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Acute Modifications of Circulating Volume and Respiratory Maneuvers in the Cardiovascular Assessment of Long-Duration Crewmembers

V.V. Bogomolov[1], I.V. Alferova[1], S.A. Dulchavsky[2], D. Ebert[3], K.M. Garcia[3], D.S. Martin[3], V.P. Matveev[4],S.L. Melton[3], A.E. Sargsyan[3], D.R. Hamilton[3], J.M. Duncan[5]

Institute for Biomedical Problems (Moscow, Russia) [1]; Henry Ford Hospital System (Detroit, MI)[2]; Wyle (Houston, TX)[3]; Gagarin Cosmonaut Training Center (Star City, Russia)[4]; NASA Johnson Space Center (Houston, TX)[5]

Introduction

This U.S. - Russian project is aimed at improved assessment of cardiac and vascular parameters associated with circulating volume and its distribution in long-duration space flight. Objective responses to modified Valsalva and Mueller maneuvers were measured by cardiac and vascular ultrasound before, during, and after temporary volume redistribution by means of Braslet-M thigh occlusion cuffs (Russia). Braslet-M cuffs are custom fitted to each crewmember prior to launch on the Soyuz as a Russian countermeasure for space adaptation fluid shifts.

Protocol

The study protocol was conducted in 14 sessions on 9 ISS crewmembers, with an average exposure to microgravity of 122 days. All data were collected by ISS crewmembers with remote guidance. Baseline cardiovascular measurements were taken by echocardiography in multiple modes (including tissue Doppler of both ventricles) and femoral and jugular vein imaging. The Braslet devices were then applied and measurements were repeated after >10 minutes. The cuffs were then released and the hemodynamic "recovery" process was monitored.

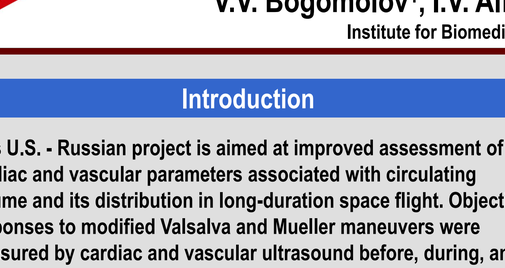

Figure 1: Diagrammatic view of the imaging protocol

Modified Valsalva and Mueller maneuvers using an ISS drinking straw as a means of providing resistance were used throughout the protocol. All ultrasound data were acquired by the HDI-5000 ultrasound system currently aboard the ISS (ATL/Philips, USA). The study protocol, including the use of Braslet-M for this purpose, was approved by the ISS Human Research Multilateral Review Board.

Figure 2: Braslet-M application

Results

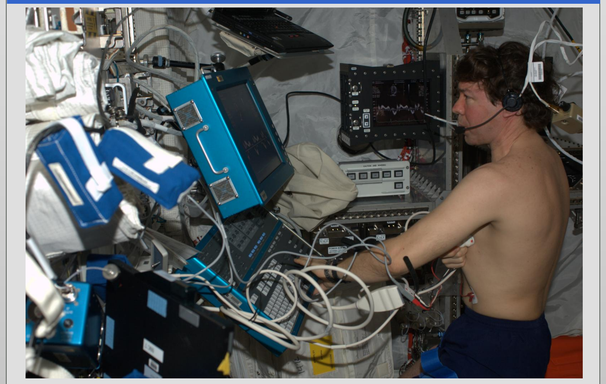

Figure 3: *Dr. Mike Barratt performing self scanning tissue Doppler. Note the Braslet-M devices in place on his upper thighs.*

Cardiac 2-D imaging

Figure 4: *Cardiac stroke volume with Braslet release (left ventricle); inset: apical four chamber cardiac 2-D image. Measurements are dependent on probe placement, prompting a greater reliance on tissue Doppler in later sessions*

Pulse wave Doppler

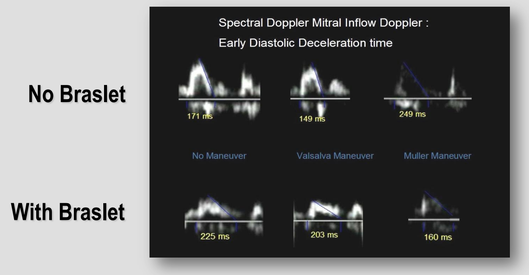

Figure 5: *Flow Doppler spectra of mitral valve inflow. Note the longer deceleration times with Braslet applied, indicating decreased cardiac preload.*

Results

Peripheral vascular 2-D imaging

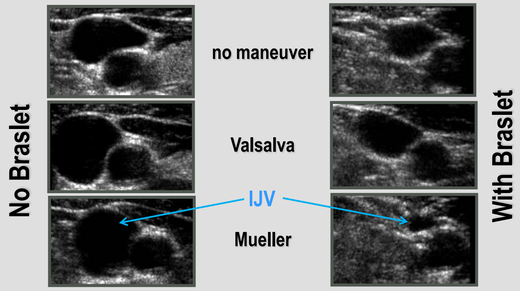

Figure 6: *Internal jugular vein (IJV) with and without Braslet. Note the collapse of the IJV with Mueller and Braslet applied.*

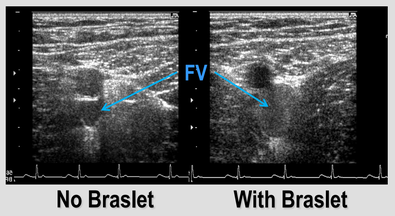

Figure 7: *Femoral vein (FV) with and without Braslet. Note the distention with Braslet application, indicating fluid sequestration in the legs.*

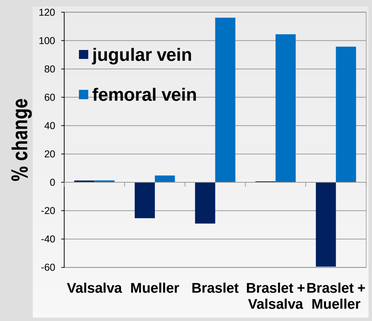

Figure 8: *Venous cross-section area change as compared to baseline (percent)*

Results

Tissue Doppler

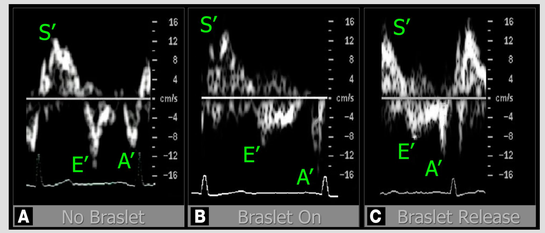

Figure 9: *Right heart tissue Doppler changes before Braslet, with Braslet, and during release. S'- systolic; E'- early diastolic; A'- late diastolic. Note the decrease in E' with Braslet.*

	% change	Stdev
A'	-1.66	24.03
E'	-29.60	16.00

Table: *Left heart tissue Doppler changes as a result of Braslet*

Discussion

Redistributed volume (central hypovolemia) in microgravity appears to be best detected by collapse of the jugular vein in response to Mueller maneuver and a decrease in E' (tissue Doppler). A secondary indicator of hypovolemia is the distension of the jugular vein in response to Valsalva maneuver.

The data validate a methodology to 1) address specific aspects of operational space medicine and space physiology, including assessment of circulating volume disturbances, and 2) expand diagnostic ultrasound imaging and Doppler techniques in microgravity. Respiratory maneuvers against the background of acute circulating volume manipulations enhance our ability to noninvasively demonstrate volume-dependency of a number of cardiac and vascular parameters.

Contact Information

Doug Ebert
Wyle Integrated Science and Engineering
1290 Hercules Ste 103, Houston, TX, 77058
E-mail: debert@wylehou.com
Phone: (281) 212-1243
Fax: (281) 212-1263