BACKGROUND

Visual Impairment/Intracranial Pressure (VIP) is a top human spaceflight risk for which NASA does not currently have a proven mitigation strategy. Thigh cuffs (Braslets) and lower body negative pressure (LBNP; Chibis) devices have been or are currently being evaluated as a means to reduce VIP signs and symptoms, but these methods alone may not provide sufficient relief of cephalic venous congestion and VIP symptoms. Additionally, current LBNP devices are too large and cumbersome for their systematic use as a countermeasure. Therefore, a novel approach that is easy to implement and provides specific relief of symptoms. This investigation will evaluate an impedance threshold device (ITD) as a VIP countermeasure.

SPECIFIC AIMS

Using a supine and head down tilt (HDT) model, this investigation will:
1. Determine if an ITD can reduce venous congestion in the head and neck
2. Determine if an ITD can reduce indicators of elevated intracranial pressure

METHODS

The experimental approach is to use a battery of tests that are currently being used to evaluate the effects of other interventions. Healthy test subjects (n=15) will participate in two sessions, one with an ITD and one with a sham ITD (placebo). Blood pH and pCO2 measures will be made immediately prior to and following each session. Subjects will be evaluated in the seated and supine positions as well as head down tilt (HDT) postures, including 6 and 15 degree HDT. Measures taken at each posture will include IJV cross sectional area, IJV and carotid artery Doppler, measures of cardiac preload, transtural Doppler (TCD), optic nerve sheath diameter (ONSD), superior ophthalmic vein (SOV) Doppler, optical coherence tomography (OCT), cochlear and cerebral fluid pressure analysis (CCFP), otocoustic emissions (OAE), intracranial pressure (ICP), facial soft tissue thickness and hyperemia, arterial blood pressure, ECG, and heart rate.

REFERENCES


PILOT RESULTS

Figure 3: Effect of ITD breathing on IJV cross-sectional area in the supine position. A: M-mode across the IJV without ITD, B: B-mode (2D) image of the IJV without ITD, C: M-mode across the IJV with ITD, D: B-mode image of the IJV without ITD. In panels A and C ECG is the green trace and respiration in red.

Figure 4: Effect of ITD breathing on internal jugular vein (IJV) time-weighted cross sectional area in different postures (n=15). IJV cross sectional area was time-averaged over one full respiratory cycle at 15° head up tilt (15HUT), Supine, and 15° head down tilt (15HDT), each posture with and without ITD breathing.

Figure 5: Noninvasive indication of ICP changes in response to ITD breathing at different postures. Tympanic Membrane Displacement (TMD) values in n=2 trials each panel. A: subjects at 15° head up tilt (15HUT), Supine, 15° head down tilt (15HDT), and Supine with ITD breathing (Supine+ITD). B: subjects at 30° head up tilt (30HUT), Supine, 15° head down tilt (15HDT), and 15° head down tilt with ITD breathing (15HDT+ITD). Higher TMD displacement values indicate lower ICP.

DISCUSSION

Pilot data demonstrate substantial reductions in IJV cross sectional area and in estimated ICP as measured by CCFP. Study funding commenced in November 2015 with human subject testing planned for spring 2016.

The investigation team recognizes that ITD use as a routine countermeasure during spaceflight may not be particularly comfortable in its current form and function. The purpose of the planned work is to 1) use the ITD as a tool to further understand VIP, and 2) establish the effectiveness of this methodology before embarking on more in-depth investigations that could optimize acceptability to crewmembers as a countermeasure.

ACKNOWLEDGEMENTS

Funded by a NASA Human Research Program Omnibus grant through the Human Health and Performance Contract (HHPC). Special thanks to the JSC Nutritional Biochemistry Laboratory (S. M. Smith and S. Zwart) for assistance with blood pH and pCO2 measures.