Effects of Head Down Tilt With or Without 0.5% CO_2 on Intracranial and Intraocular Pressure: Results from the Space-Cot Study

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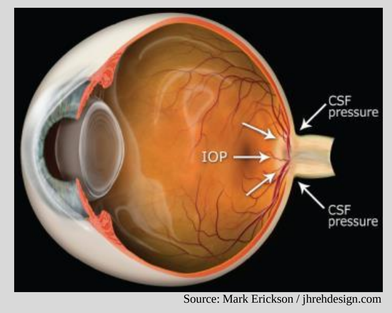
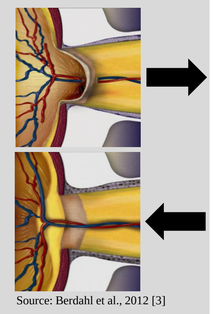
Introduction

Currently, >50% of astronauts present with structural and functional ophthalmic changes after 6 month missions on the ISS, referred to as the **Visual Impairment and Intracranial Pressure (VIIP) syndrome** [1]. Although the exact causative mechanisms of VIIP are unknown, it is hypothesized that headward fluid shifts and elevated atmospheric carbon dioxide (CO_2) levels may contribute by leading to an elevated intracranial volume, which in turn would increase intracranial pressure (ICP) once compensatory volume accommodation is exhausted. It has also been hypothesized that a mismatch in the ICP and intraocular pressure (IOP) may contribute to VIIP [2]. This was studied in a ground-based spaceflight analog in the **SpaceCot Study: S**tudying the **P**hysiological and **A**natomical **C**erebral **E**ffects of **CO_2** and **T**ilt.



Source: Mark Erickson / jhrehdesign.com


Source: Berdahl et al., 2012 [3]

Space-Cot Study Design

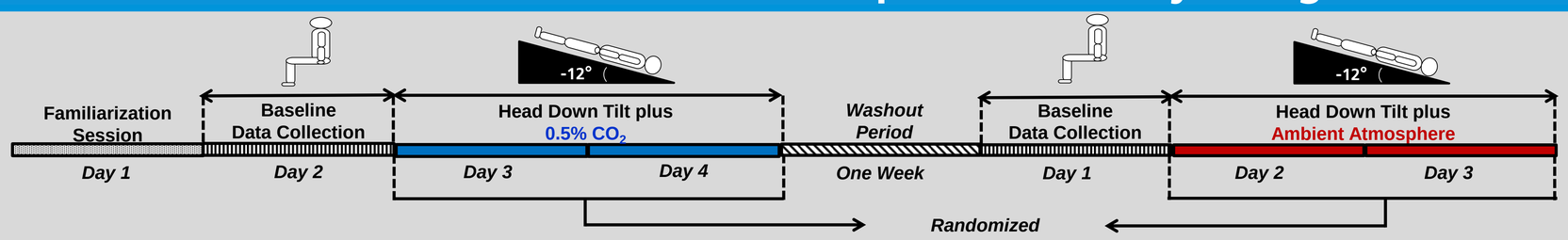


Fig. 1: Space-Cot Study Schematic

- Six healthy, male subjects (mean age: 41 ± 4 yrs; mean height, 177 ± 3.4 cm, BMI: 26.2 ± 2 kg/m^2)
- Double-blinded, cross-over design with 2 campaigns: 28 h bed rest at -12° HDT with ambient atmosphere and with 0.5% CO_2 atmosphere (*Fig. 1*)
- Short exposure to 3% CO_2 performed during the last 2 h of HDT
- Performed at the :envihab at DLR in Cologne, Germany

Objective

- To determine the effects of **headward fluid shifts** with and without the added effects of increased ambient **CO_2** on **cerebral and ocular physiology** to better understand the etiology of the **VIIP Syndrome**

Materials & Methods

- **Non-invasive Intracranial Pressure**: two-depth Doppler ultrasound examining flow through two segments of the ophthalmic artery (Vittamed, *Fig. 2*)

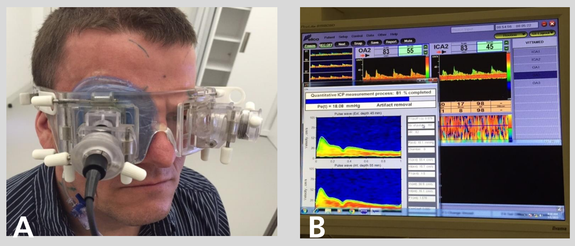


Fig. 2: Vittamed device (A) and signals from the extracranial and intracranial segments of the OA (B)

- **Intraocular Pressure:** Icare Tonometer Pro (rebound)
- **CO_2 Administration:** Atmospheric CO_2 was increased in the entire bed rest facility in the :envihab (*Fig. 3*)

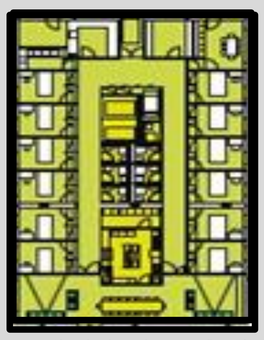


Fig. 3: :envihab bed rest facility

Data Analysis

- LME and ANOVA
- Bonferroni post-hoc contrast testing

Results

Intracranial Pressure

- ICP did not change significantly with HDT (p=0.3) in either atmosphere (*Fig. 4 and Fig. 5*)
- Atmosphere (ambient vs. 0.5% CO_2) did not have a significant effect on ICP

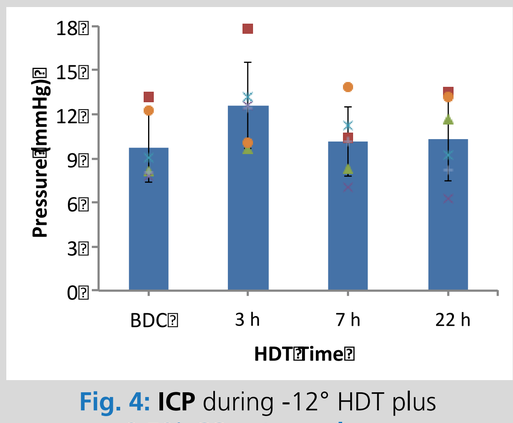


Fig. 4: ICP during -12° HDT plus **0.5% CO_2 atmosphere**

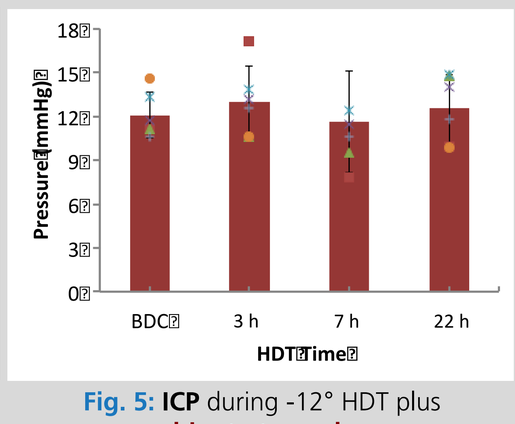


Fig. 5: ICP during -12° HDT plus **ambient atmosphere**

Intraocular Pressure

- IOP increased at 1.5 h **HDT** in both atmospheric conditions and remained elevated until 22.5 h (p<0.01, *Fig. 6*)
- Short exposure to **3% CO_2** at 27 h HDT resulted in a decrease in IOP, back to baseline values in ambient condition (*Fig. 6*)
- Significant effect of **eye lateralization** in CO_2 condition (p<0.01, *Fig. 7*), however not with ambient air (p=0.7, *Fig. 8*)

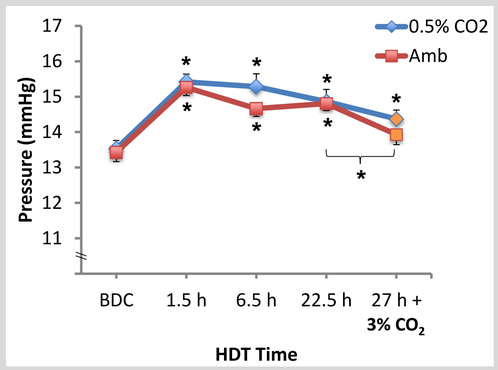


Fig. 6: IOP during -12° HDT

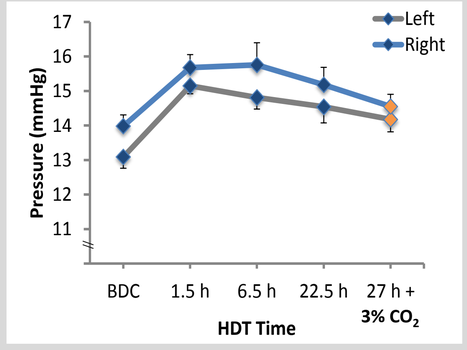


Fig. 7: IOP by eye during -12° HDT plus **0.5% CO_2 atmosphere**

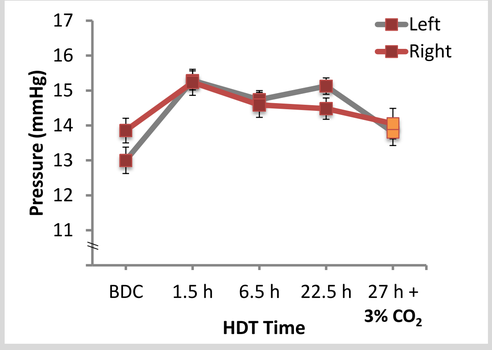


Fig. 8: IOP by eye during -12° HDT plus **ambient atmosphere**

References

[1] Mader, T.H. *et al.* (2011). *Ophthalmology* **118**: 2058-2069.
[2] Zhang, L.-F., Hargens, A.R. (2014). *Aviat. Space Environ. Med.* **85**: 78-80.
[3] Berdahl, J.P., Yu, D.Y., Morgan, W.H. (2012). *Med. Hypotheses* **79**: 719-724.

Summary & Conclusions

➢ **HDT does not significantly alter ICP**

Short-term exposure to -12° HDT does not significantly increase ICP as hypothesized, presumably due to adequate volume compensatory mechanisms in healthy subjects.

➢ **HDT increases IOP**

IOP increased during -12° HDT in both investigated atmospheric conditions.

➢ **0.5% CO_2 does not have significant effects on ICP and IOP during HDT**

In short duration exposure, 0.5% CO_2 does not have additive effects on ICP and IOP in combination with -12° HDT.

However, prior exposure to 0.5% CO_2 did prevent effects of 3% CO_2 on IOP

Innovative Aspects

- First bed rest study to investigate HDT with increased ambient CO_2 as a new ground-based analog for spaceflight
- Implemented steeper degree of HDT (-12° HDT) to investigate the effects of a larger headward fluid shift
- Significant insights into brain physiology through use of multiple techniques

Space-Cot Team

*Not all pictured

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