Space station investigation goes with the flow

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Samantha Cristoforetti conducts plethysmography and pulmonary function system measurements during Brain Drain investigation operations during Expedition 42 aboard the International Space Station. Credit: NASA

On Earth, blood flows down from a person's brain back toward the heart thanks in part to gravity, but very little is known about how this flow happens in microgravity. Many crew members aboard the International Space Station report headaches and other neurological symptoms in space, which may be related to microgravity's effect on cerebral blood circulation. The Drain Brain investigation, which was completed in July 2015, measured the blood flow from the brain to the heart of one crew member to help researchers better understand how the flow is affected by microgravity and which physical processes in the body can compensate for the lack of gravity, ensuring blood flows properly.

Cerebral blood circulation is one of the major regulators of human brain physiology. Due to the variability and complexity of the cerebral venous system (the collection of veins in and around the brain), scientists currently lack an approach for reliably and objectively measuring the cerebral venous return (the blood flow from the brain to the heart through the jugular veins). Scientists do know that, on Earth, the return is influenced by gravity when subjects are upright, and by respiration, or breathing, when subjects are laying down. However, very little is known about the mechanisms ensuring blood outflow from the brain in microgravity.

In an effort to measure this outflow, a research team led by Paolo Zamboni, MD, University of Ferrara in Italy, developed a strain-gauge plethysmography system to investigate these processes. The instrumentation was used aboard the space station both to study cerebral venous return in microgravity conditions, and to properly understand the phenomena of physiological adaptation.

Strain-gauge plethysmography is a non-invasive technique that measures variations in blood flow from the brain to the heart using a stretch sensor encircling the neck and the upper and lower extremities. The instrument was developed by the team and used for the first time in 2012 to assess the cerebral outflow comparing healthy subjects with patients affected by multiple sclerosis.

Training of Samantha Cristoforetti with high resolution vascular ultrasound images directed by PI Paolo Zamboni, MD. This system, synchronized with ECG, was used in flight to implement the plethysmography data. Credit: Paolo Zamboni, MD

"I was interested in measuring venous outflow, but current echo Doppler methodologies and other diagnostic systems are affected by very low repeatability, technical problems, and operator dependency," said Zamboni. "The challenge was to invent a non-invasive device with good repeatability."

The device is easy to use, not operator-dependent, non-invasive and portable. The protocol was implemented by high-resolution ultrasound video-clips showing in real-time the pulsation, or throbbing, of the carotids and jugulars, synchronized with electrical activity of the heart as illustrated in an electrocardiogram. Data from this investigation may contribute a more comprehensive picture of the heart-brain interaction in microgravity conditions.

During two pre-flight sessions, four in-flight sessions and two post-flight sessions, European Space Agency (ESA) astronaut Samantha Cristoforetti was monitored using the plethysmographs during normal activity, muscular activity and respiratory activity.

She described her experience in a January 2015 blog post: "While wearing these collars on my neck, arm and leg, I performed a series of breaths at 70% of my lung capacity, either remaining still or stretching and flexing my hand or my ankle. While doing that, I was breathing into our Pulmonary Function System and the software, via a graphic interface, was giving me instructions on when to start exhaling or inhaling." This allowed investigators to measure her cardiac pulse, the inflow of blood to the brain and the jugular pulse (the major outflow from the brain to the heart).

Zamboni incorporated the respiration and muscular activities into the Drain Brain protocol to better understand whether physical processes like these can compensate for the lack of gravity to ensure blood flows properly. While the instrumentation and protocol were successful, the investigation included only one test subject, so Zamboni recognizes the need to recruit additional subjects for future studies to ensure repeatability and to gather additional data.

"We need [to study] at least 15-20 subjects to ensure the data we gather is robust and so we can be more confident in our conclusions," said Zamboni.

The investigation's success could help scientists develop countermeasures that will influence the future of human spaceflight on long-duration missions.

It could also impact the medical community on Earth, especially for physicians treating patients with chronic heart failure and neurological disorders. The strain-gauge plethysmography, complemented by ultrasound analysis of the jugular pulse, could potentially make measuring blood flow in these sets of patients much easier, allowing patients and doctors to better go with the flow.

Provided by NASA

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