Intraocular Lens Use in an Astronaut During Long Duration Spaceflight

Thomas H. Mader; C. Robert Gibson; Josef F. Schmid; William Lipsky; Ashot E. Sargsyan; Kathleen Garcia; Jeffrey N. Williams

BACKGROUND: The purpose of this paper is to report the first use of an intraocular lens (IOL) in an astronaut during long duration spaceflight (LDSF). An astronaut developed a unilateral cataract and underwent phacoemulsification with insertion of an acrylic IOL. Approximately 15 mo later he flew on a Soyuz spacecraft to the International Space Station (ISS), where he successfully completed a 6-mo mission.

CASE REPORT: Ocular examination, including ultrasound (US), was performed before, during, and after his mission and he was questioned regarding visual changes during each portion of his flight.

DISCUSSION: We documented no change in IOL position during his space mission. This astronaut reported excellent and stable vision during liftoff, entry into microgravity (MG), 6 mo on the ISS, descent, and landing. Our results suggest that modern IOLs are stable, effective, and well tolerated during LDSF.

KEYWORDS: vision, phacoemulsification, cataract.

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Since the first reported use of intraocular lenses (IOLs) in aviators in 1987,[4] there has been a gradual refinement in IOL design as well as steady improvement in the surgical technique for lens removal and IOL insertion. Subsequent studies have further documented their success in aviators.[3,11,12] Currently, IOLs may be approved for use in flight personnel in all three military services as well as the U.S. astronaut corps. Although an astronaut with bilateral polymethyl methacrylate (PMMA) IOLs successfully flew on a 10-d Space Shuttle mission in 1999,[9] this paper documents the first use of an IOL in an astronaut during a long duration spaceflight (LDSF). This brief report strongly suggests that modern IOLs are safe and effective for use in astronauts during LDSF. (Note: The data used for this report were authorized in writing by the subject.)

CASE REPORT

A 58-yr-old astronaut, with over 500 total days in space, complained of a rapid degradation in vision in his left eye over a 1–2 mo period and was diagnosed with a 3+ posterior subcapsular and 2+ nuclear sclerotic cataract. Using a 2.5-mm lateral clear corneal incision, phacoemulsification was performed in his left eye followed by the insertion of a foldable 6-mm one-piece acrylic IOL within the capsular bag. His postoperative course was without complications. His postoperative dilated ocular examination documented a stable posterior chamber intraocular lens and his uncorrected distance visual acuity was 20/10. He flew on a 6-mo mission on the ISS 15 mo after this surgery.

His final prelaunch (L-2 mo) eye exam revealed a well-positioned IOL and clear capsule OS with visual acuity corrected to 20/20 in the right and 20/10 in the left with a refraction of OD: +0.75–1.00 × 090 and OS: Plano. IOP by Goldmann tonometry was 16 mmHg OU. His stereopsis, color vision, fundus photography (Canon CR-2 Plus AF, Melville, NY), and optical coherence tomography (OCT) (Heidelberg Engineering, Heidelberg Spectralis, Heidelberg, Germany) were normal. Inflight visual acuity (corrected and uncorrected-distant and near), tonometry by Tono-Pen AVIA (Reichert Technologies, Buffalo,

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NY), and fundus photography (OIS Eye Scan, Sacramento, CA) performed at launch + 30 d (L+30), L+90, and L+140 on the ISS remained unchanged from preflight throughout the entire mission. His IOL position, as documented by US (Vivid q Ultrasound with L12-5 linear array probe, Chicago, IL), remained unchanged during his mission (**Fig 1**). During his flight we documented a trace increase in the thickness of the retinal nerve fiber layer and choroid OU as measured by onboard Spectralis OCT. Postflight examination revealed no change in all the above parameters compared to preflight 2 d after returning to Earth.

DISCUSSION

British WWII aviators were the first known recipients of intraocular PMMA, also known as Plexiglas.[1] During the Battle of Britain in 1940, the Plexiglas canopies of British Hurricane and Spitfire fighter aircraft were sometimes shattered by gunfire from enemy aircraft and small plastic fragments became lodged within the eyes of the pilots. These plastic splinters were carefully monitored, some for as long as 8 yr post-injury, and observed to promote no inflammation.[1] This observation, made by the British ophthalmologist Harold Ridley (later to become Sir Harold Ridley), initiated the concept of replacing an opacified natural lens with an inert intraocular PMMA lens of the proper size and power to permanently restore vision. Harold Ridley was the first to surgically implant an IOL in a human in 1949.[1] The IOL inserted was a thick, biconvex disc fabricated from PMMA. Although there were initial setbacks from IOL decentration and power miscalculations, this procedure set the stage for the gradual evolution of IOL design and associated surgical techniques. In the 1980s, as a result of the established success of IOLs in the general population, the American military and the FDA began to allow waivers for the use of IOLs in flight personnel during terrestrial flight. The first description in the medical literature of IOL use in pilots was reported by the U.S. Army in 1987.[4] In 1991 an Israeli Air Force F-15 pilot was followed for 3 yr after IOL surgery.[3] During 100 h of flying time he suffered no IOL dislocation or other complications even with acceleration forces of up to +9 g. Documentation of IOL stability and utility in these aviators led to the first use of IOLs in an astronaut during a 10-d Space Shuttle flight in 1999.[9] In further support of IOL stability, in 2002, a U.S. Air Force pilot with an implanted IOL successfully ejected from a high performance military aircraft and sustained no IOL related damage to his eye.[12] It should be noted that any degree of natural lens dislocation or zonular compromise is disqualifying for astronaut selection. Furthermore, as part of the waiver process for pseudophakic astronauts, IOLs are carefully examined for clarity, centration, and stability.

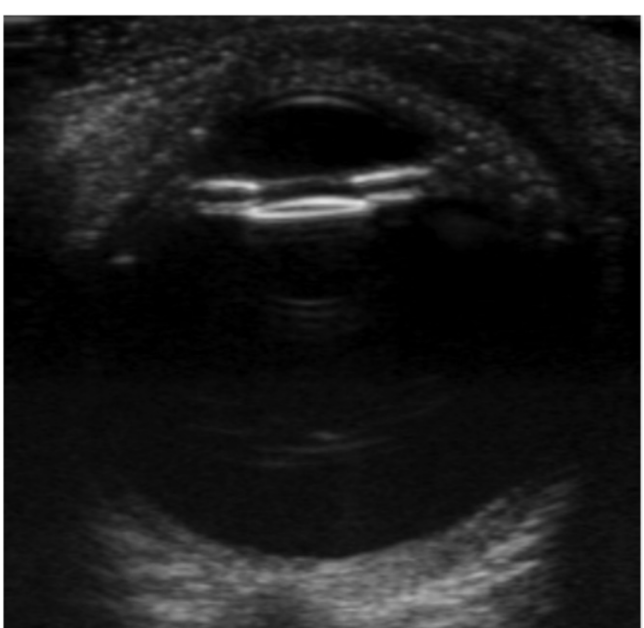

Fig. 1. In-flight (L+90) ultrasound image showing a stable, well positioned IOL.

Launch, entry into MG, and long-term MG exposure create unique physiological and anatomic changes within the eye that could impact an IOL. Each Soyuz crewmember lies in a customized, form-fitted seat liner on his back in the fetal position during launch and landing. The liner includes a head rest that helps stabilize head motion. For the referenced 6-mo mission, our astronaut was launched into space on a Russian Soyuz rocket and reported no visual difficulties or IOL displacement, as documented by US, associated with vibrations or +4 G_x (eyeballs in) forces that occur during the approximately 8 to 9 min between liftoff and transition into MG. It is important to note that previous head down bed rest[10] and transient MG studies during parabolic flight[5] documented a rise in intraocular pressure (IOP) during the first 20 s of simulated MG exposure thought to be caused by choroidal expansion. IOP elevation has also been documented in the first hours of Space Shuttle flights.[2] This rise in IOP appears to exist for several days in flight and thereafter returns to normal. Since choroidal expansion has also been documented by OCT throughout a space mission with no long-term increase in IOP, it is theorized that the anterior chamber or another volume compartment within the rigid globe must decrease in volume.[5,10] One initial concern of IOL use in MG was that perhaps this choroidal expansion could, in some astronauts, lead to a chronic low grade anterior force that might cause a forward displacement of the IOL and resultant visual changes. However, visual stability during the previously described 10-d Space Shuttle flight suggested that short duration spaceflight had no impact on IOL position.[9] Our current report documents no visual anomalies in this astronaut during launch, entry into MG, or 6 mo of MG exposure, as well as stable IOL position as confirmed by in-flight US.

This astronaut also experienced no visual changes during his approximately 10-min reentry descent in the Soyuz module that reached a deceleration of more than +4.0 G_x (eyeballs in) or during the parachute assisted module landing in Kazakhstan.

The 20–25-s parachute opening sequence and module landing have deceleration spikes somewhat higher than the relatively steady deceleration of reentry. Additionally, the off-center geometry of the parachute riser attachment to the capsule combined with the capsule roll rate of $13° \cdot s^{-1}$ induce additional lateral accelerations during parachute deployment. Dilated slit lamp examination and US confirmed no postflight change in IOL position.

Long duration spaceflight may also create a spectrum of ocular changes, including disc edema, globe flattening, choroidal folds, and a hyperopic shift in refraction.[6–8,] This shift in refraction, which may continue for years post-mission, is thought to occur largely as a result of globe flattening during LDSF. Some astronauts, as exemplified by this report, have no measurable refractive change while others may have a diopter or more of hyperopic shift.

Excellent vision during launch, entry into MG, 6 mo of spaceflight, re-entry, and landing in this astronaut suggests that the low mass and firm fixation of a modern IOL protect it from displacement. Our current report describes the first use of an IOL during a 6-mo space mission and strongly suggests that IOLs are safe, effective, and well tolerated for use in astronauts during LDSF and may extend the flight careers of astronauts with lens opacities.

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