As gravity wanes and pressures gain, it's pain and bane for the brain

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Tom Hegstad, a mechanical engineering major, works on the outer frame of the modeling device.

In space, the old movie slogan declares, "no one can hear you scream." On the other hand, you might look like it, with puffy face, swollen eyes and distended neck veins. This is what happens when, screaming or not, bodily fluids shift in the absence of gravity. They surge inward and headward, elevating pressures inside the skull – and the risk of long-term vision impairment caused by engorged blood vessels impinging upon optic nerves.

NASA astronauts and scientists have long been aware of the phenomenon, but finding a remedy requires understanding exactly what's happening inside the heads of space travelers floating weightlessly hundreds of miles above Earth – and beyond.

That's where a group of students from the University of California, San Diego and Grossmont Community College come in. They've designed a set of experiments to precisely measure intracranial pressures in microgravity using a contraption that mimics the circulatory system of the human brain.

In mid-July, the students (four UCSD students majoring in bioengineering, physiology, neuroscience and mechanical engineering and a Grossmont Community College student studying cardiovascular technology) will travel to the Johnson Space Center in Houston, Texas where they will conduct their experiments aboard a NASA plane swooping up and down in parabolic flight, each arc of the roller coaster ride producing 20 to 30 seconds of near-weightlessness. The flights are part of NASA's competitive "Microgravity University" program, which provides selected students with a rare chance to conduct research in near-zero gravity.

The UCSD/Grossmont students, who call themselves the "Saganites" after the late astronomer and science popularizer Carl Sagan, have designed a device that models fluid flow in the brain: a see-through box of Lexan panels containing assorted tubes, pumps and pressure sensors. The tubes, whose different sizes and diameters represent different arteries and veins, will be filled with a mixture of water, glycerin and xanthan gum to mimic the viscosity and other fluid properties of blood. The box itself will be filled with water to represent incompressible brain tissue.

The idea is to measure how "blood" and other cranial fluids behave in microgravity, with the hope that the findings might shed light upon intracranial pressure (ICP) in astronauts. That's something not easily deduced on Earth, where the best replications involve test subjects lying on a bed tilted six degrees head-down for long periods of time. As uncomfortable as that sounds, the measurable effects of ICP on Earth are not nearly as pronounced as they are in actual space.

"There's always some gravitational force on Earth, no matter what posture you take. If you lie head down, fluids flow toward your head, but g-forces also pull these fluids chest to back. The only way to eliminate these effects is in parabolic flight or in space," said Alan Hargens, PhD, a professor of orthopedic surgery in the UCSD School of Medicine, former NASA researcher and the Saganites' faculty advisor.

Weightless migration of bodily fluids produces a plethora of problematic symptoms. Astronauts experience nausea, headaches and chronic sinus congestion. Odder things happen too. For example, the thickness of skin over the tibia (shinbone) decreases 20 percent while the thickness of forehead skin grows about 10 percent. These altered thicknesses, along with most of the other symptoms, return to normal or disappear when their owners return to Earth.

It's the increased risk of lasting harm, such as vision loss, that primarily concerns NASA officials and the Saganites. Their hypothesis, said J.R. Bachman, the 31-year-old student team leader studying bioengineering at the Jacobs School of Engineering, is that once blood escapes the downward pull of gravity, much of it floods into the skull, dramatically boosting intracranial pressure and subsequent physical problems. The effect may hit younger astronauts harder because their brains tend to be plumper, with less room to spare inside the skull. (Aging eases this problem. Adult brains shrink an average of about two milliliters per year, or roughly one-fifth of a teaspoon.) The Saganites will test two versions of their brain model, one to broadly represent the cephalic circulatory system of the youngest American astronaut, Sally Ride, who flew aboard a space shuttle mission in 1983 at the age of 32; the other to reflect that of the oldest American astronaut in space: John Glenn, who returned to space in 1998 at the age of 77.

Not all of the Saganites' efforts are aimed upward. A major component of their project is an outreach effort to promote science awareness and the adventure of research. Specifically, the students are working with 7th grade students at Mar Vista Middle School in Chula Vista. "Our main focus is to get students to think like scientists," said Bachman. "We have them brainstorm, come up with hypotheses and collect data to test their hypotheses."

Indeed, the Saganites hope to save a few of their parabolic flights to carry out simple experiments proposed by the 7th graders. "These kinds of activities not only pique the interest of students, they help boost test scores and measurable achievement," said Maria Catalina, a science and math teacher at Mar Vista who has actually participated in weightless flights herself and is working with the Saganites through the Astronaut Teacher Alliance. "There's just something inside human beings that excites us about space flight and travel."

The UCSD students are also giving public presentations at science fairs and meeting with science students at Grossmont College. Their next public appearance will be at Space Day at the San Diego Air & Space Museum in Balboa Park on May 28, and will include an opportunity for visitors to spend time upside down on a tilt table.

"The most fun part of these events is seeing the various ways kids respond to being tilted upside down," said Bachman. "Their reactions range from a cautious curiosity to exuberant laughter. The message we want kids and their parents to leave with is that the absence of gravity causes fluids to shift toward astronaut's heads, and that this is one of the most serious health challenges that they face while living in space. What better way to drive this message home than to allow kids to experience the headward fluid shift for themselves while their parents take pictures of them hanging upside down with their faces flushed red?"

Provided by UC Davis

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