Ground-Based Studies of Headward Fluid Shifts Related to Space Flight

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BACKGROUND

Long-term space flight decreases visual acuity in more than 50% of astronauts with some reports of post-flight lumbar opening pressures up to 21 mmHg[1]. Loss of hydrostatic (gravitational) pressures in microgravity shifts blood, spinal fluid and tissue fluids towards the head, probably causing venous congestion and leading to symptoms compatible with chronically increased intracranial pressure (ICP). This is characterized as the Visual Impairment and Intracranial Pressure (VIIP) syndrome.

Simulation of gravitational stress by application of Lower Body Negative Pressure (LBNP) is proposed as a means to reduce ICP and reestablish cerebral health in astronauts during long mission stay in space.

We hypothesize that 50 mmHg of lower body negative pressure (LBNP) during supine and simulated intracranial hypertension by 15° head-down tilt (HDT) counteracts elevations in ICP and internal jugular vein cross-sectional area (IJV CSA).

SPECIFIC AIM

To assess the ability of artificial gravity by graded LBNP as a means to reduce ICP.

METHODS

In two sets of ground-based studies, a total of 20 adult volunteers were positioned in the seated, supine, and 15° HDT position. Increasing levels of LBNP from 10 – 50 mmHg were added during supine and HDT with each intervention lasting 10 minutes.

In the first study; invasive ICP was measured in five ambulatory neurosurgical patients fitted with parenchymal ICP tip-transducer probes inserted through a frontal burr hole[2].

The second study included 15 healthy volunteers in whom non-invasive ICP was quantified by evoked tympanic membrane displacement (TMP)[3]. In addition, IJV CSA was measured using standard ultrasound hardware.

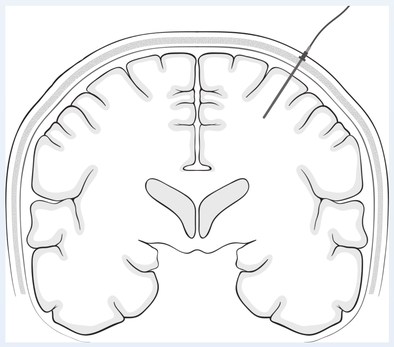

Figure 1. Placement of tip-transducer catheter. *Using local anesthetics, the probe is inserted 2-3 cm into the brain parenchyma through a frontal burr hole. Patients are carefully selected "as normal as possible" ambulatory neurosurgical patients undergoing diagnostic 24-48 hours ICP monitoring.*

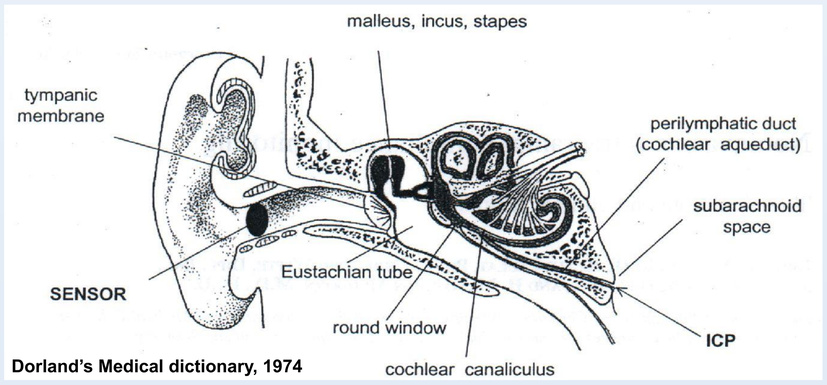

Figure 2. Noninvasive-ICP assessed using tympanic membrane displacements. *The Cerebral Cochlear Fluid Pressure device (CCFP) emits a tone to acoustically stimulate the stapedial muscle, resulting in movement of the inner-ear bone and displacement of the tympanic membrane. As cerebrospinal fluid communicates through the cochlear aqueduct to the peri-lymphatic fluid, changes in cerebrospinal fluid pressure are reflected in movement of the tympanic membrane.*

RESULTS

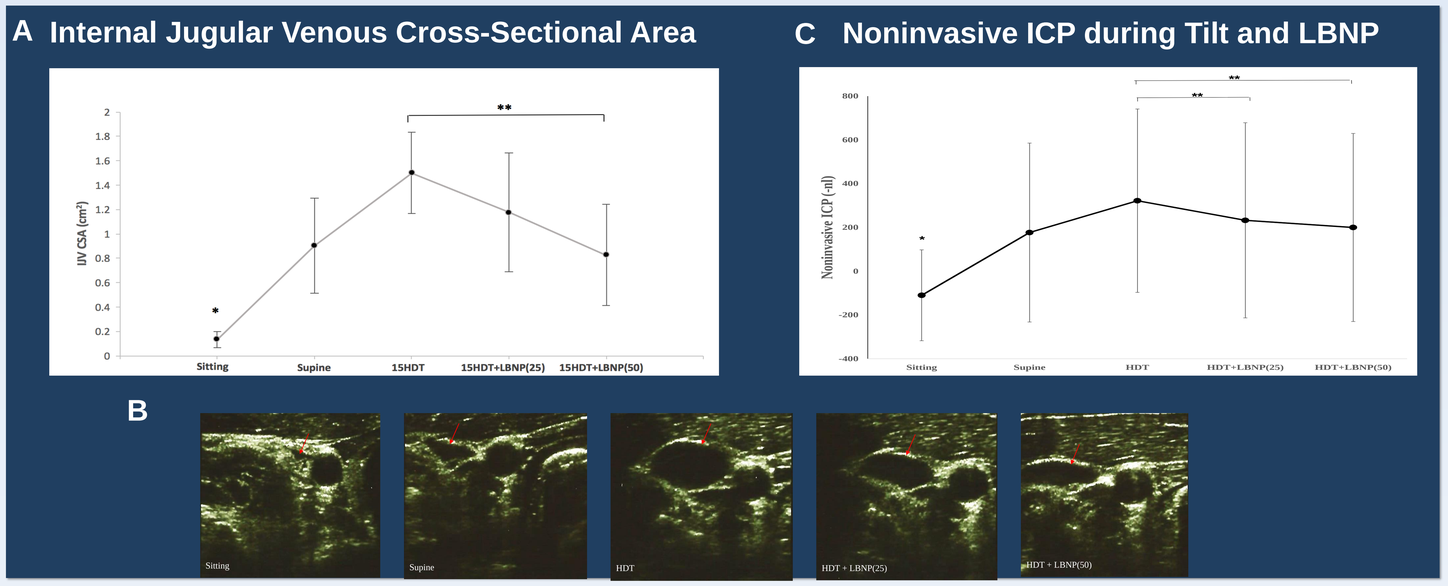

Figure 3. A and B: *IJV CSA; N=15 presented as mean ± SD cm² and ultrasound images from each of the five conditions. *Sitting posture significantly different compared to all other test conditions (p<0.05). ** Significantly different from HDT (p<0.05).* ***C:*** *mean ± SD of non-invasive estimates of ICP.*

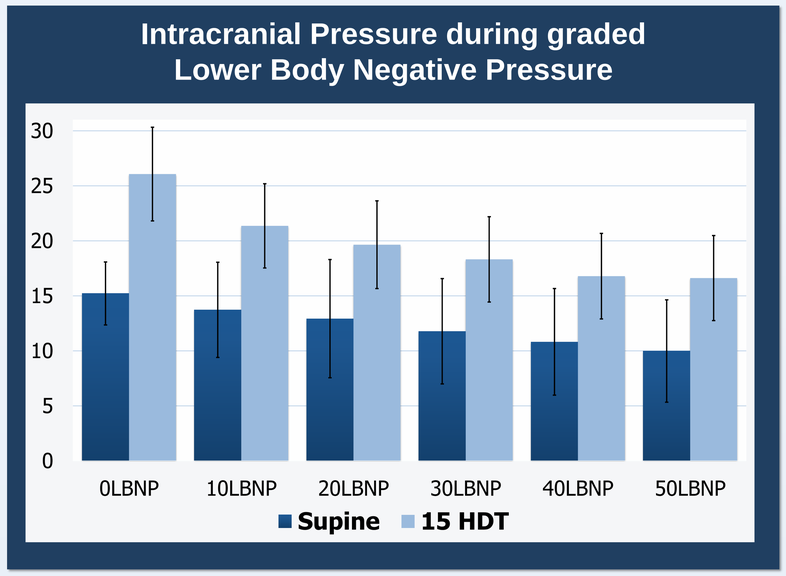

Figure 4. ICP relative to graded LBNP. *Direct invasive measurements of ICP in mmHg from supine and 15° HDT during graded application of LBNP from 0-50 at increments of 10 mmHg. N= 5 presented as mean ± SD*

DISCUSSION

LBNP counteracts the head-ward fluid shift, as evidenced by the reduction in ICP and IJV CSA experienced during 15° HDT simulated microgravity. Results from the 15 healthy subjects demonstrated that ICP, as measured by TMD, returned to supine values. This is supported by the direct measurement of ICP in 5 neurosurgical patients, who demonstrated increased responsiveness to LBNP in a simulated intracranial hypertension condition (HDT). Thus, in a situation of venous congestion and decreased cerebral compliance, which is a possible patho-physiological mechanism of VIIP, LBNP could be an efficient countermeasure.

Conclusion

LBNP shifts blood and other fluids from the head and neck to the lower body, thus reducing ICP and IJV CSA

ACKNOWLEDGEMENTS

Supported by NASA grant number NNX13AJ-12G; NSBRI grant number NCC 9-58, and the Novo Nordic Foundation grant number NNF15OC0019196. We thank all volunteers and patients who participated in this study, as well as colleagues and lab members.

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