MITIGATING HEADWARD FLUID SHIFTS WITH VENO-CONSTRICTIVE THIGH CUFFS DURING SPACEFLIGHT

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BACKGROUND

Astronauts experience a chronic headward fluid shift in weightlessness as evidenced by increased cardiac output,[1] decreased leg volume,[2] a redistribution of venous fluid,[3] and venous congestion in the upper body.[4] Alterations in cerebrospinal fluid hydrodynamics[5] and changes in cerebral venous pressure[6] secondary to the headward fluid shift may contribute to ocular changes associated with spaceflight-associated neuro-ocular syndrome (SANS). Veno-constrictive thigh cuffs (VTC; Braslets) provided to Soyuz crewmembers alleviate symptoms of the headward fluid shift during the first week of spaceflight and have been documented to reduce internal jugular vein (IJV) distension during weightlessness.[7] Application of VTCs designed collaboratively by NASA Johnson Space Center Cardiovascular and Vision Laboratory (CVL) and Clemson Textile Laboratory at Clemson University to improve fit and comfort was documented to mitigate changes in choroid thickness, intraocular pressure, and IJV area during posture-induced headward fluid shifts.[8,9]

VTC are demonstrated to reduce headward fluid shifts in both ground-based and spaceflight studies, and thus, may be a countermeasure against development of SANS. In addition, VTC are a simple mechanical countermeasure currently at a high technical readiness level (TRL) and are compact and lightweight, making them compatible with the spaceflight operations environment.

SPECIFIC AIM

To demonstrate efficacy of VTC application to mitigate a spaceflight-induced headward fluid shift.

We hypothesize that a VTC countermeasure will temporarily reverse or attenuate ocular and cardiovascular changes. In addition, the study protocol is designed to investigate what effect extended duration countermeasure exposure (~6 hours of compression at 50mmHg) has on our outcome variables.

PROJECT STATUS

CVL, Human Research Program Flight Hardware Engineering, Research Operations and Integration, and Clemson University Textile Laboratory are collaboratively preparing VTC hardware to support the flight experiment. The study has been reviewed and approved by the NASA and ESA Institutional and Human Research Multilateral Review Boards and is being considered for implementation on future ISS missions. Recently, the Flight Hardware Engineering team has integrated a pressure transducer into the cuff in order to directly measure VTC skin contact pressure.

The VTC device is expected to be flight-ready in early 2023 along with supporting experiment documentation. VTC study team are developing inflight operational procedures for VTC application during spaceflight. Data will be collected using remote guidance. A first flight and data collection onboard the International Space Stations (ISS) is anticipated in 2024.

APPROACH

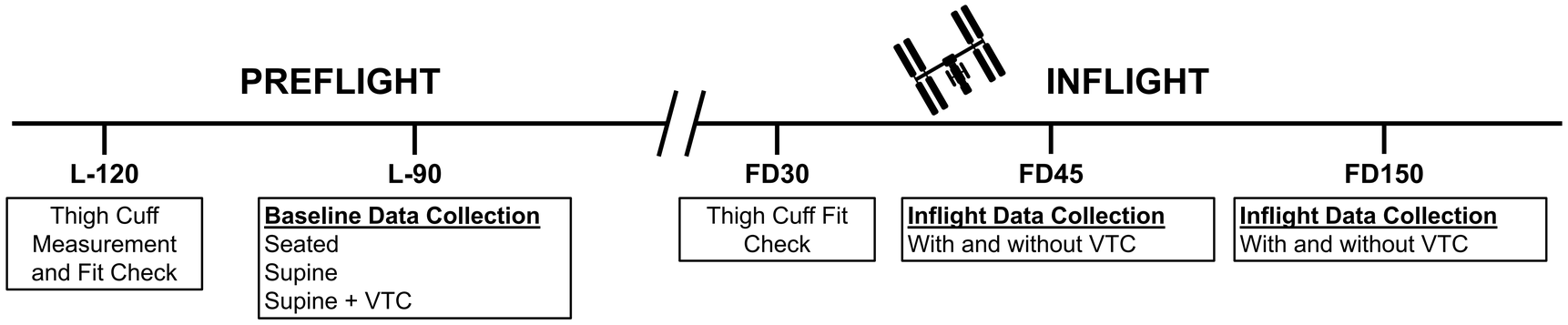
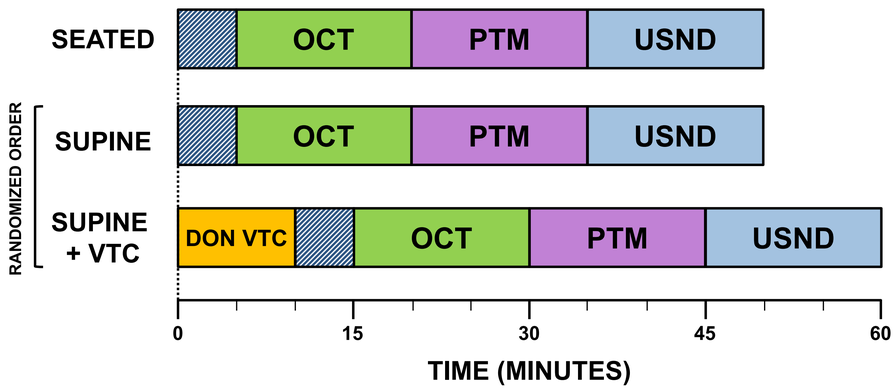


Figure 1. Thigh Cuff Study Timeline. This study will assess the efficacy of VTC to mitigate headward fluid shifts in 10 astronauts before and during 6-month spaceflight missions to the ISS. Prior to launch, crewmembers will participate in measurement and fit check sessions where skin contact pressure and ultrasound imaging of venous flow in the legs will be measured to verify appropriate VTC fit. Similar assessments will occur before and during VTC countermeasure use during spaceflight.

Baseline Preflight Data Collection



Inflight Data Collection

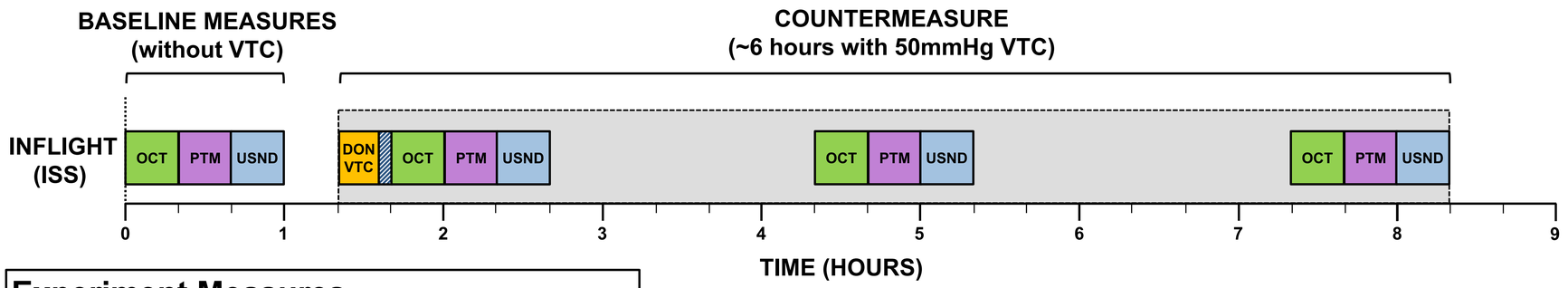


Figure 2. Data Collection Timeline. Optical coherence tomography images of the retina, intraocular pressure, ultrasound measurements of stroke volume, cardiac output, internal jugular vein area and pressure, and femoral artery and vein flow will be collected approximately 90-days before spaceflight (**Baseline Preflight Data Collection**) and at 45 and 150 days during spaceflight (**Inflight Data Collection**). Preflight data will be collected in the seated and supine postures without VTC and in the supine posture with VTC. During spaceflight, data will be collected prior to donning the VTC as well as at three time points (~30 minutes, 3 hours, and 6 hours) during use of VTC. Crewmembers will provide feedback on comfort and use of VTC before and during spaceflight.

Experiment Measures

- Optical Coherence Tomography (**OCT**)
  - Total retinal thickness, minimum rim width, retinal nerve fiber layer thickness, choroid thickness
- Pneumotonometry (**PTM**)
  - Intraocular pressure
- Ultrasound (**USND**)
  - Cardiac output and stroke volume
  - Internal jugular vein cross-sectional area, pressure, and flow characterization
  - Femoral artery and vein blood flow
- System Usability Survey (**SUS**) for comfort and ease of operation
  - Conducted preflight and inflight after each session

COLLABORATORS

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