TESTING MECHANICAL COUNTERMEASURES FOR CEPHALAD FLUID SHIFTS

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INTRODUCTION

Over the past several years, clinical observations by NASA have revealed evidence suggesting elevated intracranial pressure (ICP) in astronauts. Visual signs predominate, including disc edema, globe flattening and choroidal folds. In a few cases, clinically relevant visual symptoms have persisted over 3+ years, and in a handful of astronauts elevated ICP has been found days or months post-flight, as measured by lumbar puncture.. This visual impairment and intracranial pressure (VIIP) condition varies notably across astronauts. Contributing factors are poorly understood, but globe flattening in several astronauts with VIIP suggests an elevation in ICP. While the evidence for elevated ICP remains partially circumstantial and the etiology remains unknown, the VIIP risk is of sufficiently high priority—and the circumstantial evidence is sufficiently strong—that investigations of countermeasures for elevated ICP appear warranted. To date, no countermeasures have been tested for VIIP, although two countermeasures have been utilized in spaceflight to limit or counteract in-flight cephalad fluid shifts (and related cardiovascular changes): (1) Russian-made Braslet thigh cuffs, and (2) lower-body negative pressure. Both serve to help redistribute blood from the upper body into the lower extremities, to achieve a more Earth-equivalent fluid distribution, but both have operational challenges ranging from availability, to obtrusiveness, to calibration.

METHODS & RESULTS

This project seeks to investigate two commercial devices as mechanical countermeasures to elevated ICP. The Lymphapress device (Figure 1A) is normally used in lymphedema patients as a therapeutic massage to squeeze fluids towards the abdomen, but it can also be configured to compress fluids the other way, towards the legs, to help counter the effects of cephalad fluid shifts and elevated ICP. The Kaatsu system (Figure 1B) is designed to enhance muscle training but is similar to the Russian Braslet devices, enabling sequestration of fluid in the legs via restriction of venous return. We will test these devices in both neurointensive care unit patients with invasive ICP monitors, as well as in healthy subjects undergoing head-down tilt (HDT). A range of neurophysiological measures will be collected including near infra-red spectroscopy (NIRS), transcranial Doppler, ocular ultrasound, and more direct ICP measurements (Camino, Vittamed, Headsense). In addition to ICP changes, we will examine the physiological effects of countermeasure release-rate, as well as changes in physiological response associated with longer-duration use. Initial NIRS tests suggest Kaatsu may decrease the amplitude of cephalad fluid shifts (Figure 1C).

Figure 1: (A) Photo of Lymphapress system that uses air-bladders to squeeze fluids from one part of the body to another. (B) Photo of Kaatsu inflation-bands used to restrict venous return from the extremities. (C) Example NIRS data showing a smaller increase in oxy- and total-hemoglobin (red & black curves) during HDT (between marker-pairs) when Kaatsu is applied (bottom panel) versus not applied (top panel). Inset: Kaatsu during HDT.

DISCUSSION

This project will test whether either or both of these mechanical approaches could be used to help reduce ICP, thereby providing some of the first evidence of the suitability of mechanical countermeasures to ICP management. This work will also help determine relevant protocol(s) for gaining the maximum benefit and minimal side effects from each device in this capacity. Importantly, the devices are easy to acquire, are well supported, and have form factors that are suitable for spaceflight. The form factor would potentially even allow each astronaut to have their own device to use as-needed, rather than requiring timesharing of equipment.

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