Breathing drives CSF: Impact on spaceflight disease and hydrocephalus

Hans-Christoph Ludwig[a], Jens Frahm[b], Jutta Gärtner[c], and Steffi Dreha-Kulaczewski[c,1]

With great interest we have read the article in PNAS by Van Ombergen et al. (1) asserting that long-duration spaceflights cause persistent enlargement of brain cerebrospinal fluid (CSF) spaces in cosmonauts. Remarkably, the postflight ventricular volume changes in the lateral ventricle correlate positively with visual acuity loss—a well-known sequela of the Spaceflight-Associated Neuro-ocular Syndrome (SANS) (2). The underlying mechanisms of SANS, which comprises various structural ocular abnormalities such as globe flattening and optic disk edema (3), are still unclear. However, the current findings seem to indicate a link between changes of brain CSF spaces and the formation of SANS. In a previous structural MRI study of cosmonauts van Ombergen et al. (4) demonstrated a postflight reduction of brain white and gray matter volumes in addition to altered CSF spaces. In more detail, the latter findings refer to an increase of CSF ventricular volume and a decrease of CSF space below the vertex (4). Together, these observations corroborate, as concluded by the authors, disturbances of CSF circulation as the underlying cause. We fully agree with the authors that a shift of CSF and not blood volume underlies these processes in microgravity and thus may lead to spaceflight disease including SANS. Interestingly, the respective disturbances apparently are sustained as long as 7 mo after spaceflight (1, 4).

Our recent real-time MRI (5, 6) studies of CSF flow unraveled respiration and thus the associated pressure changes in thoracic and abdominal cavities as dominant regulators of CSF dynamics (7, 8). Forced inspiration drives CSF upward along the entire spinal canal into the head and brain ventricles against the hydrostatic pressure. The concurrent venous outflow from the brain and cranial cavity toward the heart is enhanced during inspiration and hence counterbalanced by the upsurge in the CSF system. Both closely connected and interdependent fluid systems act compensatory to each other in order to keep the intracranial volume constant, in agreement with the Monro–Kellie doctrine (7). In contrast, during deep expiration CSF moves predominantly caudal toward the spinal lumbar region, facilitated by hydrostatic forces (8). Microgravity and associated attenuation of hydrostatic pressures are likely to diminish these downward dynamics, so that the resulting prevalence of upward CSF flow may enhance net flow volumes into the head and thereby enlarge intracerebral CSF spaces. The deleterious role of the imbalance between up- and downward CSF movements driven by respiration has recently been demonstrated for the evolution of hydrocephalus in the presence of an obstruction (9).

Forced breathing, in particular deep expiration, might be a measure to counteract the changes generated during spaceflight. Further studies will unravel the pathoetiology and offer preventive or therapeutic options for spaceflight disease as well as for human diseases caused by perturbed CSF circulation like hydrocephalus or idiopathic intracranial hypertension.

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[a]Section of Pediatric Neurosurgery, Department of Neurosurgery, University Medical Center Göttingen, 37075 Göttingen, Germany; [b]Biomedizinische NMR, Max Planck Institute for Biophysical Chemistry, 37077 Göttingen, Germany; and [c]Department of Pediatrics and Adolescent Medicine, Division of Pediatric Neurology, University Medical Center Göttingen, 37075 Göttingen, Germany

Author contributions: H.-C.L., J.F., J.G., and S.D.-K. designed research; J.F. and S.D.-K. performed research; S.D.-K. analyzed data; and H.-C.L., J.F., J.G., and S.D.-K. wrote the paper.

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[1]To whom correspondence may be addressed. Email: sdreha@gwdg.de.

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