FLUID SHIFTS BEFORE, DURING AND AFTER PROLONGED SPACE FLIGHT AND THEIR ASSOCIATION WITH INTRACRANIAL PRESSURE AND VISUAL IMPAIRMENT

M. Stenger[1], S. Lee[1], S. Platts[2], A. Hargens[3], B. Macias[3], J. Lui[3], D. Ebert[1], A. Sargsyan[1], and S. Dulchavsky[4], I. Alferova[5], E. Yarmanova[5], V. Bogomolov[5].

[1]Wyle Science, Technology & Engineering Group, [2]NASA Johnson Space Center, Houston, TX, Houston, TX, [3]University of California, San Diego, CA, [4]Henry Ford Hospital, Detroit, MI, and [5]Institute of Biomedical Problems, Moscow, Russia

INTRODUCTION

With the conclusion of the Space Shuttle program, NASA is focusing on long-duration missions on the International Space Station (ISS) and future exploration-class missions beyond low Earth orbit. Visual acuity changes observed in Space Shuttle crewmembers after their short-duration missions were largely transient, but more than 30% of ISS astronauts experience more profound changes in vision, some with objective structural and functional findings such as papilledema and choroidal folds on ophthalmologic examination. Globe flattening, optic nerve sheath dilatation, optic nerve tortuosity, and other findings have been noted in imaging studies. This pattern is referred to as visual impairment and intracranial pressure (VIIP) syndrome. The VIIP signs and symptoms, as well as postflight lumbar puncture data, suggest that elevated intracranial pressure (ICP) is associated with the space flight-induced cephalad fluid shifts, but this hypothesis has not been systematically tested. The purpose of this study is to objectively characterize the fluid distribution and compartmentalization associated with long-duration space flight, and to correlate the findings with vision changes and other elements of the VIIP syndrome. We also seek to determine whether the magnitude of fluid shifts during space flight, as well as the VIIP-related effects of those shifts, can be predicted by crewmember baseline data and responses to acute hemodynamic manipulations (such as head-down tilt tests) obtained before flight. Lastly, we will evaluate the patterns of fluid distribution in astronaut subjects on the ISS during the use of lower body negative pressure (LBNP) and respiratory maneuvers to characterize and explain general and individual responses during space flight.

METHODS

This study merged 3 distinct yet overlapping proposals that were submitted to NASA in response to a 2011 NASA Research Announcement. We will examine a variety of physiologic variables in 10 long-duration ISS crewmembers before, during and after long duration space flight. Several types of measures will be included: (1) fluid compartmentalization (total body water by D_2O dilution, extracellular fluid by NaBr dilution, intracellular fluid by calculation, plasma volume by CO rebreathing, interstitial fluid by calculation); (2) tissue thickness by ultrasound (forehead/eyelids, tibia, calcaneus); (3) vascular size by ultrasound (jugular veins, cerebral and carotid arteries, Rosenthal vein, vertebral arteries and veins, portal vein); (4) vascular dynamics by MRI (head/neck blood flow, cerebrospinal fluid pulsatility); (5) ocular measures (optical coherence tomography, intraocular pressure, 2-dimensional ultrasound including optic nerve sheath diameter, globe flattening, and retina-choroid thickness, Doppler ultrasound including central retinal artery and vein, ophthalmic and ciliary arteries, and superior ophthalmic vein); (6) cardiac variables by ultrasound (inferior vena cava, tricuspid flow and tissue Doppler, pulmonic valve, stroke volume, right heart dimensions and function, four-chamber views); and (7) ICP measures (tympanic membrane displacement, distortion-product otoacoustic emissions, optic nerve sheath diameter, ICP calculated by MRI, and postflight lumbar puncture if medically indicated). On the ground, acute head-down tilt will be used as a means to induce cephalad fluid shifts whereas LBNP will be used to oppose these shifts. Controlled Mueller maneuvers (negative intrathoracic pressure) will be used to further manipulate cardiovascular variables. The combination of these interventions applied before, during, and after flight will be used to fully evaluate the relationship between fluid shifts and the VIIP syndrome.

CURRENT STATUS

The NASA Johnson Space Center Institutional Review Board has approved this study for implementation and it is currently in the select-for-flight process. Flight hardware has been ordered and is being certified, and ground testing hardware is being certified and evaluated. A ground-based shakedown study to finalize the study protocol is scheduled to begin late fall 2013. The current plan is to begin the in-flight portion of this study with the one year crew, in 2015.