NASA's Visual Impairment & Intracranial Pressure Risk: Utilizing the ISS for Risk Reduction

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1St Annual ISS Research & Development Conference
Denver Marriot City Center, CO
Tuesday June 26, 2012.

VIIP Clinical Findings

- To date 15 U.S. ISS long-duration spaceflight astronauts have developed some or all of the following findings:

Eye Findings

- Hyperopic shift
- Choroidal folds
- Cotton wool spots
- Optic Nerve Sheath Distention
- Globe flattening
- Edema of the Optic disc (papilledema)

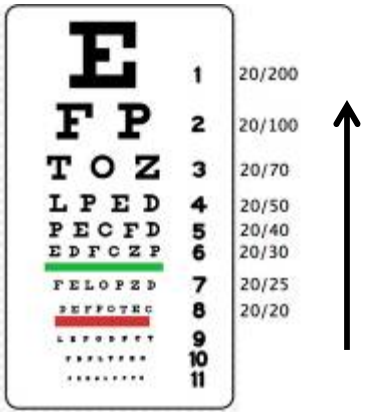
Signs of elevated intracranial pressure

- High postflight intracranial pressure in four crew members:
  - 15.4-21.3mmHg (Normal: 7-15mmHg) or,
    - 21-29 cmH2O, Normal: 9.5-20.4cmH2O

Initial Identification of the VIIP: Subjective Changes in Vision

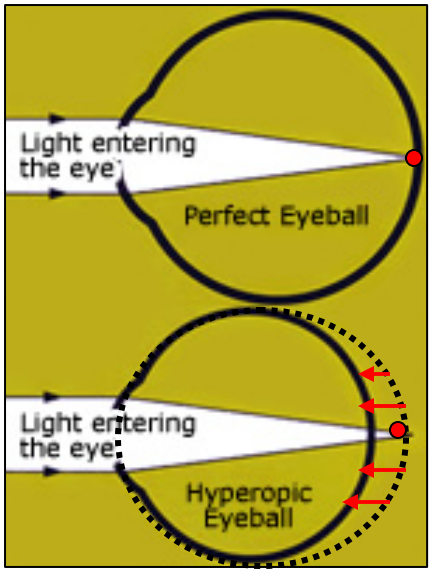
- 50% of long- duration (ISS) mission astronauts report a subjective degradation in vision, primarily increasing *farsightedness*
- ***Hyperopic shift***

Decreased near visual acuity, distant vision intact



(1 mm decrease in axial length is equivalent to a 3 diaper hyperopic shift)

Normal Eye

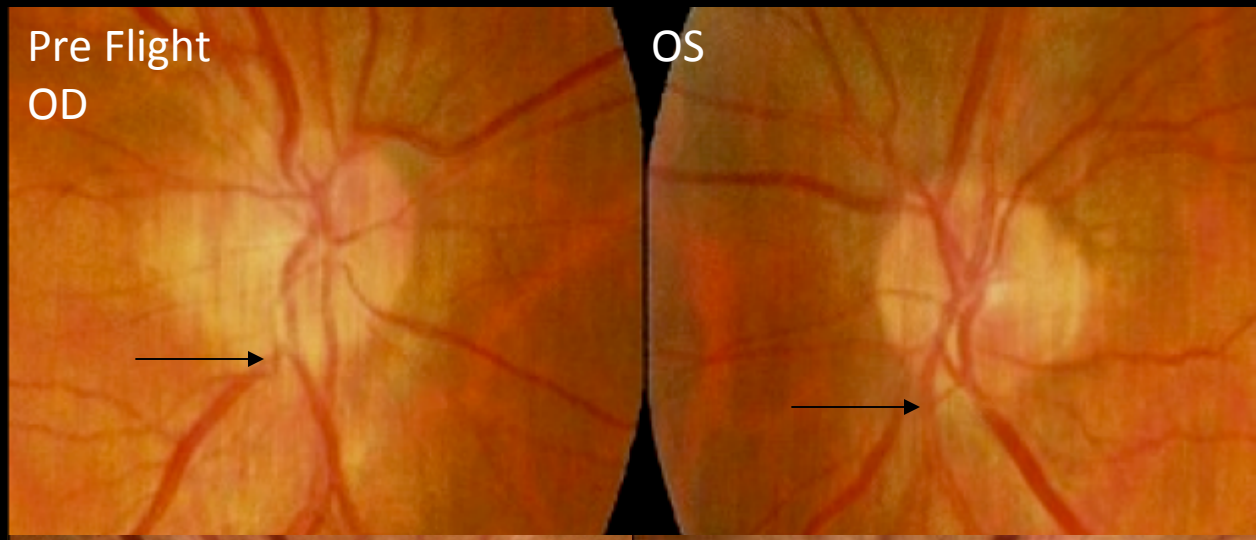


Hyperopic Eye

Pre to Post Flight Papilledema: A Clinical Sign of Raised Intracranial Pressure

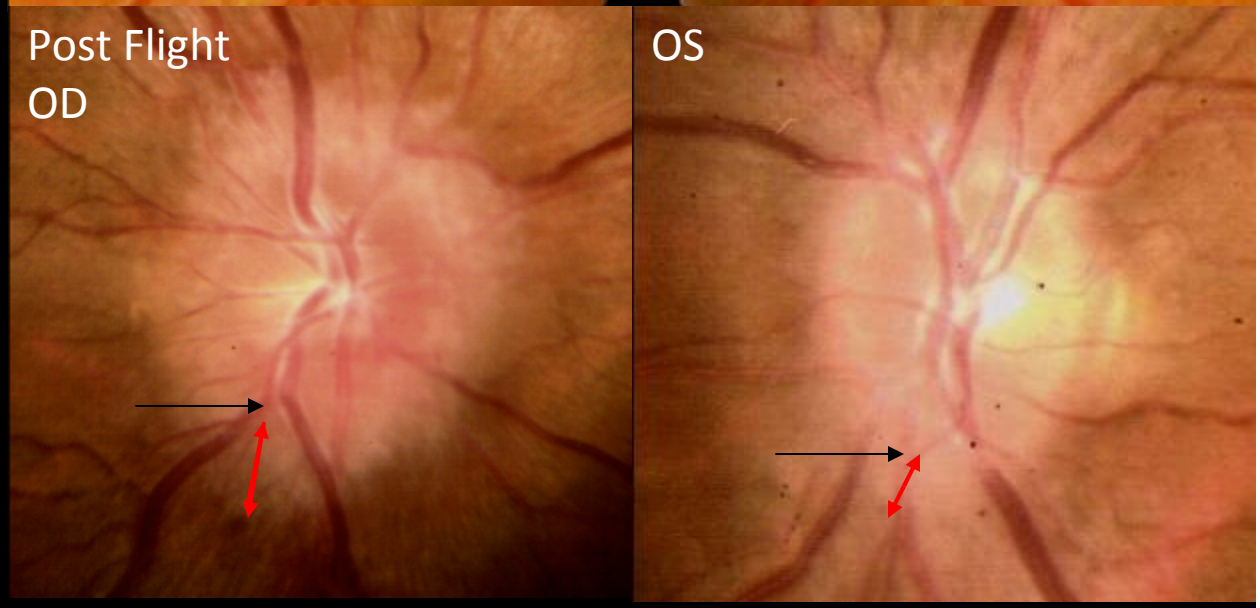
Pre Flight

Fundoscopic images of the right and left optic disc.

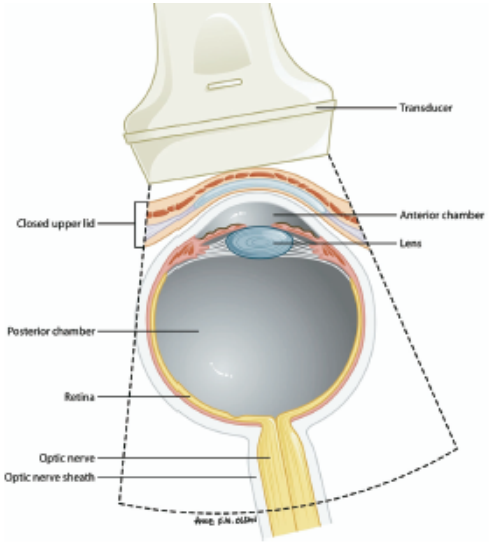


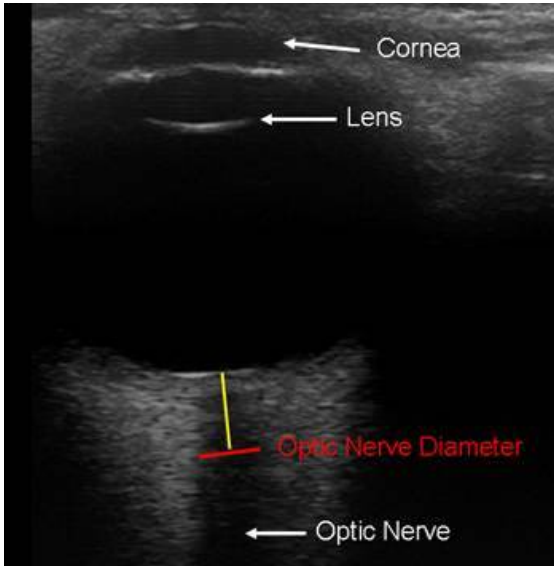
Post Flight

Fundoscopic images of the right and left optic disc showing **Grade 3 edema right** and **Grade 1 edema left** .



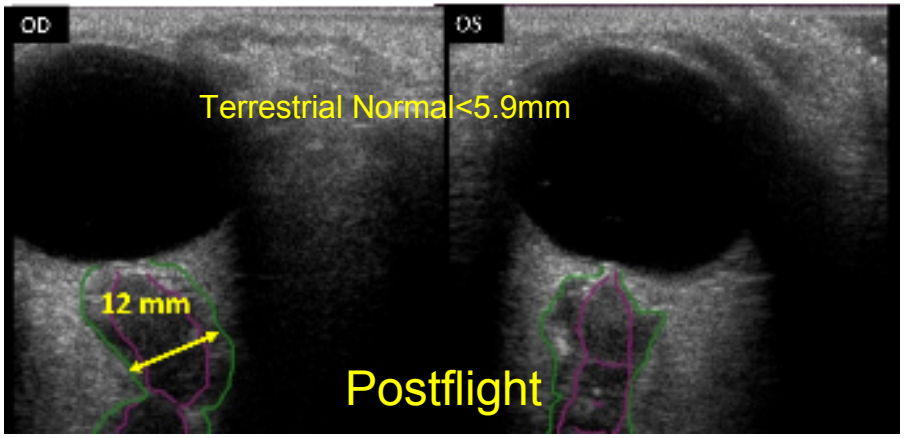
In Flight B-scan Ultrasound



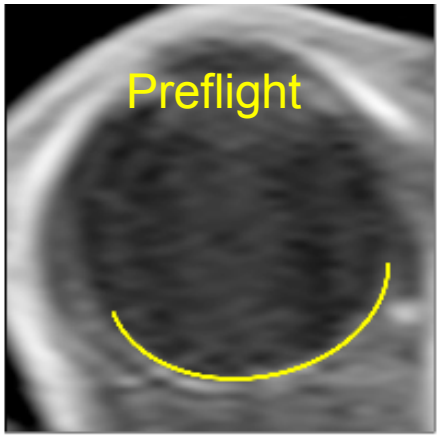


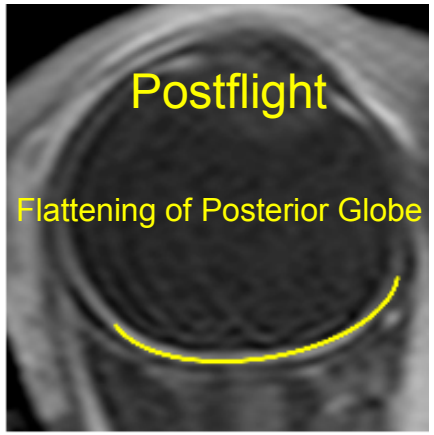
ISS Inflight Crew Ultrasound Imaging: Additional Signs of Raised Intracranial Pressure

1. Increased Optic Nerve Sheath Diameter

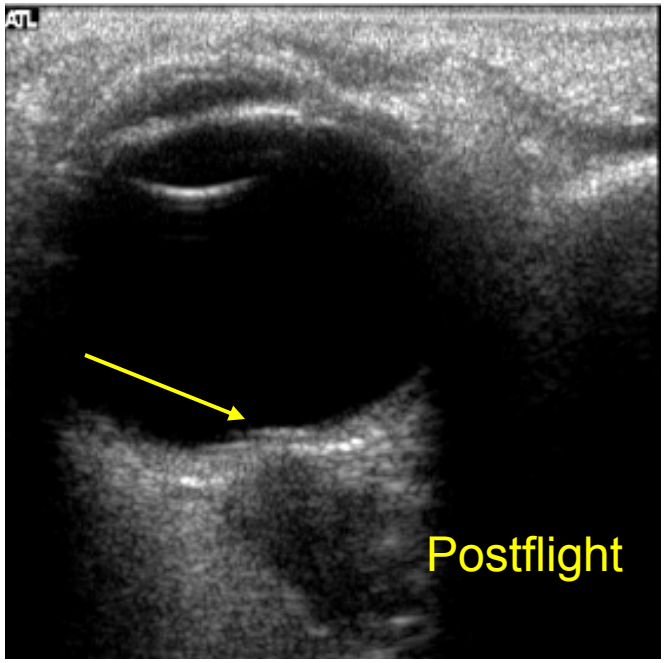


2. Posterior Globe Flattening

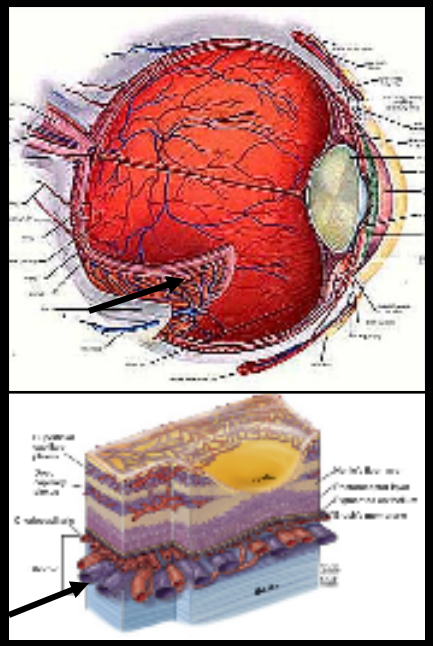


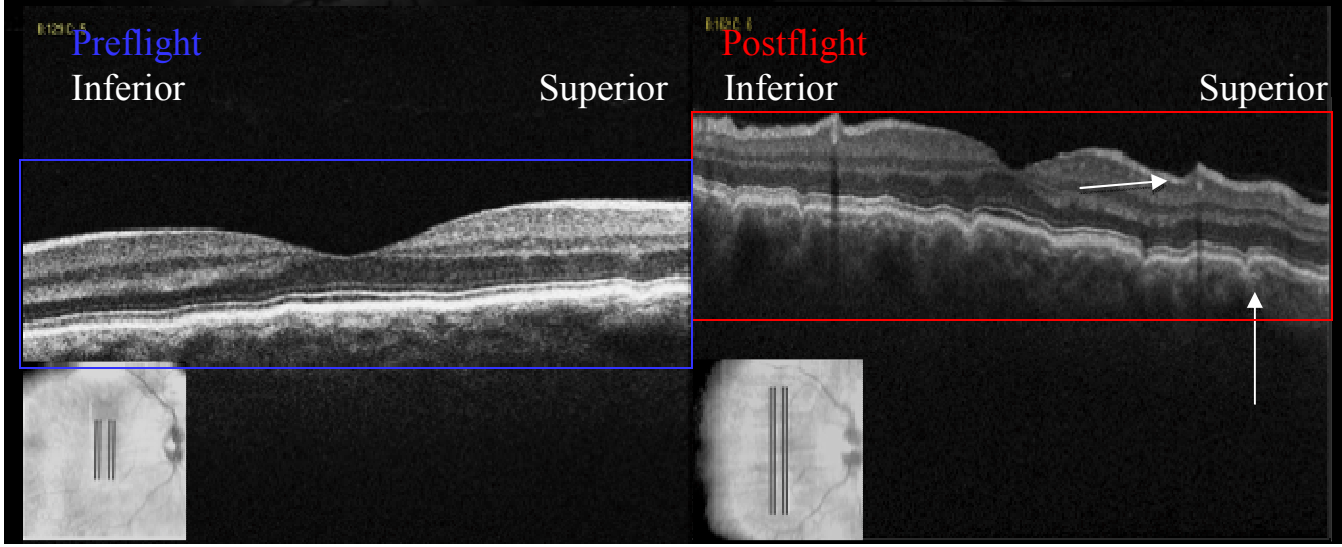


3. Raised Optic Disc



Choroidal Folds





Thickening of the choroid secondary to venous blood engorgement from uG fluid shift

VIIP Clinical Practice Guideline & Classification

Case Classification (U.S. ISS Crew) (As of Jan 2012)

- 36 U.S. ISS crew flown to date:
  - Confirmed non-cases N=5
  - *Unclassified crew N=16*

  - CPG Class One N=2
  - CPG Class Two N=8

} 30% Class 1&2

  - CPG Class Three N=1
  - CPG Class Four N=4

} 15% Class 3&4

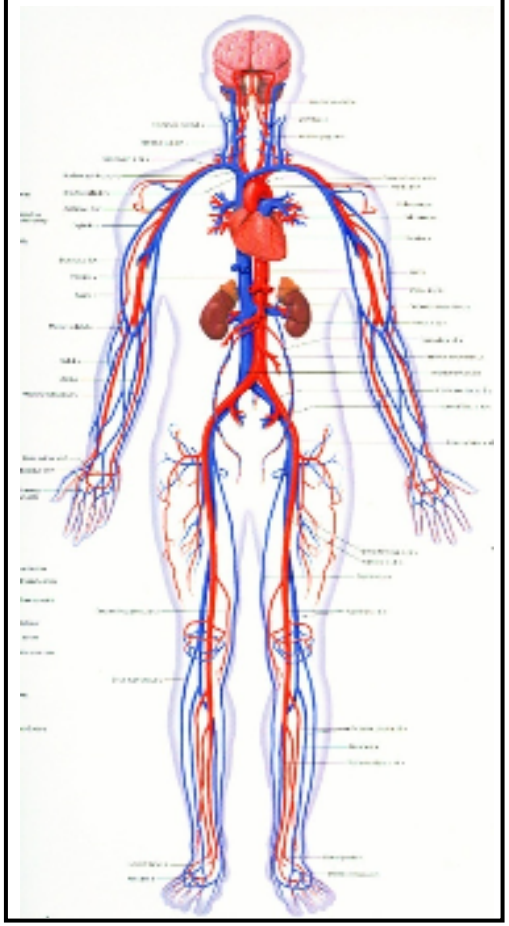
Current VIIP Incidence in U.S. crew = 41.7%

- **Potential long-term changes:**
  - Decreased near visual acuity
  - Peripheral vision loss
  - Neurocognitive changes
- **Higher risk likely on longer exploration missions (*dose-response*)**

Piecing Together Visual Impairment and Elevated Intracranial Pressure in Spaceflight

A Three-Part Story

1. The Vascular System



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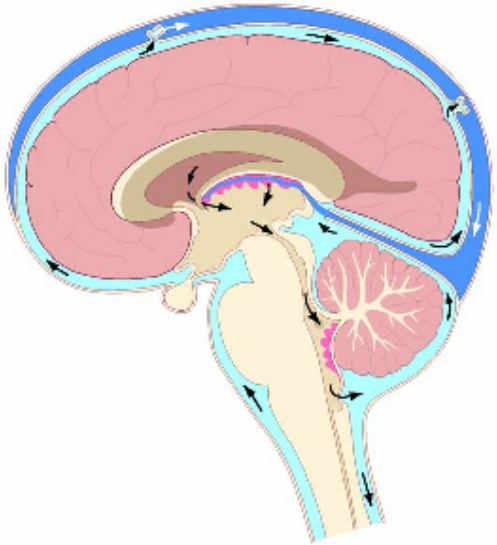
2. The Brain



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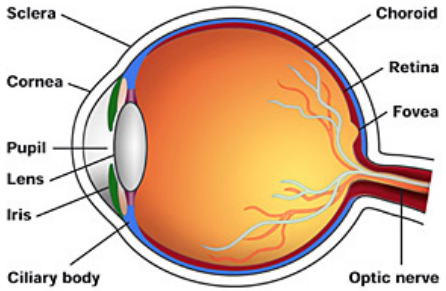
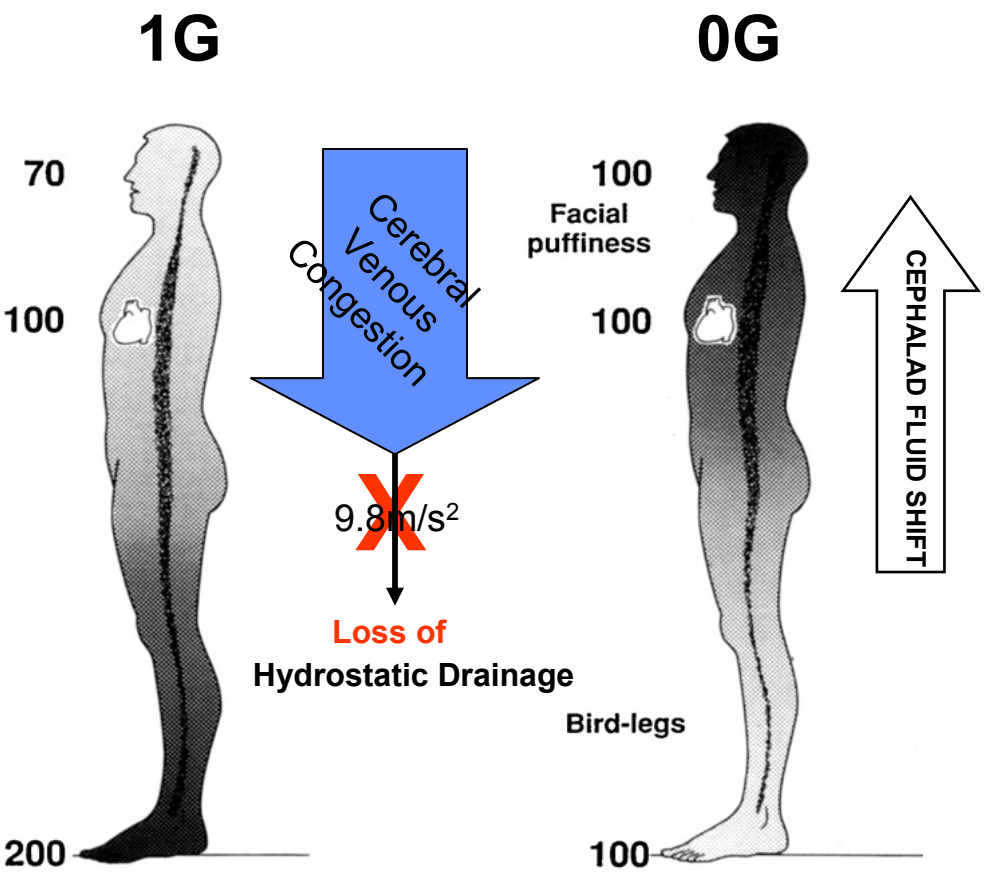
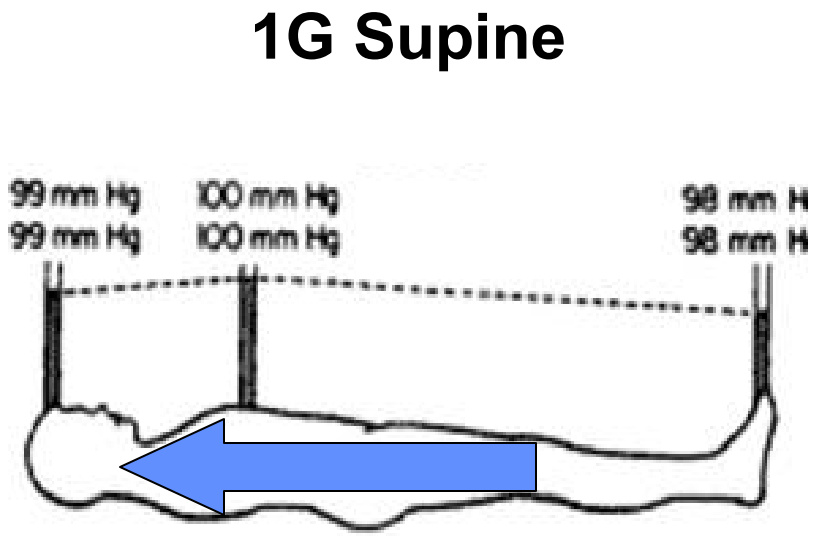
3. The Eye



Loss of Hydrostatic Drainage & Cerebral Venous Congestion

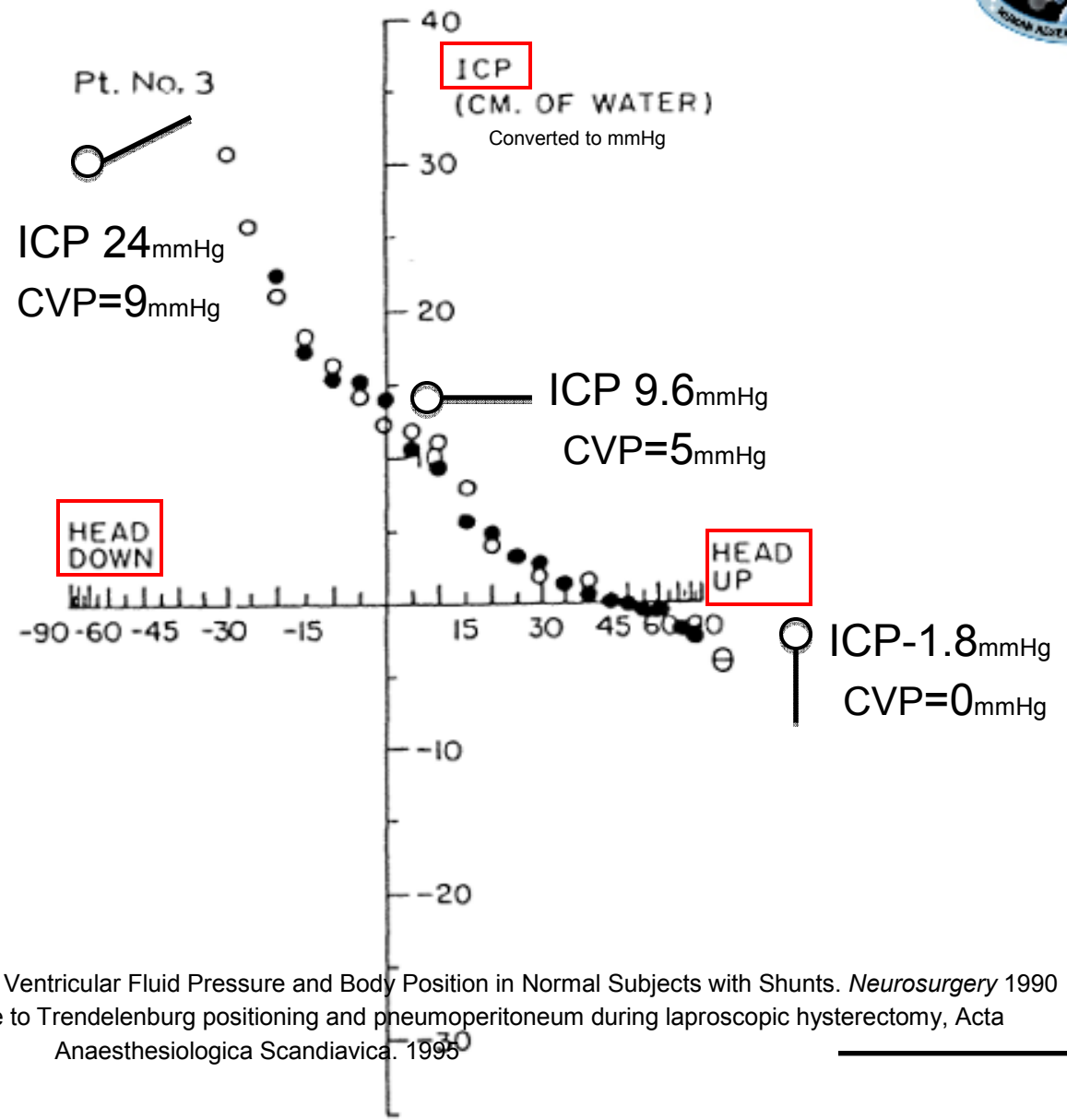




Adapted from Rowell, 1988

Adapted from Hargens & Richardson, Respiratory Physiology & Neurobiology. 2009

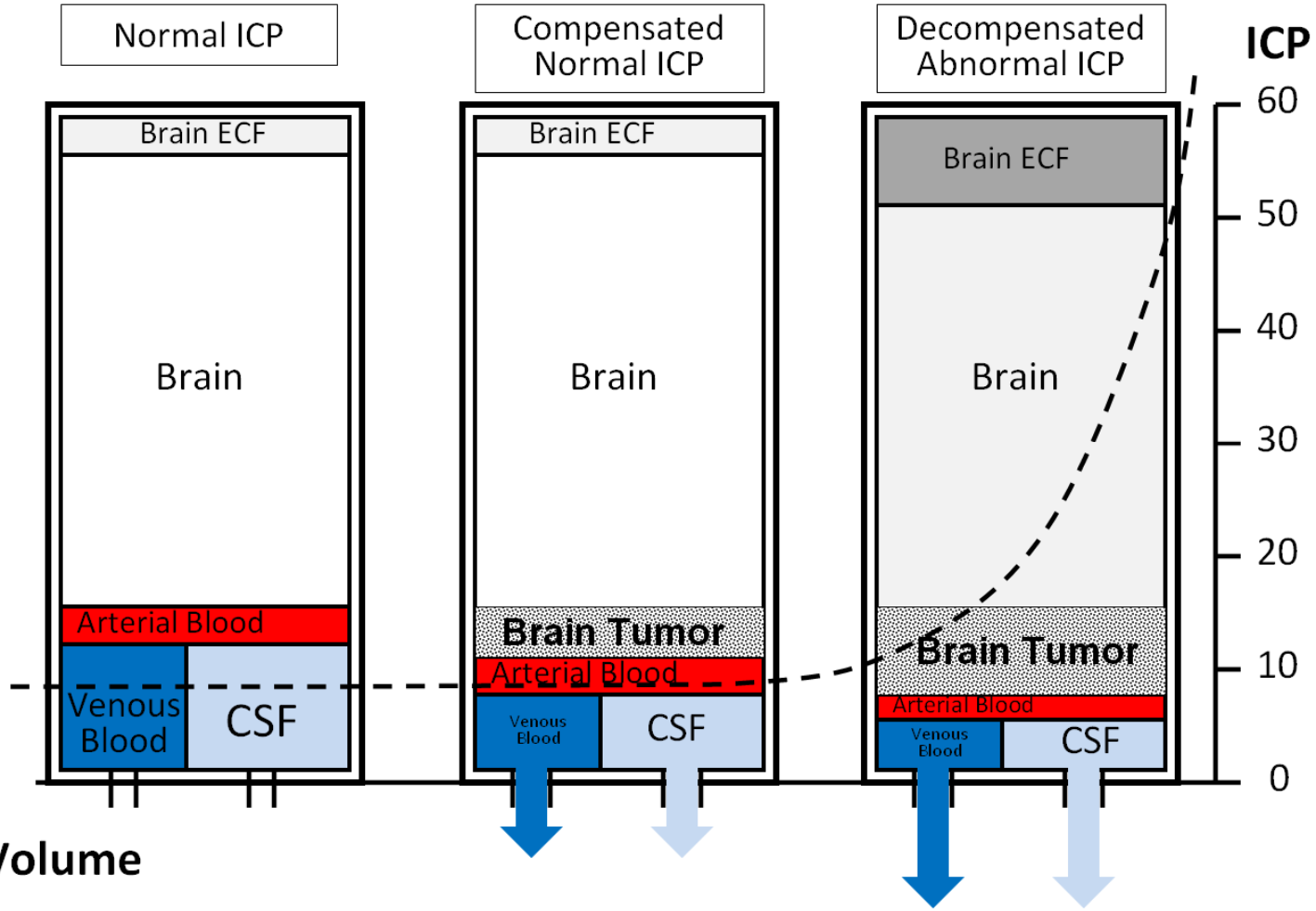
Tilt Angle vs ICP & CVP: Positional Fluid Shifts



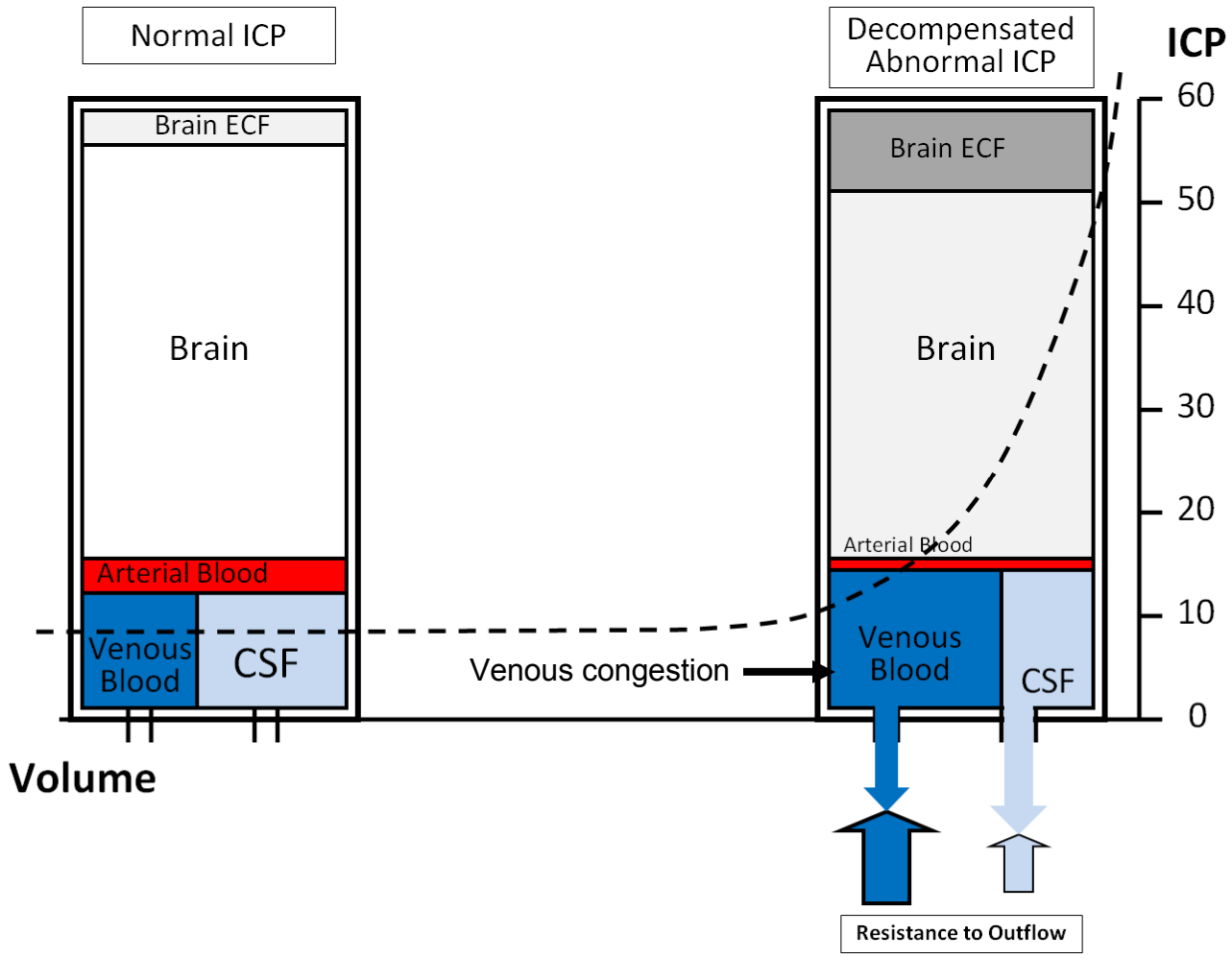
1. Chapman et al. The Relationship between Ventricular Fluid Pressure and Body Position in Normal Subjects with Shunts. *Neurosurgery* 1990
2. Hirvonen et al Hemodynamic changes due to Trendelenburg positioning and pneumoperitoneum during laproscopic hysterectomy, Acta Anaesthesiologica Scandiavica. 1995

Monroe Kelly Principle & ICP

Accommodation of up to 120ml volume change while maintaining normal ICP



Fluid Shift & Inadequate Cerebral Venous & CSF Accommodation May Increase ICP in 0G



0G Cephalad fluid shift causes venous blood & CSF outflow resistance

Occupational Data Mining in ISS Crew: Cardiovascular Variables

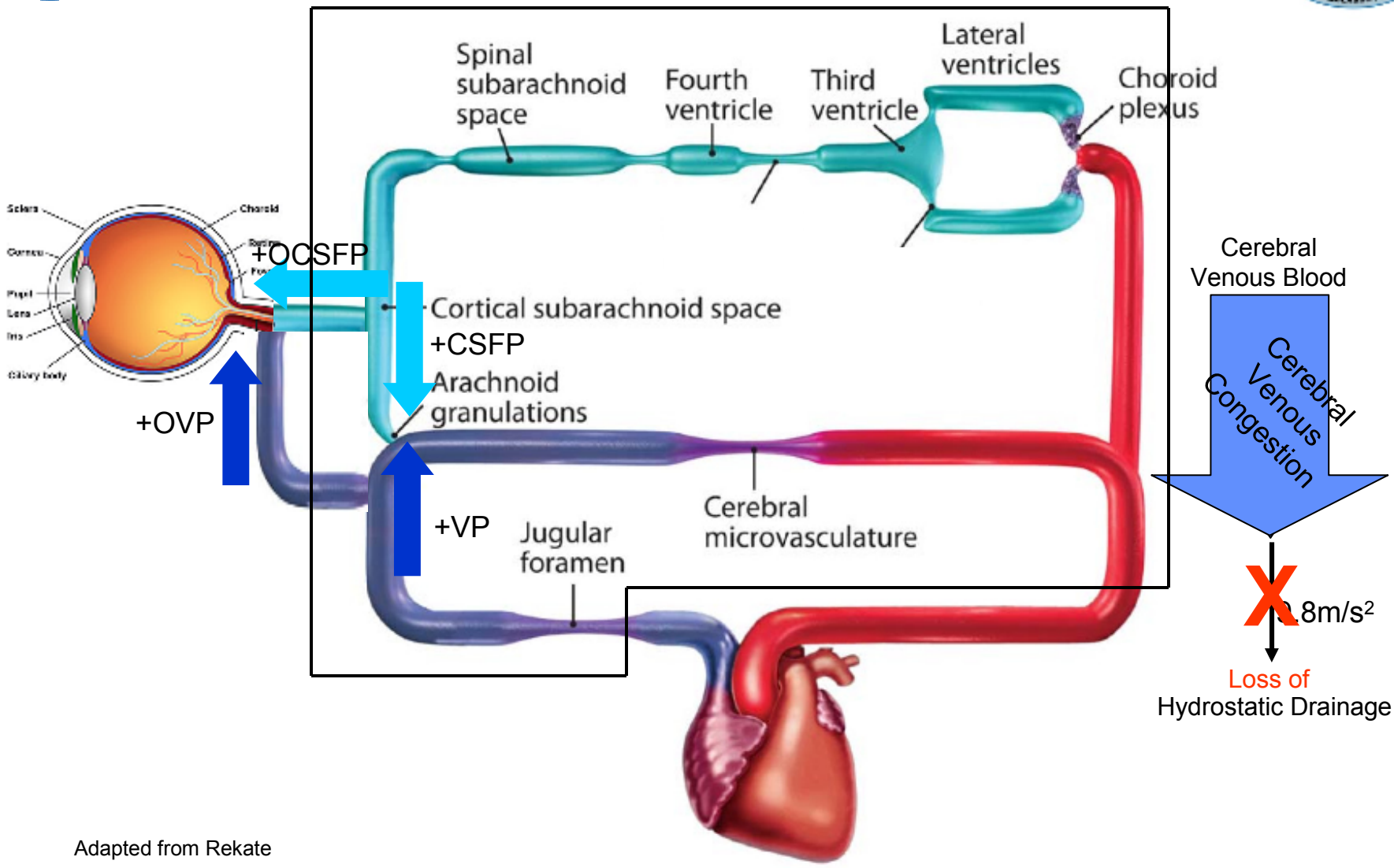
Cardiovascular Variable	Significant Correlation Across CPG Classification
Biochemistry:	
LDL	√
HDL	-
Triglycerides	-
Hemoglobin A1c	√
Fasting serum glucose	√
Homocysteine	√
Body Composition:	
Body Mass Index	√
Percentage Body Fat	√
Cardiac:	
Resting blood pressure (pre-in-post flight)	√
Pulse Pressure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

All correlated factors adversely affect vascular structure & function

Occupational Data Mining in ISS Crew : Ocular Variables

Ocular Variable	Significant Correlation across CPG Classification
Eye Findings:	
Refractive vision change	√
Retinal Nerve Fiber Layer	√
Optic Nerve Sheath Diameter	√
Intraocular Pressure	√

A Working Model: Potential Interaction of the CNS, Vascular, & Ocular System in the VIIP



Adapted from Rekate

Impact of Inflight Exacerbating Factors?

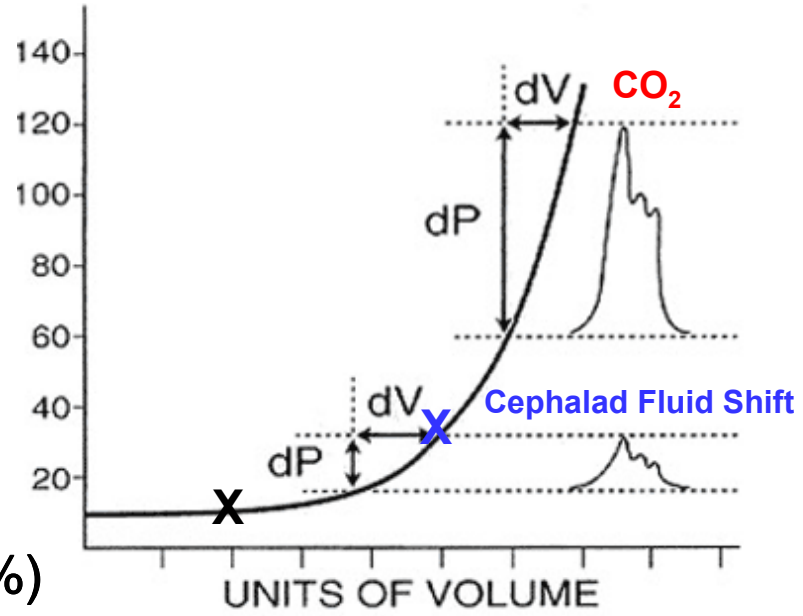
Resistive Exercise
Does in-flight resistance training cause additional transient elevations in ICP?

High Oral Sodium Intake
Prepackaged Foods
High in sodium
Up to 5000mg+ per day

Inflight Pharmaceuticals
Effects on VIIP?

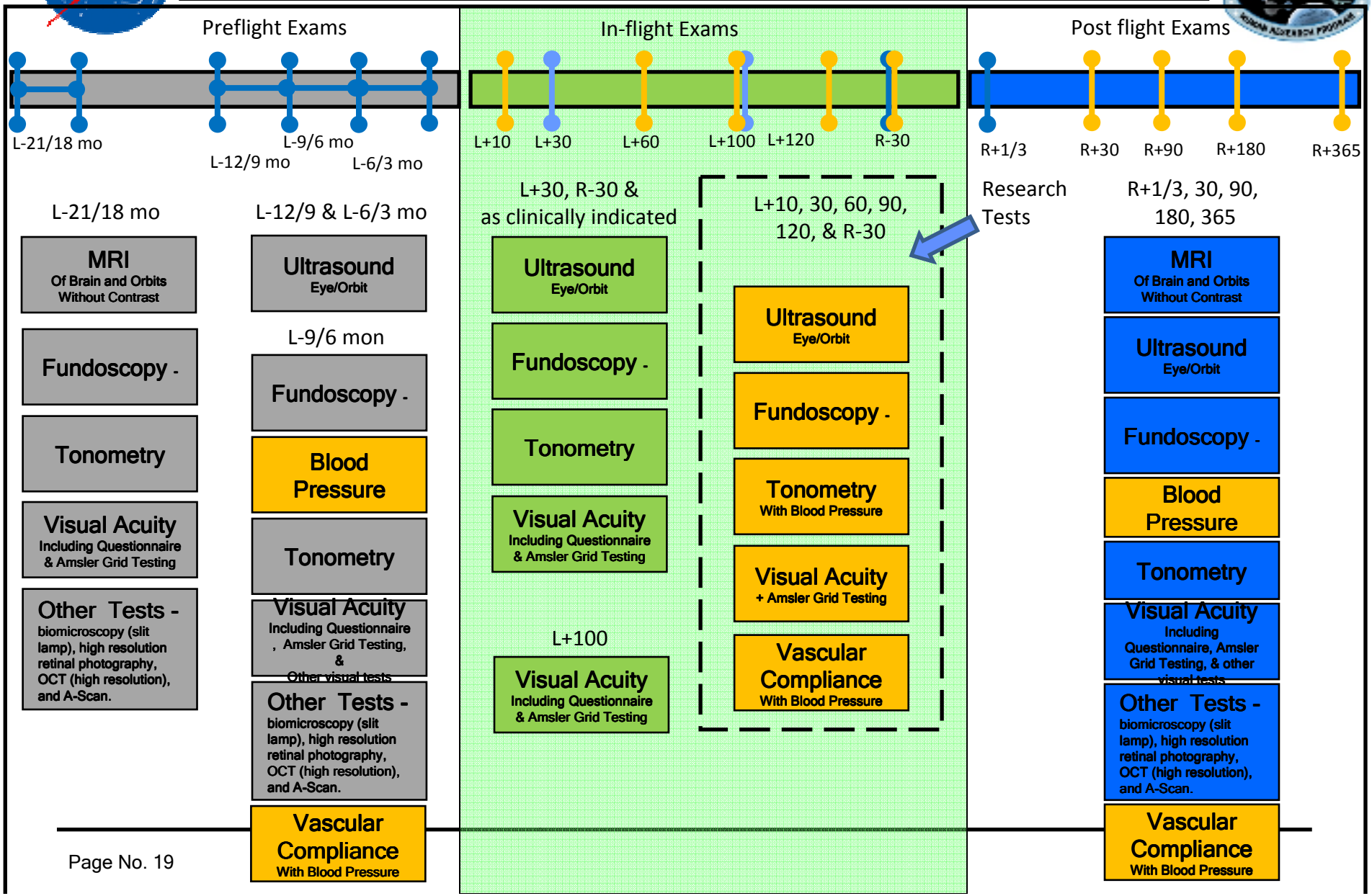
CO_2 Levels on ISS

Adapted from Alperin et al. Radiology, 2000

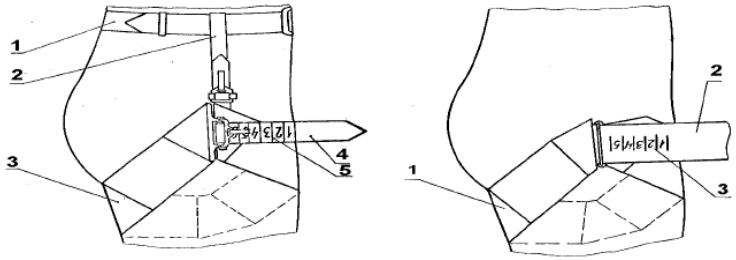


- CO_2 is an extremely potent vasodilator
  - Every 1mmHg increase $PaCO_2$=4% increase in dilation
- CO_2 mission average=3.56mmHg (0.33%)
  - 10x normal sea level atmospheric: 0.0314%
  - Average Peak CO_2=8.32mmHg (0.7%) (20x)
- *CO_2 also causes increased CSF production due to increased flux of $HCO3^-$ across choroid plexus & accompanying H2O*

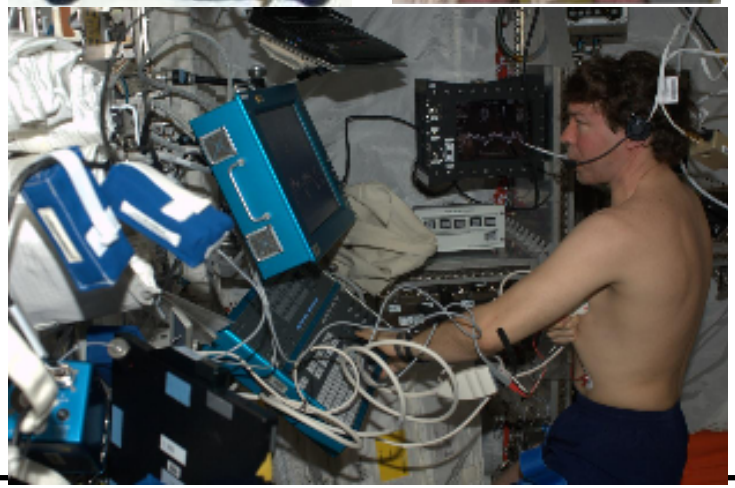
ISS In-flight Ocular Study



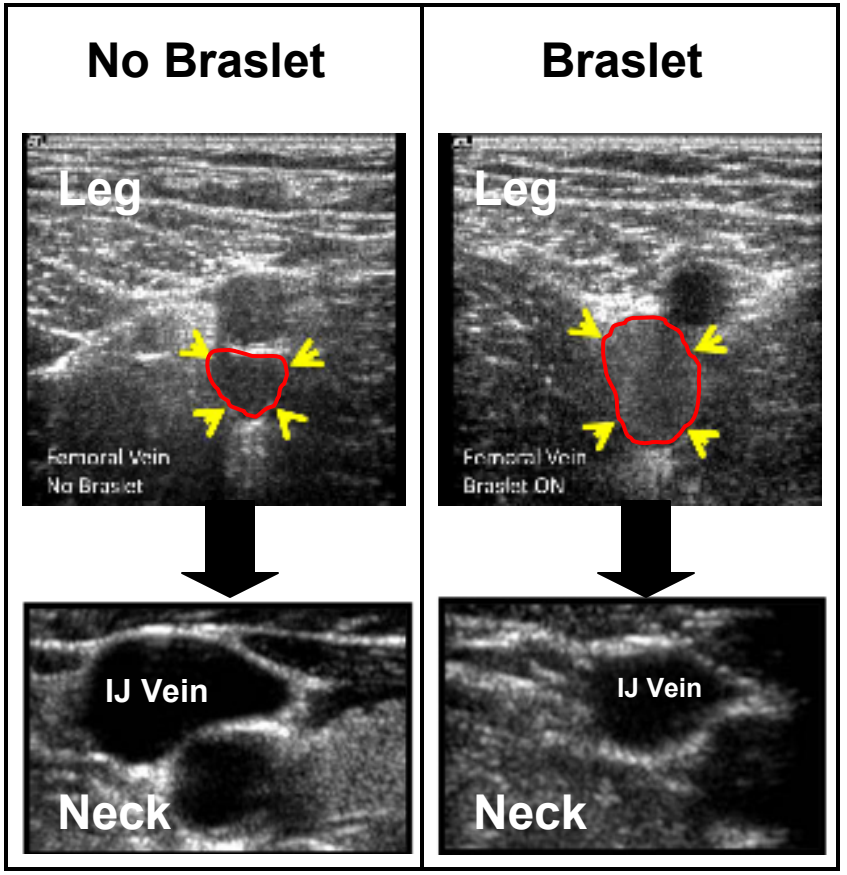
ISS In-flight Studies: Braslet Occlusion Cuff



Braslet (left): 1 – belt; 2 – pull-up strap; 3 – compression cuff; 4 – tightening strap; 5 – compression scale
Braslet-M (right): 1 – compression cuff; 2 – tightening strap; 3 – compression scale



Sequesters venous blood in the legs

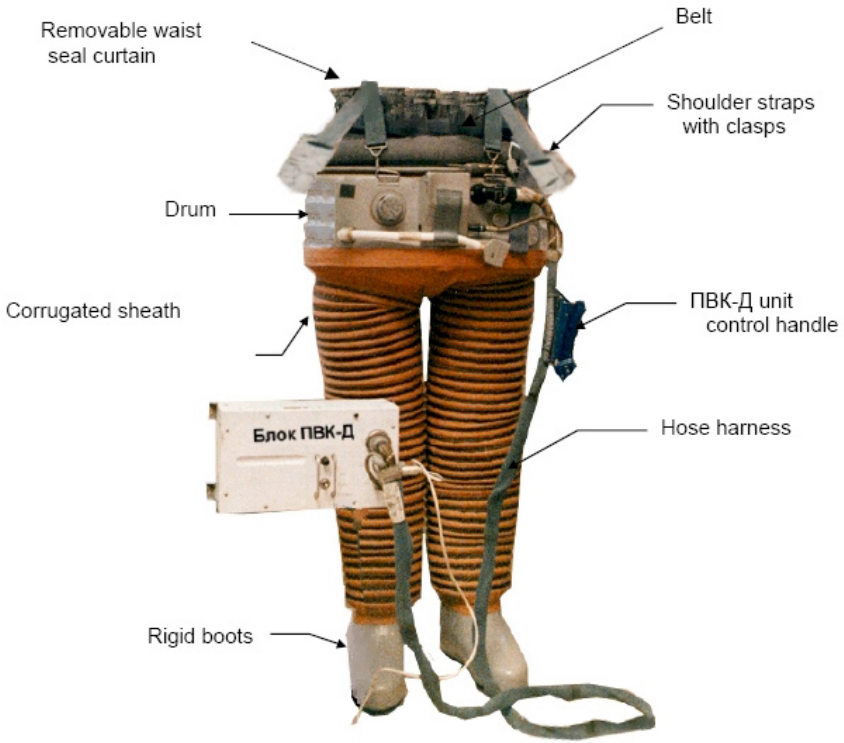


Duncan et al. NASA SDTO 17011

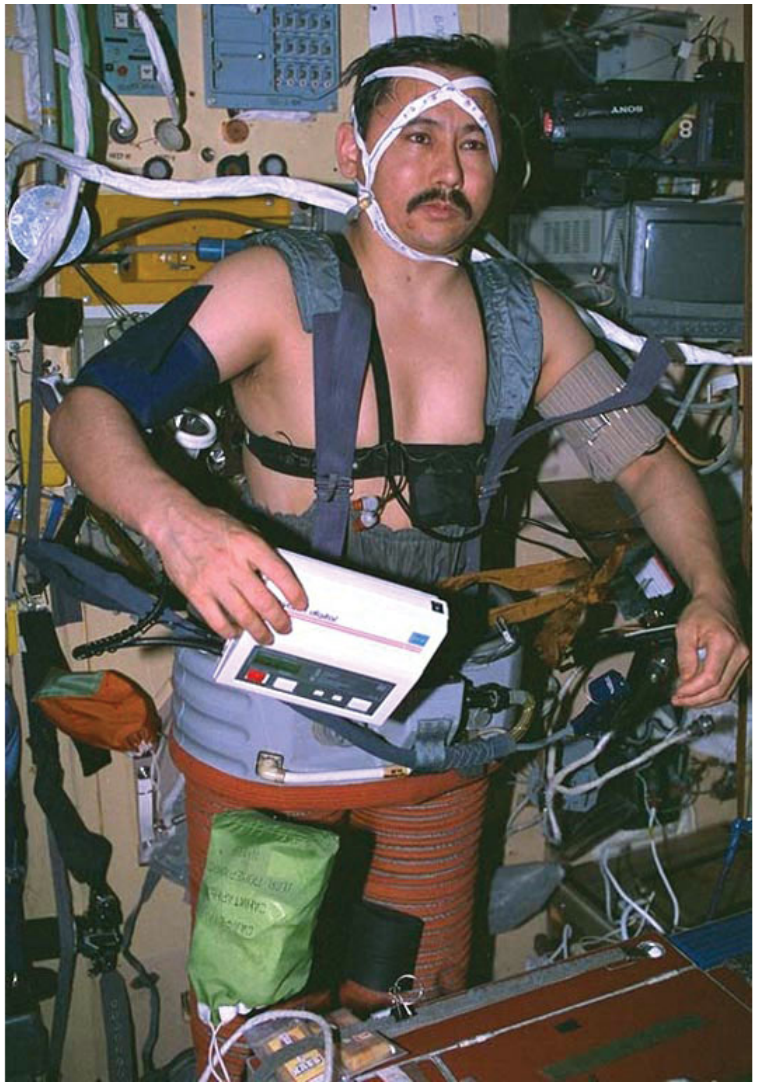
Russian Chibis LBNP Device (Negative Pressure)

Components:

Chibis suit (ПВК-1)
Chibis suit pressure control unit (ПВК-Д)
Hose harness in kit
ПВК-1 removable waist seal curtain in kit

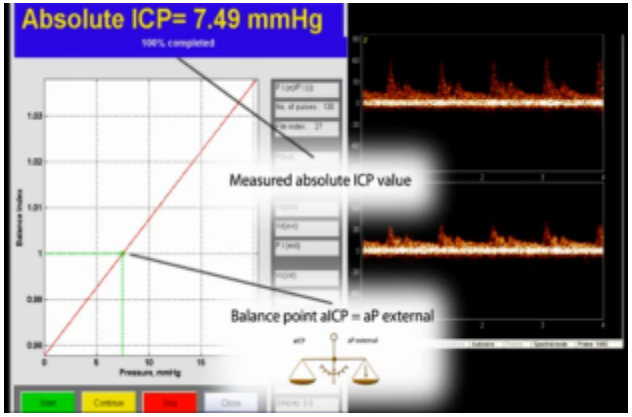


Chibis Suit (ПВК-1)

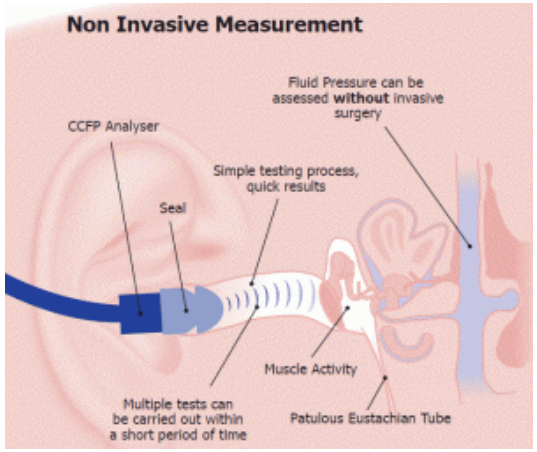


Non-Invasive Intracranial Pressure Measurement

Vittamed 205 Monitor



Cochlear and Cerebral Fluid Pressure (CCFP) Analyzer



VIIP Knowledge & Technlogy Transfer to Terrestrial Medicine

- VIIP risk has brought together leading authorities in neurology, neurosurgery & ophthalmology
- The VIIP syndrome is challenging them to view their own area of expertise from a unique perspective
- The NASA VIIP team continues to disseminate advances in understanding the VIIP syndrome with the clinical community:
  - E.g. CSF Symposium, John's Hopkins, UT Optometry
- Improved understanding of glaucoma
- Improved diagnosis & treatment of Idiopathic Intracranial Hypertension
- Technology transfer to terrestrial medicine:
  - Assessment of Intracranial pressure using novel techniques & new protocols
  - New remote guidance techniques
  - Advancing telemedicine using standard clinical tools

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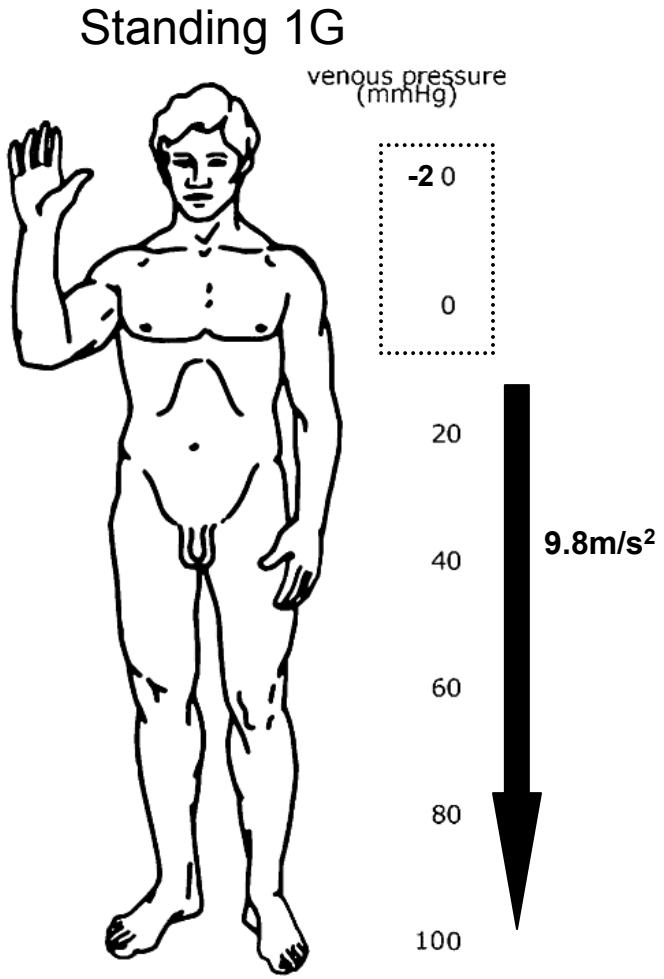
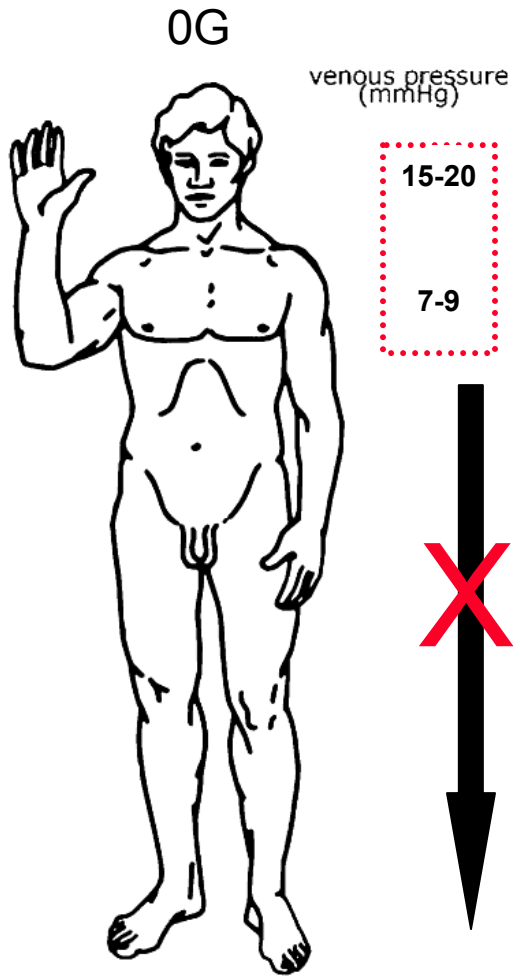
Common Characteristics of the Cases

- Approximately 6 month duration ISS mission
- All had normal preflight eye examinations

- Past medical history was negative for systemic disease; and none had used medications before or during their mission that could increase ICP (e.g., vitamin A, tetracycline, corticosteroids, or nalidixic acid)

Redistribution of Venous Pressures From 1G to 0G





- Cranium is rigid
- Venous congestion
- Obligate arterial flow
- Transcapillary leak
- ++ICP~30-40

1. Hirvonen et al. Hemodynamic changes due to Trendelenburg positioning and pneumoperitoneum during laproscopic hysterectomy, Acta Anaesthesiologica Scandiavica. 1995
2. Hinghofer-Szalkay Gravity, the hydrorostatic indifference concept and the cardiovascular system. European Journal of Applied Physiology, 2010

3. Chapman et al. The Relationship between Ventricular Fluid Pressure and Body Position in Normal Subjects with Shunts. *Neurosurgery* 1990
4. Gisolf et al. Human cerebral outflow pathway depends on posture and central venous pressure. Journal of Physiology, 2004.