Effect of high-altitude exposure on myopic laser in situ keratomileusis

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ABSTRACT

**Purpose:** To study the effect of high-altitude exposure on visual acuity after myopic laser in situ keratomileusis (LASIK).

**Setting:** Aconcagua, Mendoza, Argentina.

**Methods:** In the early postoperative period after uneventful myopic LASIK, 2 physicians prospectively assessed their visual acuity during an ascent of Aconcagua (22 841 feet). The distance uncorrected visual acuity (UCVA) and peripheral oxygenation were measured at approximately every 2000 feet of altitude.

**Results:** Both climbers developed a moderate loss of distance UCVA but described normal near and pinhole acuity consistent with a myopic shift. The distance UCVA diminished to 20/100 in the right eye and 20/125 in the left eye of Climber A and to 20/160 and 20/30, respectively, of Climber B. The vision loss worsened with increased altitude, duration of exposure, and decreased peripheral oxygenation. One week after the climb, the manifest refraction demonstrated a small myopic shift in both eyes of Climber A; these subsequently resolved.

**Conclusions:** Two climbers, 8 and 14 weeks after myopic LASIK, experienced vision loss consistent with a temporary myopic shift in the refractive error with ascent to high altitude. Climbers who have LASIK, particularly those in the early postoperative period, should be prepared for visual acuity fluctuations with high-altitude exposure. J Cataract Refract Surg 2001; 27:1937–1941 © 2001 ASCRS and ESCRS
Patients and Methods

Two physician members of a team climbing Aconcagua (22 841 feet above sea level) in Argentina had uneventful LASIK correction of myopia. They completed a prospective assessment of their visual acuity at increasing altitudes during the climb. The ascent of this peak required a series of 5 camps. Climbing for acclimatization proceeded by stages, with the climbers ascending approximately 2000 feet to carry supplies and then descending to sleep. The next day, remaining supplies would be carried 2000 feet and the next camp placed. Each day therefore resulted in a gradual ascent of an average of 1000 feet. The distance vision in each eye was measured at approximately each 2000 feet of altitude gain using an eye test chart for 10 feet (#2867–1264, Graham-Field Co.) (Figure 1). Visual acuity measurements were made at approximately the same time of day in bright, ambient early afternoon light without protective sunglasses. The climbers also recorded their peripheral oxygenation using a fingertip oximeter (Nonin Onyx 9500, Nonin Medical). Peripheral oxygenation measurements accurately parallel arterial oxygen saturation within the observed ranges (J.W. Severinghaus, unpublished study). Oxygenation measurements were taken in the morning on the second day of exposure to each altitude level to allow time for adjustment to increased altitude.

Case Studies

Climber A. A 54-year-old orthopedic surgeon had bilateral LASIK on November 22, 1999, 8 weeks before the climb. The preoperative refraction was $-4.75 \times 15$ in the right eye and $-4.75 \times 2.50 \times 158$ in the left eye; the preoperative pachymetry, 573 $\mu$m and 570 $\mu$m, respectively; and the preoperative keratometry, 41.62/42.87 $\times$ 110 and 41.25/43.25 $\times$ 74, respectively. Corneal topography showed regular with-the-rule astigmatism in both eyes. An Automated Corneal Shaper® (Chiron Vision) with a 180 $\mu$m depth plate and the VISX Star S2 excimer laser were used for the LASIK procedure. The amount of stromal ablation was 57 $\mu$m in the right eye and 55 $\mu$m in the left eye.

Four days postoperatively, the uncorrected visual acuity (UCVA) was 20/20 in both eyes and the best spectacle-corrected visual acuity (BSCVA), 20/15. The refractive error was stable from the first week postoperatively. Three weeks before the climb, the manifest refraction was $-0.50 - 0.25 \times 40$ in the right eye and $-0.25$ sphere in the left eye.

The climber experienced a loss of visual acuity in the left eye beginning at 18 000 feet of ascent and in the right eye at the summit height of 22 841 feet. The visual acuity loss correlated with increasing altitude and decreasing oxygen saturation and persisted throughout the descent to sea level. A pinhole improved the visual acuity to 20/20 at both 18 000 feet and 19 800 feet. He was able to read a book during the climb without difficulty using reading glasses (1.75 diopters).

The UCVA remained blurred for several weeks after the high-altitude climb. One week after the climb, the manifest refraction was slightly increased ($-1.00 - 0.25 \times 35$ in the right eye and $-0.50 - 0.50 \times 180$ in the left eye) compared with the refraction 3 weeks before the climb. In both eyes, the UCVA was 20/40 and the BSCVA remained 20/15. Corneal examination was unremarkable, with no evidence of corneal inflammation, edema, or dryness in either eye. One month after the climb, the manifest refraction was $-0.25 - 0.25 \times 45$ in the right eye and plano $-0.50 \times 15$ in the left eye. The UCVA improved to 20/20 in both eyes. The refraction and the UCVA remained stable over 1 year.

Climber B. A 33-year-old anesthesiologist had bilateral LASIK on September 14, 1999, 14 weeks before the climb. The preoperative refraction was $-3.50 - 0.50 \times 43$ in the right eye and $-5.25$ sphere in the left eye.
eye; the preoperative pachymetry, 475 μm and 471 μm, respectively; and the preoperative keratometry, 4.00/45.12 × 104 and 43.75/45.00 × 85, respectively. A Hansatome microkeratome (Bausch & Lomb Surgical) with a 160 μm depth plate and the VISX Star S2 laser were used for the LASIK procedure. The amount of stromal ablation was 42 μm in the right eye and 61 μm in the left eye.

Six days postoperatively, the UCVA was 20/20 in both eyes and the BSCVA, 20/20. Two weeks before the climb, the manifest refraction was plano −0.75 × 73 in the right eye and plano −0.50 × 69 in the left eye.

The climber experienced a loss of visual acuity primarily in the right eye beginning at 18 000 feet; this worsened with increasing altitude and decreasing peripheral oxygenation. A pinhole improved the acuity to 20/20 even at the summit. The near vision without correction was subjectively normal in both eyes throughout the climb. All acuity loss at altitude resolved completely upon descent to sea level. After the climb, the UCVA remained 20/20 in both eyes.

Results

Measurements of peripheral oxygenation and visual acuity at each climbing level are shown in Table 1. The relationship between increasing altitude (expressed in ten thousands of feet) and visual acuity (expressed as a decimal ratio of 20/20) is shown in Figure 2. The relationship between visual acuity (expressed as a decimal ratio of 20/20) and decreasing peripheral oxygenation (expressed as a decimal figure) is shown for Climber A in Figure 3 and Climber B in Figure 4.

Discussion

Two physician climbers with prior successful myopic LASIK experienced a loss of visual acuity during the ascent to high altitude (22 841 feet). The vision loss worsened with increased altitude, duration of exposure, and decreased peripheral oxygenation. The descent improved visual acuity in both climbers at a variable rate.

Table 1. Peripheral oxygenation and visual acuity at each altitude level in both eyes of the 2 climbers.

<table>
<thead>
<tr>
<th>Day of Climb</th>
<th>Altitude Above Sea Level (Feet)</th>
<th>Clumper A</th>
<th>Clumper B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Acuity OD</td>
<td>Acuity OS</td>
</tr>
<tr>
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<td>20/16</td>
<td>20/16</td>
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<tr>
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OD = right eye; OS = left eye; O₂ Sat = percentage of peripheral oxygenation
The value of this study has been to prospectively document visual acuity deterioration that has been only casually observed and to record the recovery phase.

We propose that the etiology of the reduced vision in these 2 climbers is a myopic shift in refractive error in the post-LASIK cornea that results from hypoxia. Both climbers noted impaired distance but normal near vision and improvement in distance vision with pinhole testing, all suggesting a myopic refractive error. The severity of the distance visual loss in each climber (20/125 in Climber A and 20/160 in Climber B) corresponded to a significant amount of refractive error. A hyperopic or astigmatic shift leading to this level of visual loss would likely have blurred the near acuity as well in either climber, particularly the 54-year-old presbyopic Climber A. This climber, only 8 weeks post-LASIK, experienced substantial bilateral visual loss of longer duration than that of the 33-year-old Climber B. Subsequently, Climber A noted persistent, slowly resolving blurred distance vision for several weeks after returning to sea level. One week after the climb, the UCVA was reduced in both eyes; it was improved 3 weeks later. This further substantiates a transient myopic shift as the best explanation for the loss of distance acuity experienced by these climbers. Unfortunately, the near point of accommodation and refraction with trial lenses were not measured so the type and quantity of refractive error during the climb could not be conclusively established.

Other potential causes of reduced vision including exposure-induced corneal dryness or keratitis are less likely as they would diminish both distance and near vision. No surface anomalies were seen at the 1-week post-climb examination in Climber A despite his persistent visual loss. Anecdotally, a third physician climber on this expedition (55 year old with high myopia corrected with spectacles) with no prior refractive surgery reported no change in distance or near vision.

The consequences of altitude exposure on the LASIK cornea requires further study. Several reports indicate that a hyperopic shift in refractive error occurs in patients with prior RK following exposure to high altitudes. Mader et al. demonstrate that RK patients at high altitudes have the greatest increase in peripheral corneal thickness near the radial incisions, which appears to cause central corneal flattening. Nelson et al. show that ocular surface hypoxia (induced experimentally by 100% nitrogen atmosphere goggles) causes a myopic shift in post-LASIK eyes. Theoretically, patients with prior myopic LASIK exposed to altitude-induced hypoxia may develop a nonuniform increase in corneal thickness involving the corneal flap, which steepens the central cornea and results in the myopic shift observed in the climbers in this study.

Both climbers in this study were in the early postoperative period after myopic LASIK. Refractive stability after myopic LASIK typically occurs at 3 to 6 months. This early exposure to altitude stress may have contributed to the visual acuity fluctuation they experienced. Anecdotal reports of post-LASIK patients exposed to high altitude in the early postoperative period are conflicting. White and Mader describe a 52-year-old climber, 3 months after LASIK for high myopia, who observed a mild reduction in distance acuity, consistent with a myopic shift, after ascending to 19 500
Davidorf\textsuperscript{3} reports a 29-year-old climber who had recently had LASIK for low myopia, with no change in UCVA, refraction, or near point of accommodation after ascending to 16,000 feet. The amount of hyperopic shift during high-altitude exposure in RK patients appears to diminish with increased postoperative time.\textsuperscript{2} The consequences of altitude exposure on patients 6 months or more after myopic LASIK may also be of less magnitude.

The effect of altitude exposure on patients who have had myopic LASIK remains unpredictable and the effect after hyperopic LASIK has not been observed. Multiple factors including duration and extent of altitude exposure, the amount and type of preoperative refractive error, cold exposure effects, time since surgery, patient age, relative hypoxia, and corneal drying may influence refractive stability at extreme altitude and remain to be studied.

The visual loss experienced by these 2 climbers was unexpected and represents a potential hazard to individuals involved in high-altitude climbing. Fortunately, there was no compromise of personal safety in this instance. Anticipating an increased exposure of LASIK patients to these extremes of nature, patients should be prepared for visual acuity fluctuations and reduced vision at high-altitude exposure. Individuals who have had myopic LASIK may want to wait at least 6 months for refractive stability before high-altitude exposure. There may be some benefit in having eyeglasses of minus lens power in the event of an acute myopic shift in the refractive error. Further study will be necessary to understand these observations better.

**References**

3. Davidorf JM. LASIK at 16,000 feet (letter); reply by Mader TH, Parmley VG, White LJ. Ophthalmology 1997; 104:565–566

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None of the authors has a financial interest in any product mentioned.

Suzanne D. Dixon, MD, MPH, assisted in data analysis and manuscript preparation. Mark F. Ozog, MD, clinically assessed Climber B and Mindy E. Sterner, OD, Climber A.