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Protecting the human brain in space: The choice of impedance, occlusion or vacuum

Astronauts develop visual impairments during long-duration missions on the International Space Station (Space flight–Associated Neuro-ocular Syndrome, SANS) with evidence of unilateral and bilateral optic disc oedema, globe flattening, choroidal and retinal folds, hyperopic refractive error shifts, and nerve fiber layer infarcts. These observations are reminiscent of pathological changes observed in patients with intracranial hypertension (i.e. pathologically high intracranial pressures). Yet, when intracranial pressure was measured invasively during microgravity on-board parabolic flight, it actually fell below the supine posture, but importantly not to the level observed when sitting upright on earth. Given these data, we speculated that the absence of diurnal, postural reductions in intracranial pressure relative to intraocular pressure in microgravity creates a persistently lower pressure gradient at the posterior aspect of the eye (i.e., a lower translaminar pressure gradient), that over many months may result in optic remodelling. Therefore, it seems reasonable to develop a physiologically driven countermeasures to persistently (6 - 8 hours) reduce intracranial pressure towards values seen in the upright posture during space flight.

To document the most efficacious method to lower intracranial pressure, we conducted a series of studies that measured intracranial pressure invasively in the supine posture and when 1) breathing on an impedance threshold device, 2) with pneumatic inflation of bilateral thigh cuffs (30 mmHg) and 3) graded lower body negative pressure (- 0 to -50 mmHg). Based on these studies, we performed a follow-up investigation to document the protective effect of daily low-level lower body negative pressure on the eye during 3 days of simulated microgravity by -6° head down tilt bedrest. Participants lay in the -6° head-down tilt position for three days (control) and again with lower body negative pressure (-20 mmHg) applied for 8 hours per day (10am-6pm). -6° was strictly enforced, participants did not raise their heads for any reason. A multi-imaging assessment of the eye (optical coherence tomography, magnetic resonance imaging and ultrasound) was performed to document any protective effects.

This presentation will discuss the potential pathology of Space flight–Associated Neuro-ocular Syndrome, the efficacy of three potential countermeasures and initial insights into the efficacy and safety of prolonged (8 hrs) low-level lower body negative pressure.

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