Assessment of visual contrast sensitivity in hyperbaric oxygen

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Oriani G, Magni R, Michael M, Musini A, Durante A, Campagnoli P, Brancato R. Assessment of visual contrast sensitivity in hyperbaric oxygen. Undersea Hyperbaric Med 1994; 21(4):387–390.—Hyperbaric oxygen therapy is used in ophthalmology in ischemic pathologies of the anterior and posterior segments. Our experiment was done on a healthy group of volunteers aged between 10 and 50 yr. We examined the subject’s vision before and after acute HBO exposure (60 min at 2.5 atm abs with pure oxygen) to verify whether vasoconstriction induced by hyperoxemia can influence eyesight. We measured the psychophysical determination of the threshold contrast according to Maione–Maffei’s zebra test. The results demonstrated that contrast sensitivity is significantly improved for almost all the studied frequencies in normal subjects after acute HBO exposure. We hypothesize that the visual system has a reserve which is activated by an improvement of retinal oxygenation.

contrast sensitivity, hyperbaric oxygen, vasomotion

Exposure to hyperbaric oxygen increases the oxygen supply in chorioretinal perfusion (1, 2). Several animal studies have shown a considerable increase in the partial pressure of O₂ in the vitreous humor near the retina (1, 3); HBO therapy has been used with apparently good results according to several reports of various ocular pathologies involving acute or chronic ischemia (4–10).

Hyperoxia when there is ischemia does not cause vasoconstriction (HBO corrects the ischemia), probably because ischemia causes a vasogenic stimulus that prevails over the vasoconstrictive reflex mediated by the sympathetic system. If the tissue has normal oxygenation, the vasoconstrictive stimulus (due to hyperoxia) is strong enough to prevent damage in normal tissue. Animal studies have shown that an increase of O₂ at the retinal circulation level causes considerable vasoconstriction, directed to maintain a constant tissue oxygenation (1, 2). In patients treated for non-retinal pathologies, temporary alterations (scotoma and narrowing of visual field), probably due to an excessive vasoconstriction of retinal vessels, have been described (11, 12).
Previous studies do not reveal whether visual function in normal subjects can be changed by HBO. If the prevalence of the vasoconstrictive mechanisms were operative they could aggravate the vasoregulation mechanism in the retina. We studied a group of normal subjects to ascertain whether HBO therapy improves, deteriorates, or does not modify visual function.

METHOD

We studied 17 patients (34 normal eyes) who had 20/20 vision without optical correction, using the contrast sensitivity psychophysical test; we used the Maione-Maffei zebra test. The patients received an HBO treatment lasting 90 min, with a period of compression with air, followed by 60 min breathing 100% O₂ and by a slow decompression, always pure O₂, at 2.5 atm abs. Immediately after the HBO treatment the Maione-Maffei zebra test was administered again. The results of the examination of each spatial frequency were evaluated by Wilcoxon's test to determine whether HBO had made a significant difference. In some cases the values obtained from the Maione-Maffei zebra test were omitted (Table 1) because the subject did not give a definite answer. In the Maione-Maffei zebra test (13), contrast sensitivity is considered to be the reciprocal of the threshold value that is the smallest difference between the maximum and minimum luminance between the contiguous spaces of a target, in comparison with the luminance of the whole target: contrast = maximum luminance - minimum luminance/maximum luminance + minimum luminance.

Usually the target consists of a series of black-and-white alternating bars. The spatial frequency of the bars, which is expressed in cycles/degree, represents the second variable. In the Maione-Maffei test, contrast sensitivity is measured by seeking the smallest difference that the subject can discern in the luminance between the two bars. The test starts by presenting two bars with a lower contrast and with a different spatial orientation. In the zebra test, the bars may be vertical, 10° oblique toward the right and toward the left,

<table>
<thead>
<tr>
<th>Cycles/Degree</th>
<th>Mean Value</th>
<th>Standard Deviation</th>
<th>Wilcoxon Matched Pairs Test</th>
<th>Degrees of Freedom</th>
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<tbody>
<tr>
<td>0.66 Pre</td>
<td>4.06</td>
<td>1.79</td>
<td>t = 20.5</td>
<td>32</td>
</tr>
<tr>
<td>Post</td>
<td>3.38</td>
<td>0.66</td>
<td>P = 0.0248</td>
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<tr>
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<td>1.04</td>
<td>t = 21</td>
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<tr>
<td>Post</td>
<td>3.38</td>
<td>0.92</td>
<td>P = 0.8589</td>
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</tr>
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<td>0.86</td>
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<td>t = 22</td>
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<td>0.76</td>
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<tr>
<td>Post</td>
<td>4.21</td>
<td>1.17</td>
<td>P = 0.0329</td>
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</table>
and the direction of the bars is arranged in a pseudo-random way. The patient is asked to recognize the correct orientation. To avoid a learning effect, the patient is not informed about the results of the test performed before HBO. In practice, the test is made for six different spatial frequencies (the thickness of the bars), and for each bar a decreasing contrast is evaluated until the bars are correctly identified (threshold value). The symbol used is that of a stylized zebra which, when the bars are not seen, assumes the shape of a horse.

RESULTS

The Maione-Maffei zebra test allows a more complete evaluation of visual function than the determination of visual acuity alone. The test showed an improvement after HBO treatment for all the studied spatial frequencies except one in which the value remained unchanged (Table 1). In two cases (3 and 6 cycles/degree), the result was very significant \(P < 0.01\) and in two cases (0.66 and 24 cycles/degree) the improvement was significant \(P < 0.05\). The contrast-threshold curve (Fig. 1) shows the uniform decrease of threshold.

![Contrast threshold before and after HBO therapy.](image)

DISCUSSION

Our subjects were all emmetropic to estimate if contrast sensitivity changed with the HBO therapy. Visual acuity did not improve because all the patients had 20/20 vision. Contrast sensitivity is a more important aspect of visual function than visual acuity. Contrast sensitivity depends on the integrity of retinal (macular) receptors, and it depends anatomically on interneuronal connects, because the contrast depends on inhibition and facility of synaptic mechanisms. Performance requires a good availability of \(O_2\) and glucose in the presence of light, which can occur in the complex retinal cone pigment isomerization process and in its reversal. HBO therapy may induce some negative effects on visual function but these may be temporary or occur only in exceptional cases. The rule seems to be an improvement, perhaps temporary, of contrast sensitivity. The values we have found are very encouraging because the improvement occurs not only for one spatial frequency but for almost all of the frequencies studied. We wondered about the reason for this improvement in normal subjects; we originally expected poor performance due to the vasoconstriction mechanism caused by HBO therapy. We advance the hypothesis that the visual system usually does not work optimally and that in hyperoxemia visual performance may be closer to its true capacity. Activation of the sympathetic system causes an increase in cardiac and respiratory rhythm; visual function may be more fully activated as well. We believe that our results demonstrate the presence, in normal subjects, of a visual reserve that could be elicited by a greater supply of \(O_2\) at the chorioretinal level.

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REFERENCES