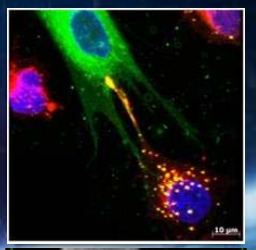
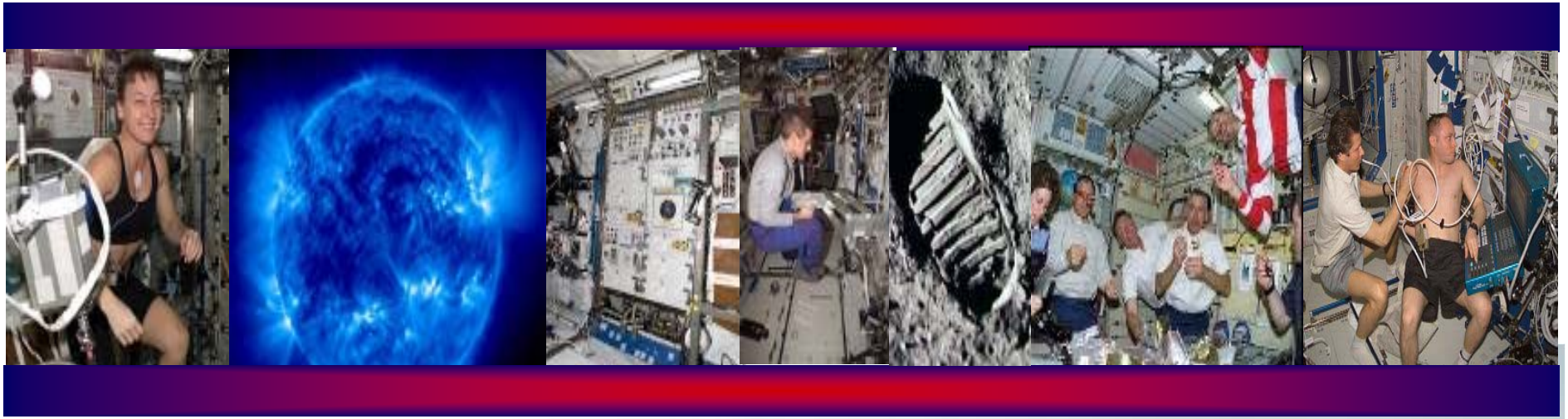
National Aeronautics and Space Administration

Human Research Program






Jennifer Villarreal
August 2014



The goal of the Human Research Program is to provide human health and performance

knowledge,

countermeasures,

technologies, and

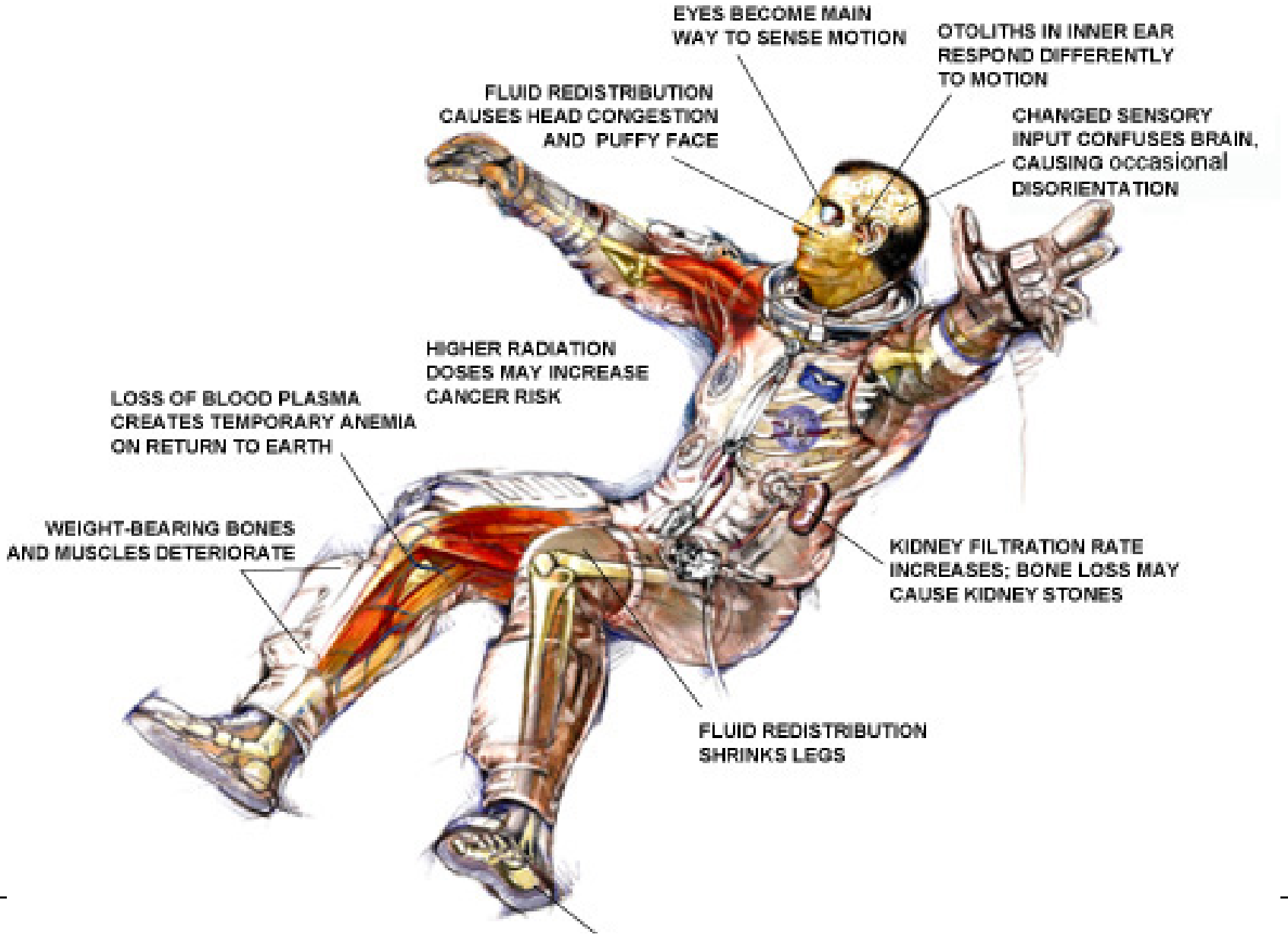
tools

to enable safe, reliable, and productive human space exploration.

Ocular Health in ISS Crews

NASA Human Research Program

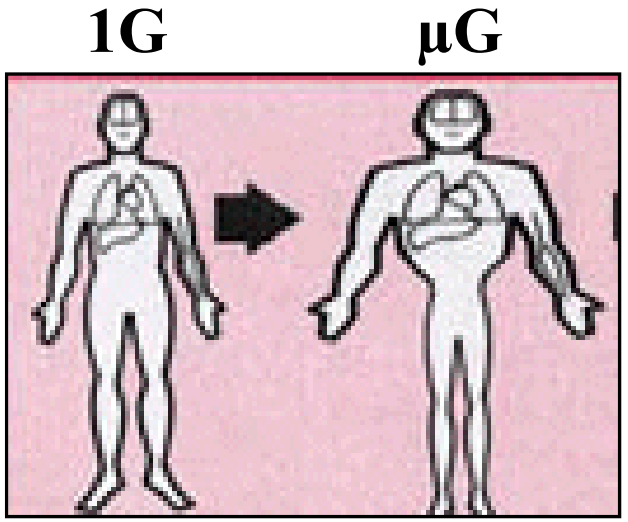
Jennifer Villarreal, M.S.E.



What is VIIP?

The Visual Impairment Intracranial Pressure (VIIP) syndrome

- NASA's number one human spaceflight risk
- Related to microgravity exposure
- Characterized by changes in eye structure, visual acuity, and ↑ intracranial pressure (ICP)



Leading hypotheses

- Microgravity → Headward fluid shift and loss of gravity-assisted drainage of venous blood from brain
- Leads to increased ICP

Potential consequences of prolonged ↑ ICP

- Long-term ocular structural changes
- Reduced visual acuity
- Mild short-term memory impairment (reported in an analog terrestrial population)

Ocular Health in ISS Crews

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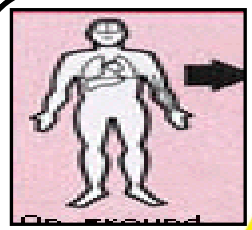
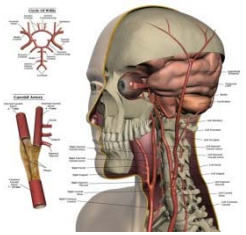
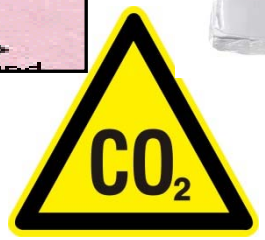
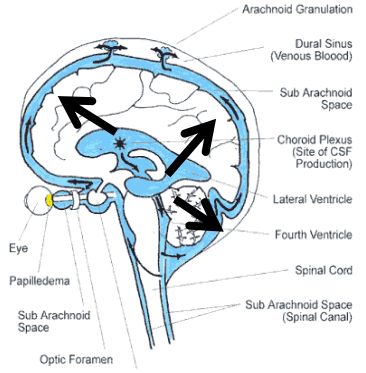
1. Contributing factors





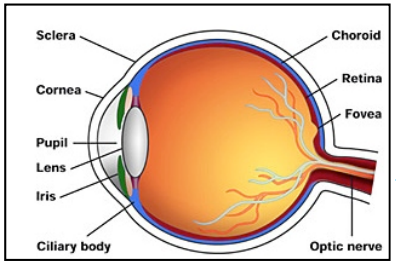


2. Intracranial pressure (ICP) ↑



3. Elevated ICP & fluid shift affect the eye

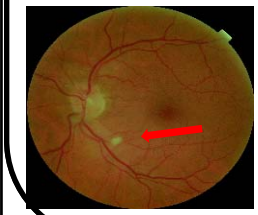
Hyperopic Shifts
Up to +1.75 diopters



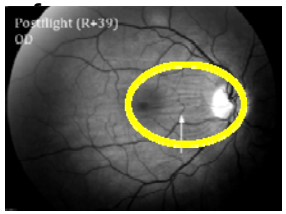
+ICP

Increased Optic Nerve Sheath

"Cotton wool" Spots - Altered blood flow



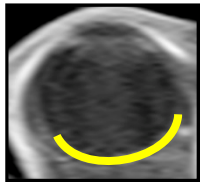
Choroidal Folds
Ridges in back



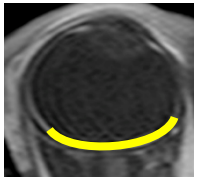
Optic Disc Edema (Swelling)

Scotoma
Abnormal visual field

Globe Flattening



Normal Globe



Flat Globe

Current U.S. ISS VIIP Incidence

45 U.S. crewmembers completed ISS missions (as of Feb. 2014):

- First 16 crewmembers not evaluated (no MRI, OCT or ocular ultrasound)
- Latest 29 crewmembers evaluated:
  - Non-cases N=8
  - **Confirmed cases N=21**

Clinical Practice Guidelines (CPG) classification for the 21 cases:

- CPG Class One N=2
- CPG Class Two N=13

} 71.2 % Class 1&2

- CPG Class Three N=2
- CPG Class Four N=4

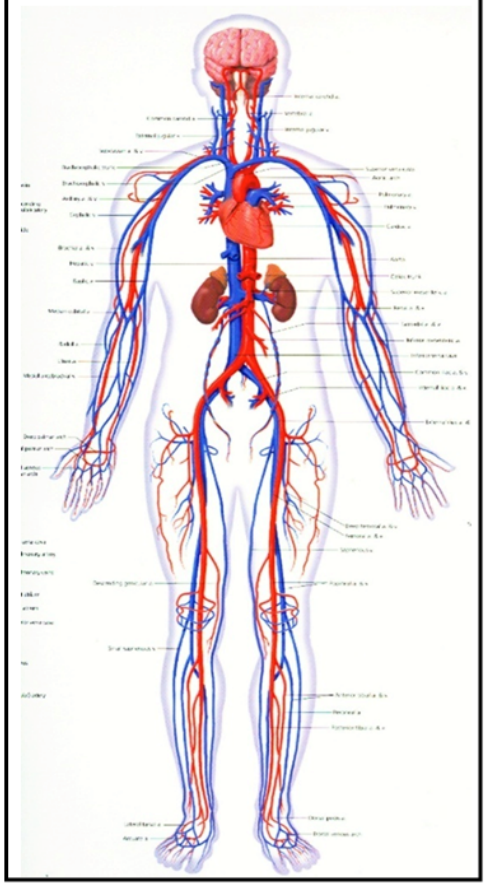
} 28.6 % Class 3&4

↓ Increasing severity

Current VIIP Incidence as a % of U.S. ISS crew tested= 72.4%

Systems Affected in VIIP:

1. The Vascular System



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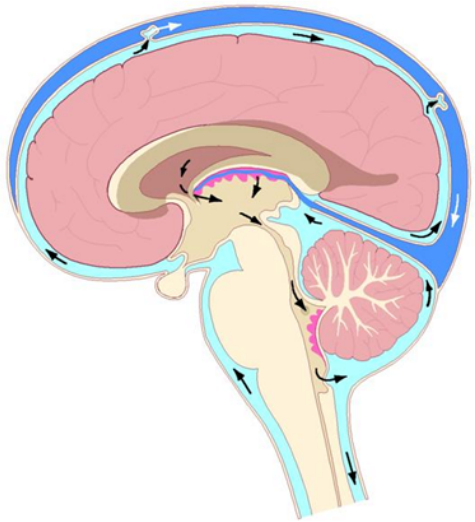
2. The Brain



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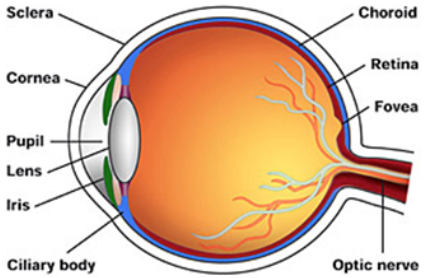
3. The Eye



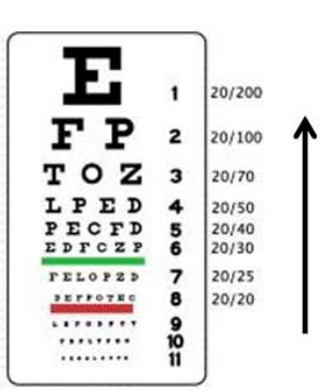
Data mining in ISS crew reveals correlations between cardiovascular variables & VIIP severity

Cardiovascular Variable	Significant Correlation Across CPG Classification
Biochemistry:	
LDL	√
HDL	-
Triglycerides	-
Hemoglobin A1c	√
Fasting serum glucose	√
Homocysteine	√
Body Composition:	
Body Mass Index	√
Percentage Body Fat	√
Cardiac:	
Resting blood pressure (pre-in-post flight)	√
Pulse Pressure (pre-in-post flight)	√
CT Coronary Calcium Score	-
Aerobic Capacity:	
Decreased Maximal Oxygen Uptake	√

Initial Identification of VIIP: Changes in Vision

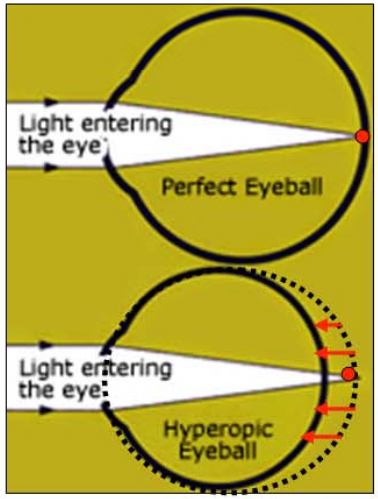
- 50% of long- duration (ISS) mission astronauts report a subjective degradation in vision, primarily increasing *farsightedness*
- ***Hyperopic shift***

Decreased near visual acuity, distant vision intact



(1mm decrease in axial length is equivalent to a 3 diopter hyperoptic shift)

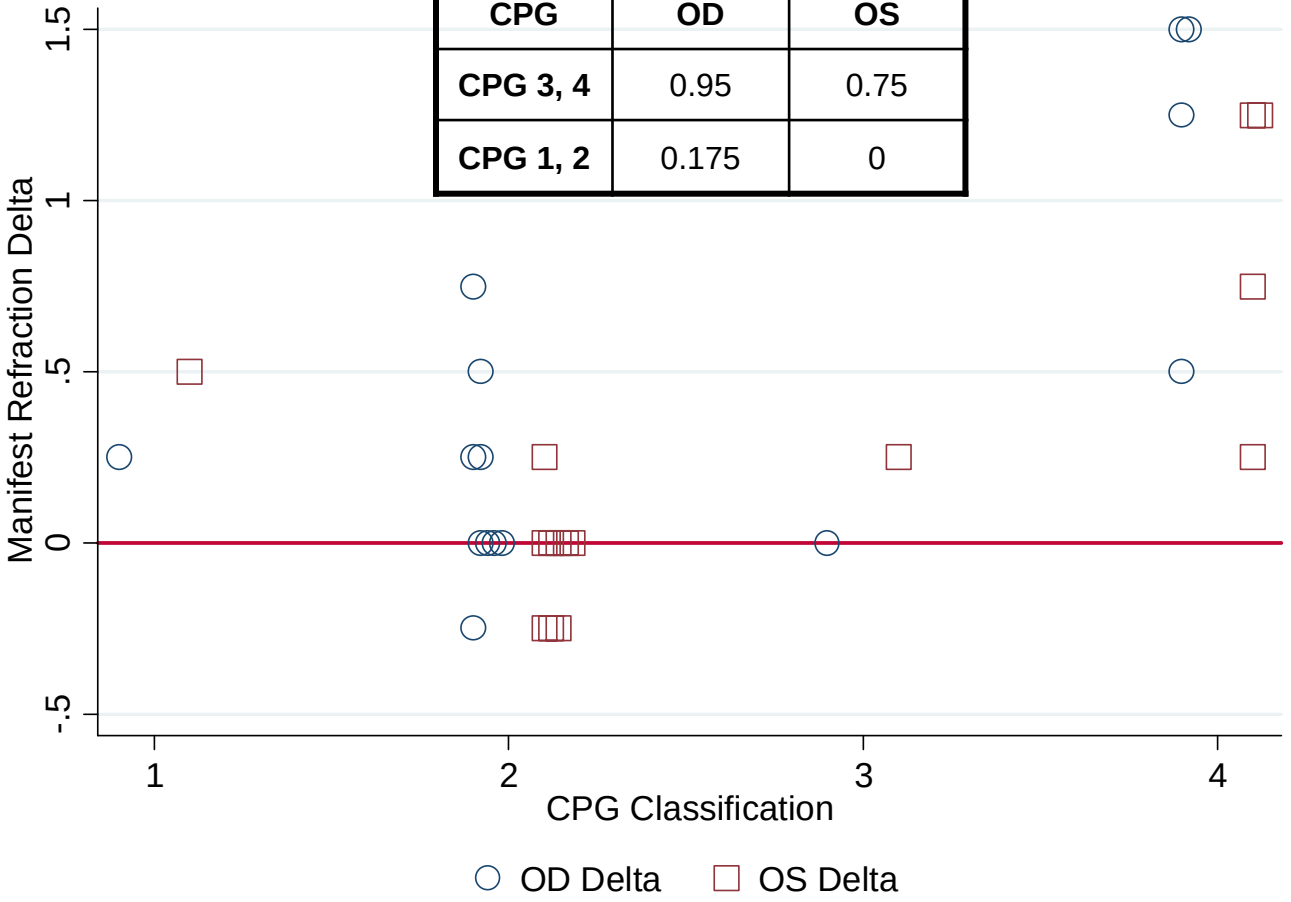
Normal Eye



Hyperopic Eye

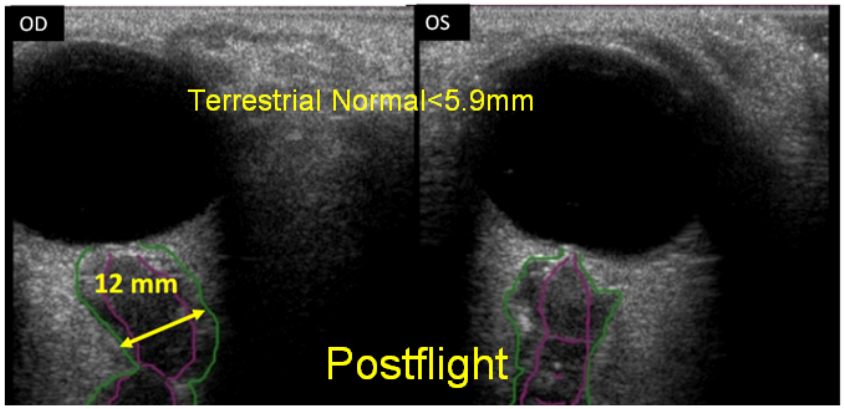
Refractive Change in Diopters: ISS Preflight to Postflight vs CPG Class

Mean Diopter Change per CPG		
CPG	**OD**	**OS**
CPG 3, 4	0.95	0.75
CPG 1, 2	0.175	0

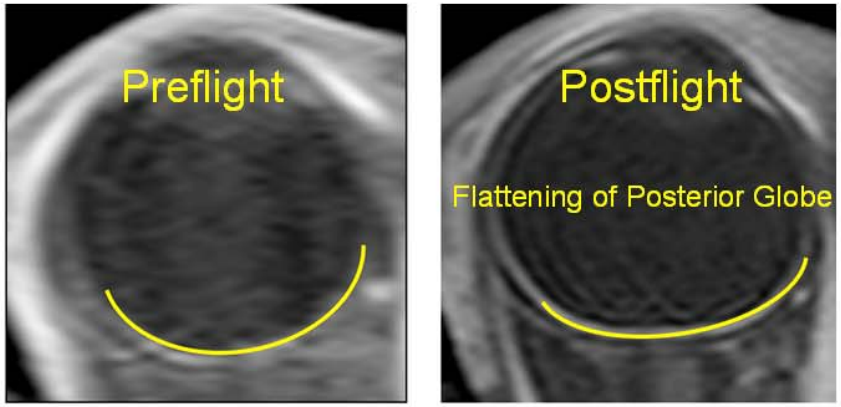


ISS Inflight Crew Ultrasound Imaging: Signs of Raised Intracranial Pressure

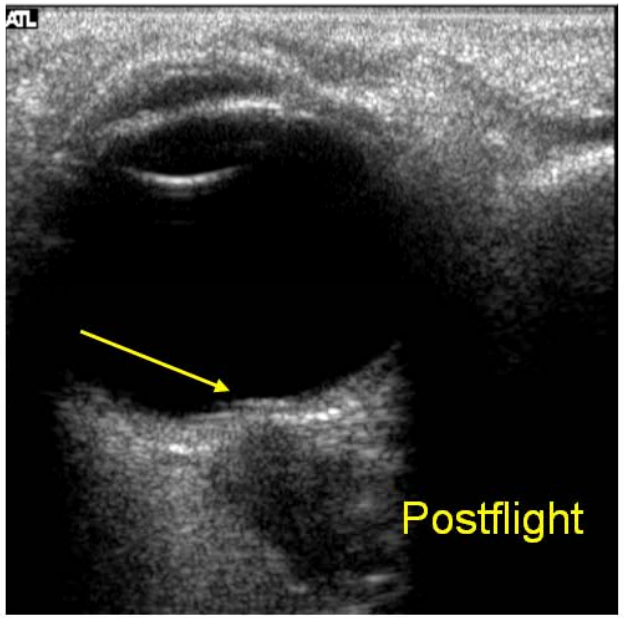
1. Increased Optic Nerve Sheath Diameter



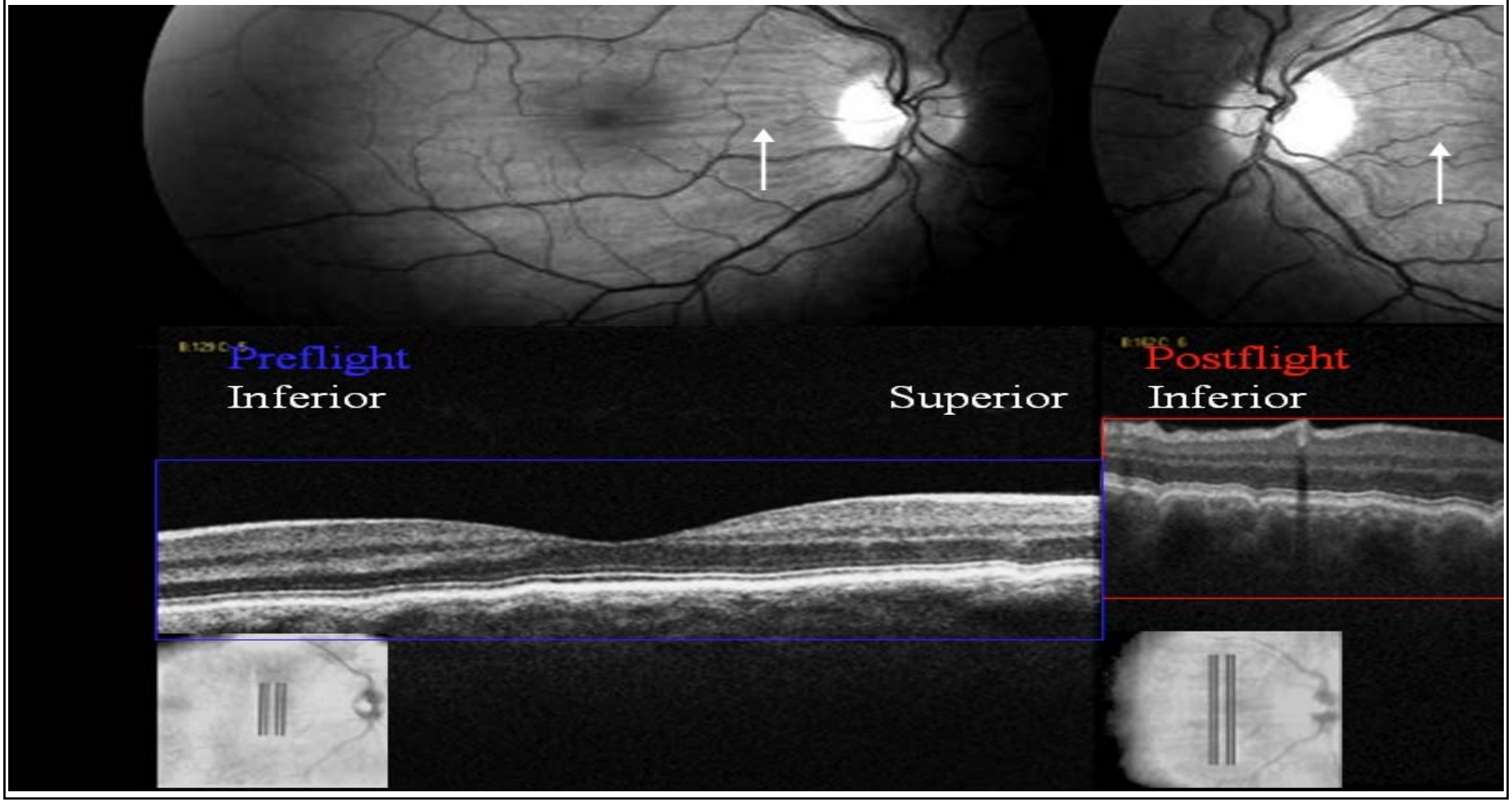
2. Posterior Globe Flattening



3. Raised Optic Disc



Fluid Shift, Venous Congestion & the Formation of Choroidal Folds

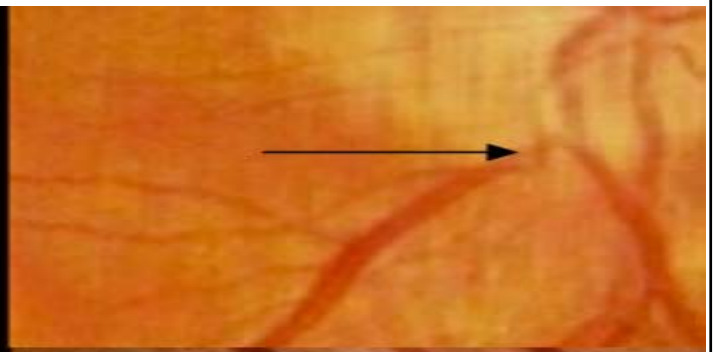


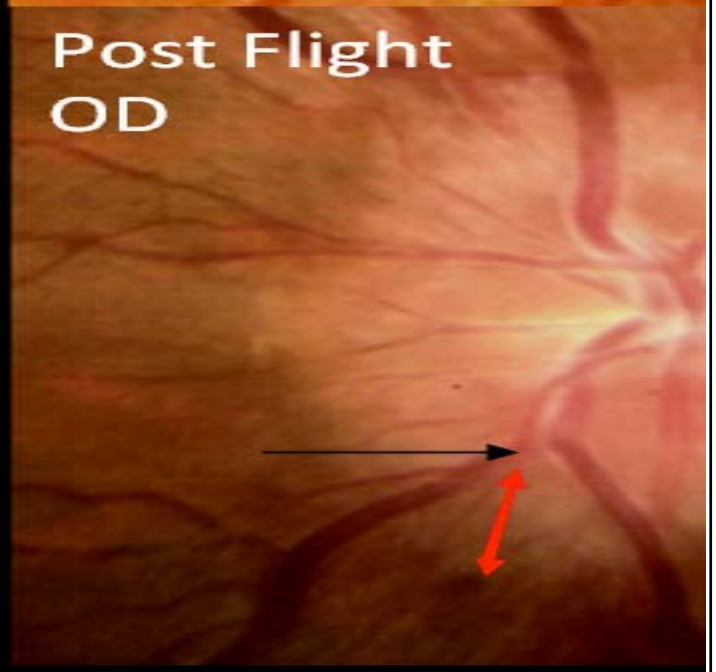
Pre to Postflight Disk Edema: A Clinical Sign of Raised Intracranial Pressure

sc.

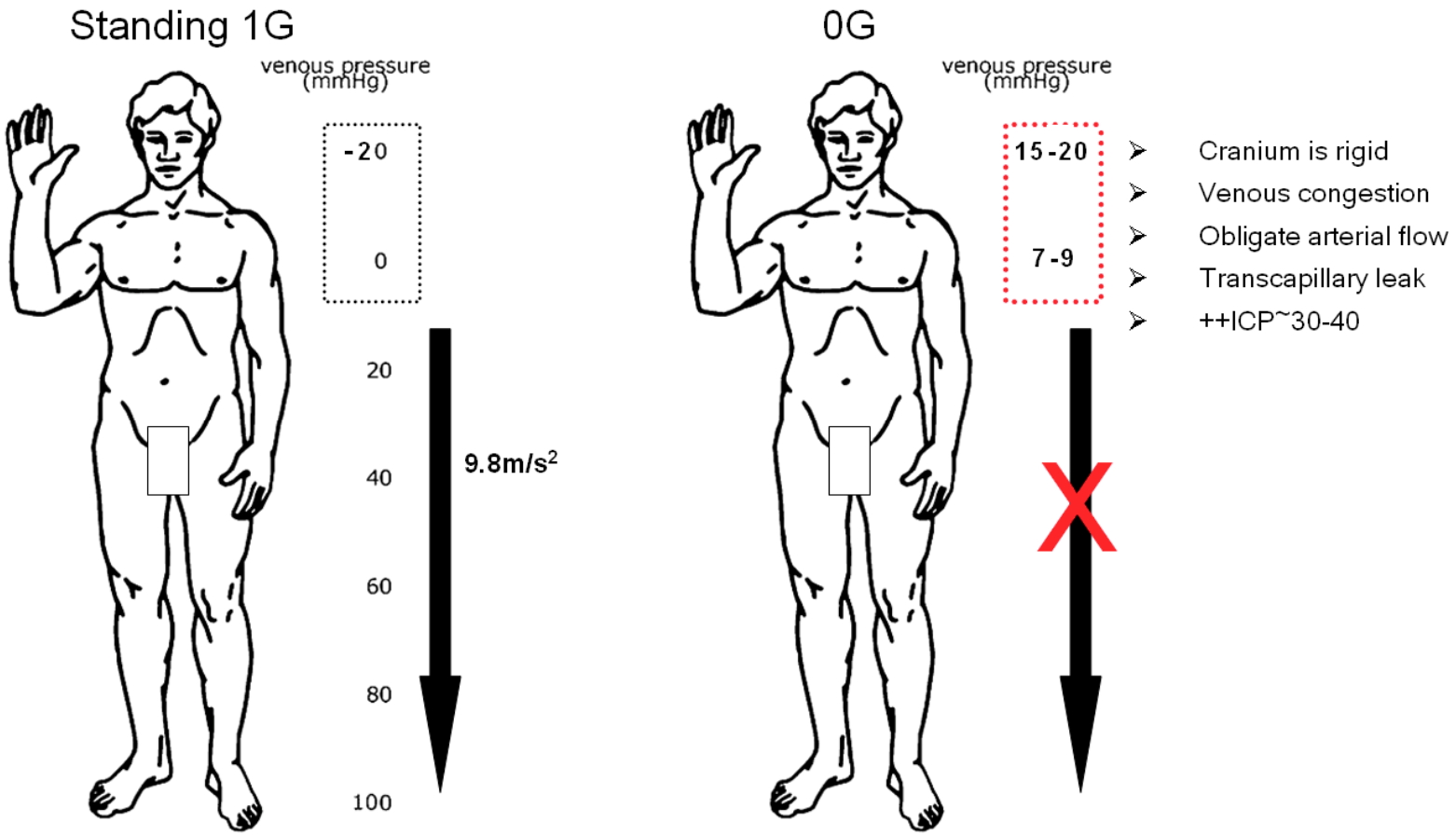
Post Flight

ndoscopic images of
e right and left optic
c showing **Grade 3**
ema right and **Grade**
edema left .



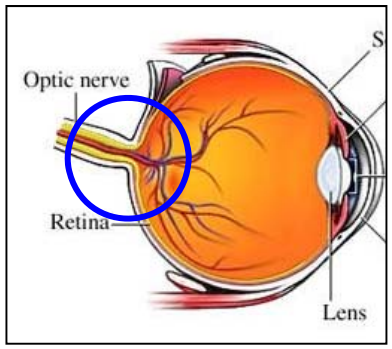


Redistribution of Venous Pressures From 1G to 0G

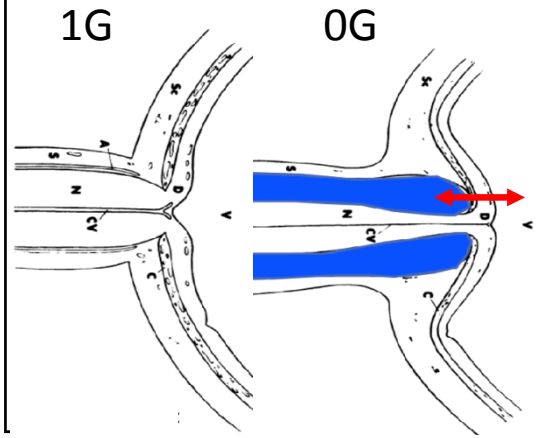


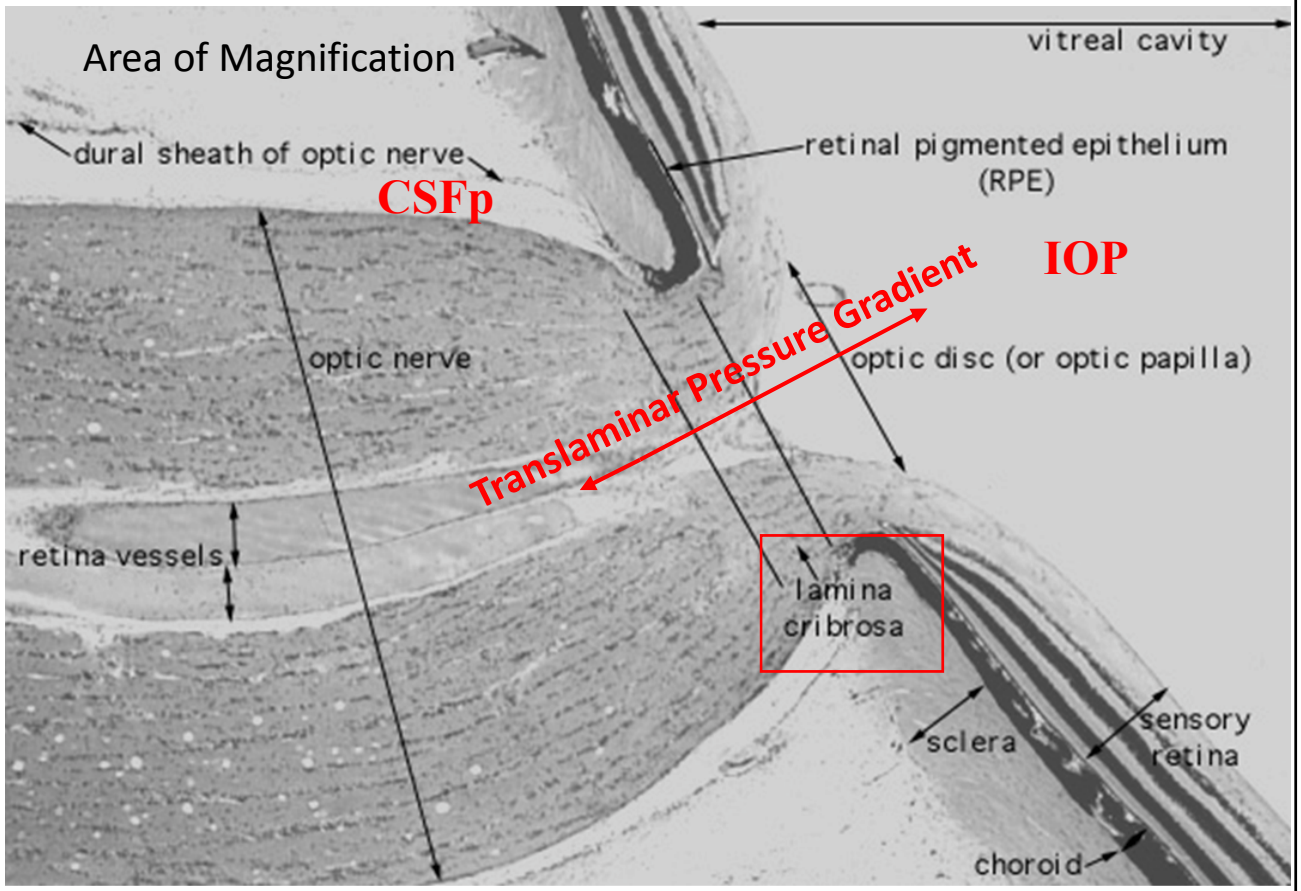
The Lamina Cribosa & the Translaminar Pressure Gradient: A Mechanism for Papilledema

Area of Interest:



Translaminar Pressure Gradients:





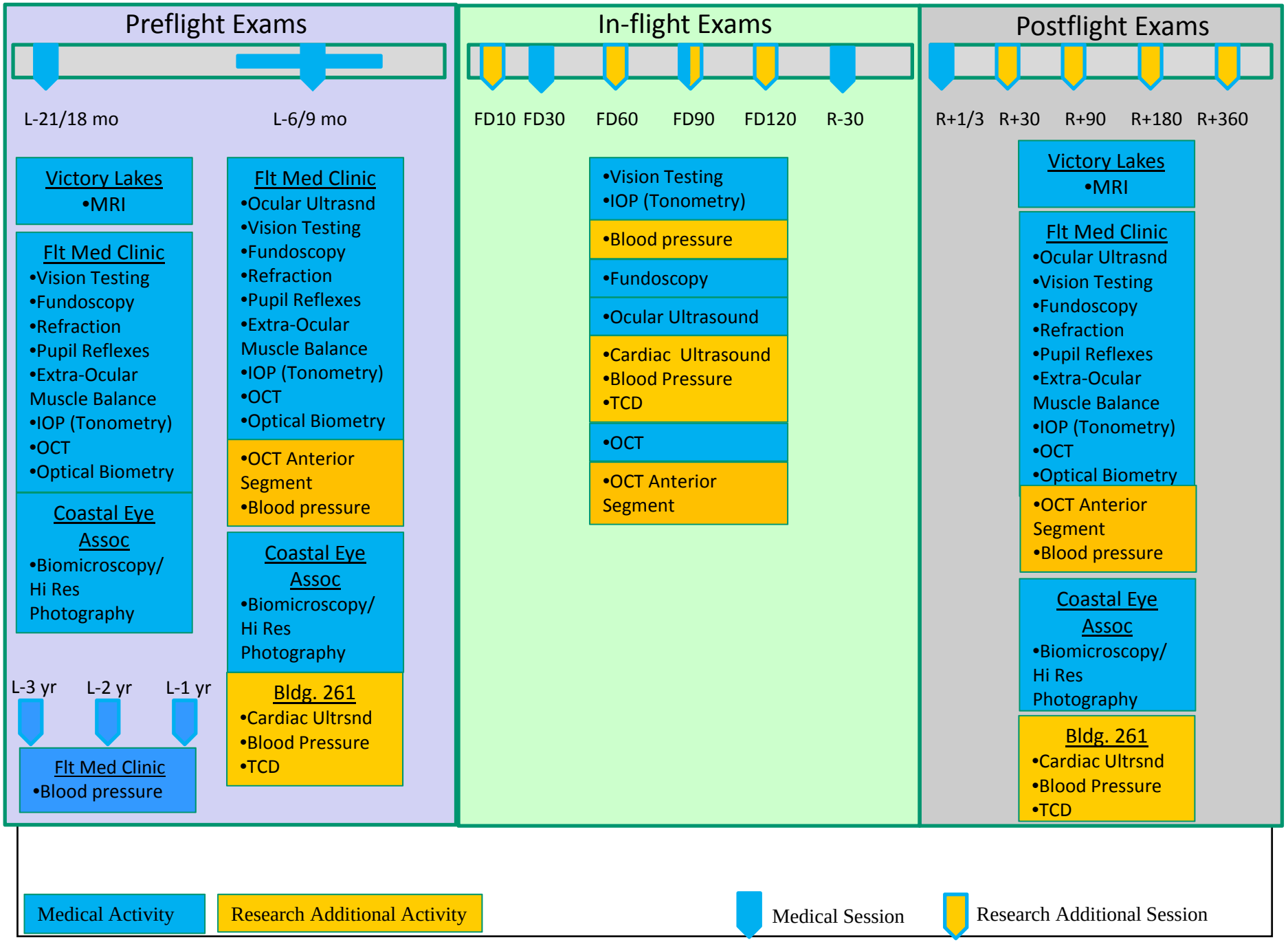
Potential Long Term Consequences of VIIP

1. Hyperopic shift in vision resulting in decreased near visual acuity requiring correction
2. Development of scotoma (blind spot) due to cotton wool spot (retinal infarction) resulting in direct operational impact
3. Peripheral vision loss, initially undetected until threshold of 50% loss occurs
4. Persistent elevation in ICP postflight
5. Neurocognitive changes:
   - Association between chronically elevated ICP and white matter changes i.e. degenerative changes. Due to inability to adeqautely clear toxic metabolites secondary to CNS metabolism such as amyloid and beta proteins
6. Dose response effect appears to be present, and may be higher in susceptible individuals
   - E.g. cohort of Shuttle-only flyers found to have grade 1-2 VIIP signs postflight
7. Higher risk, greater consequences likely on longer exploration missions (*dose-response*)

Ocular Health Study Rationale & Aims

1. **The current frequency of crew medical testing is insufficient to:**
   a) Define the temporal sequence for the appearance of signs and symptoms in-flight and resolution of signs and symptoms postflight
   b) Identify whether VIIP signs and symptoms recover postflight and determine the impact of prolonged changes on crew health
   c) Delineate the interaction between duration of weightlessness and severity of symptoms, i.e. the dose-response
   d) Outline the mechanism for the VIIP syndrome to aid in the development of protective countermeasures and treatments

2. **Data from this study will:**
   a) Improve the understanding of VIIP incidence, signs, symptoms, susceptibilities, and timeline for development and recovery
   b) Guide development of countermeasures and targeted treatments to prevent VIIP and its complications


Preflight Exams
L-21/18 mo
L-6/9 mo
Victory Lakes
•MRI
Flt Med Clinic
•Vision Testing
•Fundoscopy
•Refraction
•Pupil Reflexes
•Extra-Ocular Muscle Balance
•IOP (Tonometry)
•OCT
•Optical Biometry
Coastal Eye Assoc
•Biomicroscopy/ Hi Res Photography
Flt Med Clinic
•Ocular Ultrasnd
•Vision Testing
•Fundoscopy
•Refraction
•Pupil Reflexes
•Extra-Ocular Muscle Balance
•IOP (Tonometry)
•OCT
•Optical Biometry
•OCT Anterior Segment
•Blood pressure
Coastal Eye Assoc
•Biomicroscopy/ Hi Res Photography
L-3 yr
L-2 yr
L-1 yr
Flt Med Clinic
•Blood pressure
Bldg. 261
•Cardiac Ultrsnd
•Blood Pressure
•TCD
In-flight Exams
FD10
FD30
FD60
FD90
FD120
R-30
•Vision Testing
•IOP (Tonometry)
•Blood pressure
•Fundoscopy
•Ocular Ultrasound
•Cardiac Ultrasound
•Blood Pressure
•TCD
•OCT
•OCT Anterior Segment
Postflight Exams
R+1/3
R+30
R+90
R+180
R+360
Victory Lakes
•MRI
Flt Med Clinic
•Ocular Ultrasnd
•Vision Testing
•Fundoscopy
•Refraction
•Pupil Reflexes
•Extra-Ocular Muscle Balance
•IOP (Tonometry)
•OCT
•Optical Biometry
•OCT Anterior Segment
•Blood pressure
Coastal Eye Assoc
•Biomicroscopy/ Hi Res Photography
Bldg. 261
•Cardiac Ultrsnd
•Blood Pressure
•TCD
Medical Activity
Research Additional Activity
Medical Session
Research Additional Session

Ocular Health in ISS Crews

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Inflight Tests – Flight Day 10, 30, 60, 90, 120, R-30

Fundoscopy – 85 minutes per session

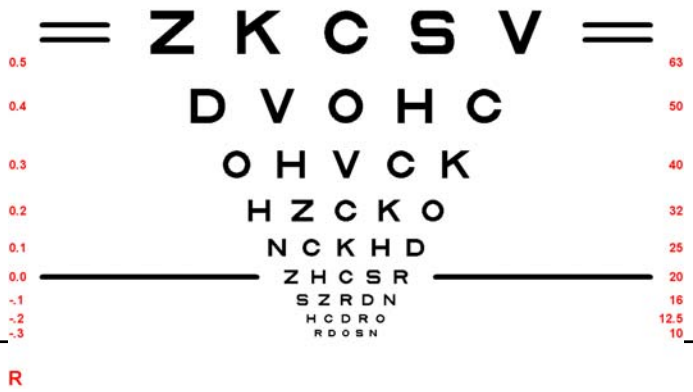
- Fundoscopy will take images and video clips of the eye.
- Crew will set up fundoscope and video camera, dilate the subject's eyes, and perform the fundoscopy exam.

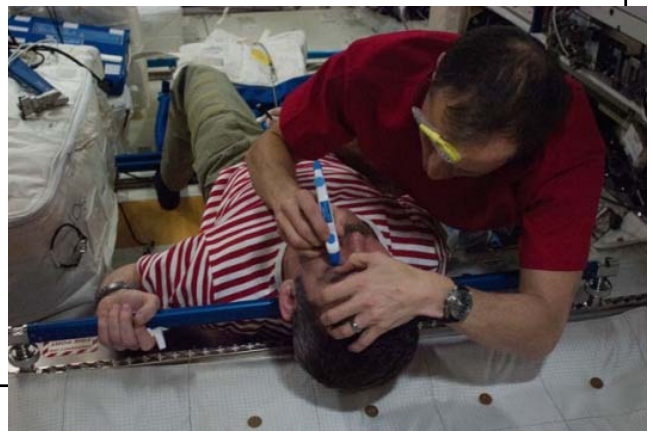
Tonometry with Blood Pressure – 80 minutes per session

- Tonometry will measure the subject's intraocular pressure.
- Crew will setup the Tonometer and video camera, and numb the subject's eyes.
- Operator will take the subject's blood pressure after five minutes of quiet rest, and then perform the tonometry exam.

Visual Testing – 50 minutes per session

- Subject will perform standard computer-based visual tests including Visual Acuity, Amsler Grid, Contrast Sensitivity, and a vision questionnaire.





Inflight Tests – Flight Day 10, 30, 60, 90, 120, R-30

Ocular Ultrasound, Vascular Compliance, & Transcranial Doppler – 250 min/session

- Subject will perform ocular ultrasound, vascular compliance (cardiac ultrasound, ECG, blood pressure), and Transcranial Doppler exams.
- Blood pressure measurement taken prior to the cardiac ultrasound.

Optical Coherence Tomography (OCT) – 185 minutes/session

- OCT exam will capture images of the retina and optic nerve. Operator and remote guidance are required.
- Crew will setup OCT Camera and Spectrometer on the MWA, configure the OCT Laptop software, and perform exam.

Experiment Summary

The Ocular Health study will systematically collect physiological data from ISS crewmembers to:

- Provide a greater understanding of the causes and effects of changes to the eye and brain resulting from the space environment
- Define individual susceptibilities
- Develop preventive and treatment strategies for use before, during and after spaceflight.

Terrestrial Benefits:

- The VIIP syndrome has similarities to terrestrial medical conditions such as glaucoma, Normal Pressure Hydrocephalus, Idiopathic Intracranial Hypertension, and high-altitude related illnesses
- Advances in the tools, techniques, and countermeasures that NASA develops in its VIIP research will benefit these terrestrial clinical populations
- Identifying the cause(s) and risk factors for the VIIP syndrome will also inform the cause(s) and risk factors for these terrestrial conditions.

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Improved Diagnostic Tools on Space Station

Ocular Health in ISS Crews	NASA Human Research Program
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How Heidelberg Engineering Helps

Extraordinary Effort Exceeds Expectations

- Early delivery
- Solved microgravity incompatibility with alternate XYZ Stage configuration
- Performed vibration testing of camera & power box to optimize schedule
- Solved laptop interface challenge with softward mods (Danke Tilman Otto!)
- Excellent training and proactive problem resolution planning (Danke Roland Dosch!)
- Extra training, problem resolution, operational support (Danke Steve Thomas!)
- Responsive technical and logistical support (Danke Tom Tomasso!)
- Knowledgable and flexible sales support including loaner units (Danke Andy Lackey and Ali Trafreshi!)
- And special thanks to Gerhard Zinser, the driving spirit behind it all!

Ocular Health in ISS Crews

NASA Human Research Program

Jennifer Villarreal, M.S.E.

North Sea, Germany, Denmark, and south Scandinavia in a photo taken by the Expedition 27 crew aboard the International Space Station

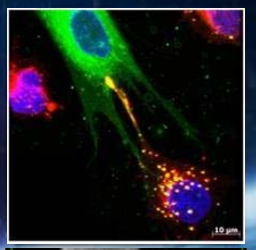
European Space Agency astronaut Luca Parmitano, Expedition 37 flight engineer, during Optical Coherence Tomography (OCT) setup in the Node 2 module of the International Space Station

What's next?

National Aeronautics and Space Administration

The National Aeronautics and Space Administration recognizes and thanks Heidelberg Engineering for their outstanding contribution to the international space program, exemplary customer service and technical support.






Jennifer Villarreal
August 2014