1040-5488/06/8303-0195/0 VOL. 83, NO. 3, PP. 195–198
OPTOMETRY AND VISION SCIENCE

RESEARCH NOTE

Hypermetropia-Succeeded Myopia After Hyperbaric Oxygen Therapy

KNUT EVANGER, MSc, OLAV H. HAUGEN, MD, PhD, LEIF AANDERUD, MD, PhD, EINAR THORSEN, MD, PhD, and BARBARA K. PIERSCIONEK, PhD

Department of Hyperbaric Medicine, Haukeland University Hospital, Haukeland, Norway (KE, LA, ET); Department of Ophthalmology, Haukeland University Hospital, Haukeland, Norway (OHH); Institute of Medicine, University of Bergen, Bergen, Norway (ET); and Department of Biomedical Science, University of Ulster, Coleraine Northern Ireland, United Kingdom (BKP)

ABSTRACT

A 58-year-old man presented with a change in vision during hyperbaric oxygen (HBO) therapy. Subsequent follow-up visits showed a hypermetropic shift, which succeeded the myopic shift after each of two series of HBO treatments. The maximal refractive amplitude was 3.00 D (range –1.37 D to +1.62 D) in the right eye and 2.75 D (range –1.25 D to + 1.50 D) in the left eye. Refraction stabilized after 1.5 years at +0.62 D and +0.50 D to pretreatment values in the right and left eye, respectively. The findings are discussed with regard to possible changes in the structure of the lens. (Optom Vis Sci 2006;83:195–198)

Key Words: hyperbaric oxygen therapy, myopic shift, hypermetropic shift, lens transparency, refractive index

Hyperbaric oxygen (HBO) therapy is used in the treatment of a number of medical conditions, including decompression sickness, carbon monoxide poisoning, arterial gas embolism, anaerobic infections, and other disorders characterized by local ischemia. The patient breathes 100% oxygen at a pressure of 200 to 240 kPa in a hyperbaric chamber. HBO therapy has been shown to stimulate growth of capillaries, fibroblast proliferation, and collagen synthesis in ischemic tissue.[1]

Temporary refractive changes toward increased myopia or reduced hypermetropia is a frequently reported ocular side effect in patients undergoing prolonged periods of daily HBO therapy.[2–8] We present an atypical case in which a hypermetropic shift followed the myopic shift in a patient after each of two series of hyperbaric oxygen exposures.

CASE REPORT

A 58-year-old man had been treated with surgery followed by radiation therapy (60 Gy) for gingival cancer. The orbitae were shielded during radiation therapy. As a result of mandibular osteoradionecrosis after a latent period of nine month, the patient had 21 days of HBO treatment at 2.4 kPa for 90 minutes administered by an oronasal mask. One-week before the HBO therapy, the patient had a routine eye examination. The refractive state was assessed with an autorefractor (Nidek AR-1200) on each eye and thereafter by the standard subjective refraction method without the use of cycloplegia. The monocular visual acuity was 20/20 in both eyes (as measured with a Snellen chart at 6 m) with a prescription of +0.75–0.25 × 80° OD and +1.25–1.00 × 90° OS. This correction was equal to the distance prescription in his current bifocals (with a reading addition of 2.50 D).

The patient returned to the clinic 2 weeks after completing 21 days of HBO therapy with the complaint of change in vision. He reported reduced quality of distance vision and was confused whether to use the reading or the distance portion of his bifocals for near vision. A myopic shift of –1.37 D in the right eye and –1.25 D in the left eye was found (best correction to 20/20 vision: –0.50–0.50 × 80° OD and plano –1.00 × 100° OS). With this prescription, the reading addition was unchanged (2.50 D). A slit lamp examination (RO 2000; Rodenstock, Munich, Germany) revealed no abnormalities of the anterior segment and media. Family history was negative for diabetes mellitus or any ocular disease.

When the patient attended a second follow-up visit 3 weeks after HBO therapy, the refraction had reversed to +0.25–0.50 × 80° OD and +0.50–1.00 × 100° OS. A significant hypermetropic shift appeared, which peaked at +1.75–0.50 × 80° OD and +2.00–1.25 × 100° OS, 6 weeks after treatment. There was no measured change in refraction at the 7-week follow-up visit. On review after 8 weeks, the right eye showed 0.25 D less hypermetropia, whereas the refraction remained stable in the left eye.

HBO therapy was then repeated for 10 days after dental surgery and resulted in a myopic shift, which was largest at the second follow-up examination 2 weeks after repeated HBO therapy. The prescription at this time was +0.75–0.50 × 70° OD and +1.25–1.00 × 105° OS. The refractive state recessed within the range of pretreatment values and remained stable in both eyes on review 1 week later. A change toward hypermetropia reoccurred at the 4-week visit, which proceeded to a maximal hypermetropic shift of +1.62 D in the right eye and +1.50 D in the left eye by 11 weeks after treatment (+2.50–0.50 × 75° OD and +2.75–1.00 × 100° OS).

Subsequent follow-up examinations showed a slow decrease in hypermetropia, which after 78 weeks (1.5 years) leveled out at +0.62 D and +0.50 D to pretreatment values in the right and left eye, respectively (+1.50–0.50 × 80° OD and +1.75–1.00 × 90° OS). At every visit, the best-corrected visual acuity reached 20/20 in both eyes. All the measurements were performed by a single investigator (the first author) with no review of the test data before the retest was performed. A standard end point of maximum plus for best visual acuity was used.

The results obtained by the monocular subjective refraction method (the fogging technique) and by the objective refraction (autorefractor) were converted to spherical equivalents for refractive change comparisons. The autorefractor measurements showed consistently more positive or less negative refractive values compared with the subjective refraction and these biases were statistically significant. The mean differences in spherical equivalents were +0.30 D ± 0.16 D ($p = 0.000$) in the right eye and +0.36 D ± 0.15 D ($p = 0.000$) in the left eye. Paired samples comparisons between objective and subjective measurements revealed high correlations, 0.977 in the right eye and 0.975 in the left eye. Subjective refraction was chosen as the standard of comparison, and the refractive changes fitted to a time scale in Figure 1 show significant myopic and hypermetropic shifts (≥0.50 D) after both series of HBO treatments.

In 19 (95%) of 20 follow-up examinations, the refractive changes occurred bilaterally within the margin of ≤0.25 D between the right and left eye. The largest difference of 0.37 D was revealed as one temporary exception only. Changes in refraction were mainly found in the spherical part of the ametropia, and there were no measured variations in total astigmatism (cylinder power) larger than 0.25 D. The cylinder axis varied within 70° to 90° in the right eye and within 90° to 110° in the left eye.

At its most myopic and hypermetropic state, the keratometry values (C-BES; Rodenstock) averaged 7.57 to 7.60 mm in corneal curvature radius in the right eye and 7.50 to 7.52 mm in the left eye. The ocular tension measurements (Xpert; Reichert, Buffalo, USA) were all within 11 to 12 mm Hg. Examination by the slit lamp through dilated pupils (Mydriacyl 1%) revealed no change in crystalline lens transparency and fundus appearance. The patient passed the Farnsworth D-15 color vision testing in both eyes. When the patient was called on for a routine visit after 4 years, the refraction had barely altered from the value measured 2.5 years earlier. There was only a 0.25 D reduction in hypermetropia in the right eye.

DISCUSSION

A myopic shift is commonly described in HBO-treated patients.[2–8] The myopic shift found in this patient was within the range of collated data from other patients treated with a standard HBO therapy protocol.[6] After cessation of the hyperbaric oxygen exposure, the myopic shifts tend to revert to baseline values.[2,4,6] Recently, a temporary hypermetropia (+2.00 D) was observed as an initial phenomenon in a single patient who recovered by 8 to 9 weeks after completed treatment.[9] The patient in our case report showed relatively slow changes in refraction and terminated with a longlasting low-level hypermetropia, which is difficult to explain on an osmotic basis.[10]

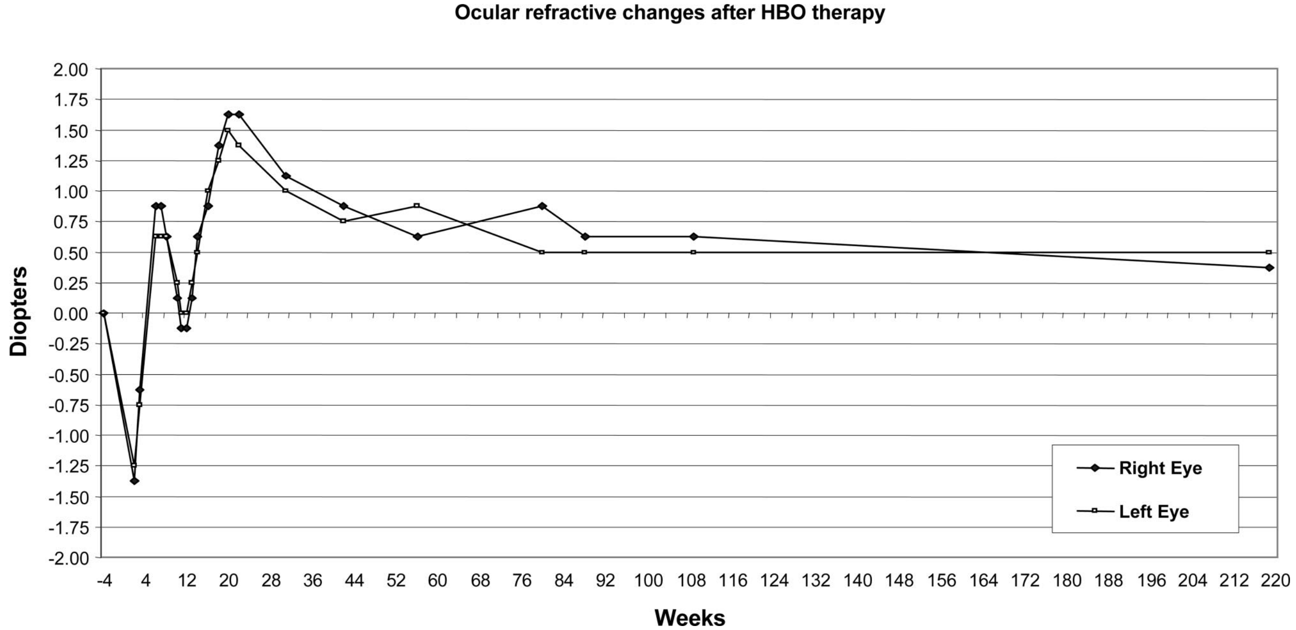

FIG 1.

The pattern of refractive changes in a patient who had undergone two sessions of Hyperbaric Oxygen (HBO) therapy plotted against time in weeks. Negative values indicate progression towards myopia; positive values indicate progression toward hypermetropia.

Sufficient changes in central corneal power, anterior chamber depth, and axial length of the eye or accommodative tonus have not been found to explain the degree of ocular refractive changes in HBO-treated patients.[2–4,8] Although the exact mechanism remains obscure, the myopic shift has been attributed to refractive index change within the crystalline lens.[4] Ultrasonographic measurements showed no change in total lens thickness.[4]

Oxidative stress has been proposed to cause an aggregation of proteins in the lens nucleus[11,12] with an implication of increased refractive index and a consequent myopic shift. Some support for this notion has been provided from studies on guinea pig lenses: *in vivo* treatment with HBO resulted in a decrease in the water-soluble and an increase in the insoluble protein proportion.[13] However, it should be noted that increases in insoluble protein on extraction may not necessarily represent increased aggregation in the intact lens, because high levels of water-insoluble protein have been found in clear bovine lenses.[14] The relatively high level of insoluble proteins extracted from older lenses is more likely to reflect an age-related increase in aggregation on extraction, because older proteins may be more vulnerable to abrupt changes in their immediate environment.

A manifestation of protein aggregation in the intact lens is opacification or loss of clarity and this has been reported after HBO treatment in human[7] and guinea pig lenses.[13] Recently, a study conducted by Bantseev et al.[15] showed that HBO treatment of guinea pig lenses results in a decrease in sharp focusing of laser rays. This may result in a loss of optical quality but should not necessarily be interpreted as an increase in light scatter if, like in Bantseev et al.'s findings, all rays that are traced through the lens cross the optic axis at some point. Furthermore, results from guinea pig lenses may not reflect the situation in the human lens, because the former contains ζ-crystallin, a protein not found in its human counterpart.[16]

If indeed, the refractive changes after HBO treatment are attributable to changes in the lens proteins, it is not clear how this may occur. The total amount of protein in the lens must remain the same so there cannot be any overall reduction or increase in protein concentration. Any change in response to HBO therapy would therefore have to relate to how the proteins and water interact and/or in their respective distributions. This would result in a change in the refractive index within the lens. Whether this change affects the entire lens or is restricted to cortical or nuclear regions is not known. The refractive index in the lens is relatively constant in the nuclear region and manifests as a gradient in the cortex.[17] To contribute to the refractive shifts reported in this study, maximal amplitude of 3.00 D (range –1.37 D to +1.62 D) in the right eye and 2.75 D (range –1.25 D to +1.50 D) in the left eye, the fluctuation in nuclear refractive index would need to be around ± 0.005[18] for nuclear refractive indices of 1.401 to 1.411.[17,19] This would, according to the Gladstone-Dale formula,[20] equate to changes in local protein concentration of around 3 mg. Given that there can be no overall loss or gain of protein but only a redistribution of protein and water in localized regions, these calculated values would be very likely to manifest as opacities by slit lamp examinations.

Because no such reduction in the clarity of the lens nucleus was found, any changes to the structure of the lens were most likely to have occurred in the cortex. A change in cortical refractive index would not require an overall increase or decrease in magnitude, but only very slight changes in the gradient sufficient to alter the refractive power to a measurable degree.[21]

The underlying causes for the refractive changes reported in this study are not clear, and it is not possible to reach any conclusions from a single case. The long-term low hyperopic shift may simply be reflecting a progression that would have occurred without HBO therapy, because such changes in presbyopes are not uncommon. However, this is the first reported case in which a hypermetropic shift has immediately succeeded a myopic shift in a patient after each of two series of HBO treatments. Any explanation needs to take into account that significant increases and decreases in ocular refractive power can occur in patients treated with a standard HBO therapy protocol without causing clinically detectable loss of lens transparency or reduction in best-corrected visual acuity.

Received May 19, 2005; accepted December 6, 2005.

REFERENCES

1. Thom SR, ed. Undersea & Hyperbaric Medical Society. Hyperbaric Oxygen Therapy: A Committee Report. Kensington, MD: Undersea and Hyperbaric Medical Society, 1999.
2. Lyne AJ. Ocular effects of hyperbaric oxygen. Trans Ophthalmol Soc UK 1978;98:66–8.
3. Anderson B Jr, Farmer JC Jr. Hyperoxic myopia. Trans Am Ophthalmol Soc 1978;76:116–24.
4. Ross ME, Yolton DP, Yolton RL, Hyde KD. Myopia associated with hyperbaric oxygen therapy. Optom Vis Sci 1996;73:487–94.
5. Fledelius HC, Jansen EC, Thorn J. Refractive change during hyperbaric oxygen therapy. A clinical trial including ultrasound oculometry. Acta Ophthalmol Scand 2002;80:188–90.
6. Evanger K, Haugen OH, Irgens Å, Aanderud L, Thorsen E. Ocular refractive changes in patients receiving hyperbaric oxygen administered by oronasal mask or hood. Acta Ophthalmol Scand 2004;82: 449–53.
7. Palmquist BM, Philipson BO, Barr PO. Nuclear cataract and myopia during hyperbaric oxygen therapy. Br J Ophthalmol 1984; 68:113–7.
8. Anderson B Jr, Shelton DL. Axial length in hyperoxic myopia. In: Bove AA, Bachrach AJ, Greenbaum LJ, eds. Underwater and Hyperbaric Physiology IX: Proceedings of the Ninth International Symposium on Underwater and Hyperbaric Physiology. Bethesda, MD: Undersea and Hyperbaric Medical Society, 1987:607–11.
9. Fledelius HC, Jansen EC. Hypermetropic refractive change after hyperbaric oxygen therapy. Acta Ophthalmol Scand 2004;82:313–4.
10. Eva PR, Pascoe PT, Vaughan DG. Refractive change in hyperglycaemia: hyperopia, not myopia. Br J Ophthalmol 1982;66: 500–5.
11. Spector A. The search for a solution to senile cataracts. Proctor lecture. Invest Ophthalmol Vis Sci 1984;25:130–46.
12. Bron AJ, Brown NAP. Lens structure and forms of cataract. Top Aging Res Eur 1986;6:3–11.
13. Giblin FJ, Padgaonkar VA, Leverenz VR, Lin LR, Lou MF, Unakar NJ, Dang L, Dickerson JE Jr, Reddy VN. Nuclear light scattering, disulfide formation and membrane damage in lenses of older guinea pigs treated with hyperbaric oxygen. Exp Eye Res 1995;60:219–35.
14. Pierscionek B, Augusteyn RC. Protein distribution patterns in concentric layers from single bovine lenses: changes with development and ageing. Curr Eye Res 1988;7:11–23.

15. Bantseev V, Oriowo OM, Giblin FJ, Leverenz VR, Trevithick JR, Sivak JG. Effect of hyperbaric oxygen on guinea pig lens optical quality and on the refractive state of the eye. Exp Eye Res 2004;78: 925–31.
16. Huang QL, Russell P, Stone SH, Zigler JS Jr. Zeta-crystallin, a novel lens protein from the guinea pig. Curr Eye Res 1987;6:725–32.
17. Pierscionek BK. Refractive index contours in the human lens. Exp Eye Res 1997;64:887–93.
18. Southall JPC. Mirrors, Prisms and Lenses: A Text-Book of Geometrical Optics, 3rd ed. New York: Macmillan, 1933.
19. Pierscionek BK. Variations in refractive index and absorbance of 670 nm light with age and cataract formation in human lenses. Exp Eye Res 1995;60:407–14.
20. Barer R, Joseph S. Refractometry of living cells. Part 1. Basic principles. Q J Microsc Sci 1954;95:399–423.
21. Pierscionek BK. Presbyopia and the effect of refractive index. Clin Exp Optom 1990;73:26–36.

Knut Evanger
Essilor Norge as, N-3601
Kongsberg, Norway
e-mail: knut.evanger@essilor.no