-cornea distance was set between 1.5 and 2 cm and held constant throughout the recordings. In addition, a constant very low level artificial room illumination was used throughout all the experiments. The experimental eye was chosen randomly and measurements were obtained without pupil dilatation. A stable direct current¸ examination was used throughout all the experiments. The experimental eye was chosen randomly and measurements were obtained without pupil dilatation. A stable direct currentDirektiver und instabile Fixation wurden ausgeschlossen. 

**Statistics**

The SBP and DBP readings were used to calculate the mean arterial blood pressure (MBP) according to the formula: MBP = DBP + 0.42 (SBP – DBP). Mean ophthalmic arterial blood pressure (OAP) was calculated based on formulae derived from ophthalmodynamometric studies, with mean OAP in the sitting position calculated as OAP = 0.74 × MBP and OAP in the supine position calculated as OAP = 0.84 × MBP. Mean ocular perfusion pressure (OPP) was calculated according to the formula: OPP = OAP – IOP. The differences between sitting and supine positions were calculated for OPP and ChBF by accounting for heteroscedasticity. Departure from normal distribution of the variables was assessed by means of the Shapiro-Wilk W test for normality and measurements in the sitting position were compared with those in the supine position using a paired t test. The dependence of change in ChBF on change in OPP was assessed by computing the significance of the slope of the line regressing the percentage difference in ChBF on the percentage difference in OPP. A p value of ≤0.05 was considered statistically significant.

**RESULTS**

The distribution of the data for ChBF in the sitting (p = 0.28) and supine positions (p = 0.46), MBP in the sitting (p = 0.91) and supine positions (p = 0.43), HR in the sitting (p = 0.69) and supine positions (p = 0.49), and OPP in the sitting (p = 0.63) and supine positions (p = 0.28) was normal. Changes in ChBF, MBP, HR, and OPP were also normally distributed (p = 0.86, p = 0.09, p = 0.13, and p = 0.78, respectively). The variation (coefficient of variation) between the two series of ChBF measurements was comparable (10.28% and 9.58% in the sitting and supine positions, respectively: p = 0.58, paired t test). The mean (SD) results for the measured parameters IOP, SBP, DBP, MBP, HR, and ChBF are shown in table 1. MBP decreased by 7.8 (4.9)%, HR by 8.2 (9.6)%, and ChBF by 6.6 (11.6)%. The mean (SD) estimated OPP was 50.7 (5.9) mm Hg and 53.2 (4.8) mm Hg in the

**Figure 1** A curve fitted according to the distance-weighted least squares smoothing procedure and regressing the relative change in choroidal blood flow on the relative change in ocular perfusion pressure (dotted line) suggested a nearly linear fit except for the lowest end of the curve, suggesting an outlier. When the procedure was repeated after excluding the extreme points at the upper and lower end (solid line), the curve showed a steady decrease in choroidal blood flow with decreasing ocular perfusion pressure.

**Table 1** Mean (SD) parameters in the sitting and supine positions

<table>
<thead>
<tr>
<th></th>
<th>Sitting position</th>
<th>Supine position</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOP (mm Hg)</td>
<td>13.0 (2.2)</td>
<td>14.0 (2.1)</td>
<td>0.0006</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>106.2 (12.6)</td>
<td>102.7 (7.2)</td>
<td>0.046</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>71.5 (8.6)</td>
<td>63.6 (6.9)</td>
<td>0.0001</td>
</tr>
<tr>
<td>MBP (mm Hg)</td>
<td>86.1 (8.7)</td>
<td>80.0 (6.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>64.1 (8.1)</td>
<td>59.0 (10.1)</td>
<td>0.0006</td>
</tr>
<tr>
<td>ChBF (arbitrary units)</td>
<td>9.5 (2.2)</td>
<td>8.9 (2.1)</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

ChBF, choroidal blood flow; DBP, diastolic blood pressure; IOP, intraocular pressure; MBP, mean arterial blood pressure; SBP, systolic blood pressure. *Paired t test.
sitting and supine positions respectively (p = 0.0005), with a mean (SD) increase of 5.4 (5.6)%.

Because of a negative mean change in ChBF during an estimated mean increase in OPP, it was hypothesised that mean OAP in the supine position had been overestimated. Considering the measured parameters in table 1 and an adjusting factor for the estimate of the mean OAP in the sitting position of 0.74, a new adjusting factor for the estimate of the mean OAP in the supine position was calculated in order to obtain no change in perfusion pressure for no change in ChBF. Solving the equation yielded an adjusting factor of 0.767 instead of 0.84. With the new adjusting factor for the estimate of the mean OAP in the supine position, the mean (SD) OPP was 50.7 (5.9) mm Hg and 47.3 (4.4) mm Hg (the latter parameter was still normally distributed: p = 0.31) in the sitting and supine positions respectively (p = 0.0002), with a mean (SD) decrease of 6.7 (5.0)%.

Scrubbing distance-weighted least squares curves regressing change in ChBF on change in OPP (fig 1), a steady decrease in ChBF with decreasing OPP was observed. A linear fit was therefore computed to the entire data set and the relative change in OPP correlated positively with the relative change in ChBF ($R^2 = 0.20$, $p = 0.036$; fig 2). Residual analysis applying the $2 \times \sigma$ limit did not unveil outliers in this regression analysis which showed a slope of 1.04.

**DISCUSSION**

This study assessed the response of subfoveal ChBF to change in body posture. The experimental set up was designed to provoke a change in OPP while limiting neurovegetative input during change in perfusion pressure. Enough time was scheduled after the subjects had assumed the supine position to allow the regulatory mechanisms to take effect. The change from a sitting position to a supine position resulted in a change in ChBF which depended linearly on the change in OPP.

**Figure 2** Relative change in choroidal blood flow (%)

-30 -20 -15 −10 −5 0 5

Change in choroidal blood flow (%)

-16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6

Change in perfusion pressure (%)

The measured change in ChBF, they hypothesised an active mechanism acting between the heart and the eye, buffering the increase in OPP. It is likely that this effect—possibly based on myogenic mechanisms which usually need more time to take effect—may have been even more marked when the subjects were allowed to rest for 30 minutes in the supine position. Obviously, the estimate of change in OPP was erroneous and with a correcting factor of 0.767 instead of 0.84 in the supine position, a zero change in OPP corresponded to a zero change in ChBF. This suggests some external control mechanisms regulating the OPP in the ophthalmic artery, similar to the control mechanisms in the carotid system. Consequently, the change in the gradient in OPP between the heart and the cerebral circulation is buffered in the supine position. As expected, a reduction in systemic blood pressure was observed after assuming the supine position and OPP dropped. The decrease in OPP and ChBF were of similar amplitude and amounted to $-6.7\%$ and $-6.6\%$ respectively, confirming the findings of Longo et al. Furthermore, the regression line between the two variables showed a slope of 1.04 indicating an absence of a regulatory response within the choroid.

We confirmed the findings of Longo et al while allowing a much longer time for the vasculature to adapt. Myogenic responses of an autoregulated vessel may require several minutes to induce stable vessel diameters following an acute increase in systemic blood pressure resulting from neurovegetative stimulation during isometric exercise, several studies have shown relative stability of the ChBF during increased OPP. However, it must be remembered that the vascular response in the choroid after exercise induced changes in OPP may be driven by direct sympathetic input to the choroid and not represent an autoregulatory response intrinsic to the choroidal vessels. Furthermore, a recent study—which also avoided direct interventions on the eye such as applying a suction cup or stimulation of the neurovegetative system—found a passive response of the choroidal vasculature to changes in perfusion pressure. The inconsistency between the latter finding and an earlier result from the same group suggests that the use of means such as a suction cup to increase IOP may elicit mechanisms responsible for a non-linear pressure-flow relationship in the choroid.

In the present study a relative increase in OPP was observed when estimates of the blood pressure in the ophthalmic artery were calculated with the same factors as in a previous study. Longo et al found that the increase in calculated OPP estimated using data based on ophthalmodynamometric measurements was much less than the increase calculated with the hydrostatic model and, because the estimated change in perfusion pressure fitted the measured change in ChBF, they hypothesised an active mechanism acting between the heart and the eye, buffering the increase in OPP. It is likely that this effect—possibly based on myogenic mechanisms which usually need more time to take effect—may have been even more marked when the subjects were allowed to rest for 30 minutes in the supine position. Obviously, the estimate of change in OPP was erroneous and with a correcting factor of 0.767 instead of 0.84 in the supine position, a zero change in OPP corresponded to a zero change in ChBF. This suggests some external control mechanisms regulating the OPP in the ophthalmic artery, similar to the control mechanisms in the carotid system. Consequently, the change in the gradient in OPP between the heart and the cerebral circulation is buffered in the supine position. As expected, a reduction in systemic blood pressure was observed after assuming the supine position and OPP dropped. The decrease in OPP and ChBF were of similar amplitude and amounted to $-6.7\%$ and $-6.6\%$ respectively, confirming the findings of Longo et al. Furthermore, the regression line between the two variables showed a slope of 1.04 indicating an absence of a regulatory response within the choroid.

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change in intravascular pressure,20 21 while metabolic mechanisms seem to occur within a few seconds.21 Because the supine position was assumed for at least 30 minutes, there is good reason to be confident that control mechanisms had enough time to take effect in the present experimental set up and seem, in fact, to have influenced blood pressure in the ophthalmic artery. However, as in the study by Longo et al., because ChBF was measured with a device which assessed only the subfoveal choroid, the results presented hitherto may not apply to the remainder of the choroid.

In conclusion, our results show that subfoveal ChBF decreases proportionally with decreasing OPP, suggesting a passive response to changes in body posture. In contrast, the carotid system seems to regulate the perfusion pressure in its branches.

Authors’ affiliations
P Kaeser, S Orgül, C Zawinka, G Reinhard, J Flammer, University Eye Clinic, Basel, Switzerland

REFERENCES
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