THE VISUAL IMPAIRMENT INTRACRANIAL PRESSURE SYNDROME IN LONG DURATION NASA ASTRONAUTS: AN INTEGRATED APPROACH


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INTRODUCTION

The Visual Impairment Intracranial Pressure (VIIP) syndrome is currently NASA’s number one human spaceflight risk. The syndrome, which is related to microgravity exposure, manifests with changes in visual acuity (hyperopic shifts, scotomas), changes in eye structure (optic disc edema, choroidal folds, cotton wool spots, globe flattening, and distended optic nerve sheaths). In some cases, elevated cerebrospinal fluid pressure has been documented postflight reflecting increased intracranial pressure (ICP). While the eye appears to be the main affected end organ of this syndrome, the ocular affects are thought to be related to the effect of cephalad fluid shift on the vascular system and the central nervous system. The leading hypotheses for the development of VIIP involve microgravity induced headward fluid shifts along with a loss of gravity-assisted drainage of venous blood from the brain, both leading to cephalic congestion and increased ICP. Although not all crewmembers have manifested clinical signs or symptoms of the VIIP syndrome, it is assumed that all astronauts exposed to microgravity have some degree of ICP elevation in-flight. Prolonged elevations of ICP can cause long-term reduced visual acuity and loss of peripheral visual fields, and has been reported to cause mild cognitive impairment in the analog terrestrial population of Idiopathic Intracranial Hypertension (IIH). These potentially irreversible health consequences underscore the importance of identifying the factors that lead to this syndrome and mitigating them.

Suspected pathophysiological mechanisms leading to VIIP clinical manifestations.
1) Cephalad fluid shifts and loss of gravity assisted venous drainage from the brain leads to:
2) Increased ICP, which is manifested with:
3) Structural and functional changes to the eye.

Current U.S. ISS VIIP Incidence:
- 51 U.S. ISS astronauts missions:
  - Unclassified astronauts: 15 (15%); ORBIT, OCT or other US
  - Known cases: N = 9 (18%)
  - Confirmed cases: N = 2 (7%)
- Classification of cases:
  - Class One: 6%, Class Two: 10%, Class Three: 6%, Class Four: 11%
- Current VIIP Incidence as a % of U.S. ISS astronauts tested: 7%

The integrated VIIP program that has been developed includes efforts to decrease environmental contributing factors such as elevated carbon dioxide levels onboard the ISS and sodium levels in space foods (operational efforts), development of Clinical Practice Guidelines for guiding diagnosis and treatment of affected crewmembers (clinical efforts), data mining of previously collected data to find patterns of susceptibility to VIIP development (occupational surveillance efforts), and a research program which includes flight studies, bed rest studies, animal studies, and studies on analogous terrestrial populations to elucidate the underlying mechanisms leading to VIIP, evaluate technologies to allow safe invasive and noninvasive intracranial pressure measurements, and test potential countermeasures (research efforts).

The operational and research communities at NASA are working collaboratively in an effort to understand the mechanisms causing the VIIP syndrome and to provide mitigation and countermeasures. The Medical Operations division (MedOps) has instituted extensive preflight, in-flight and postflight testing as part of occupational surveillance. Pre- and postflight tests include functional eye exams (vision testing), structural eye exams (fundoscopy, ocular ultrasound, optical coherence tomography [OCT] and biomicroscopy), intracranial pressure (tonometry), and eye, brain, and cerebrovascular anatomy via magnetic resonance imaging (MRI). The Ocular Health study, a prospective investigation, aims to define the temporal pattern for the appearance of signs and symptoms, delineate the association between duration of weightlessness and severity of symptoms (i.e., the dose-response), establish preflight baseline characteristics, characterize the nature of in-flight changes, and document changes from pre to postflight. The study expands upon inflight medically required data collection with the addition of additional time points, cardiovascular compliance (via ultrasound with concurrent ECG and blood pressure), and noninvasive intracranial pressure (via pulsatility index, measured by transcranial Doppler [TCD]).