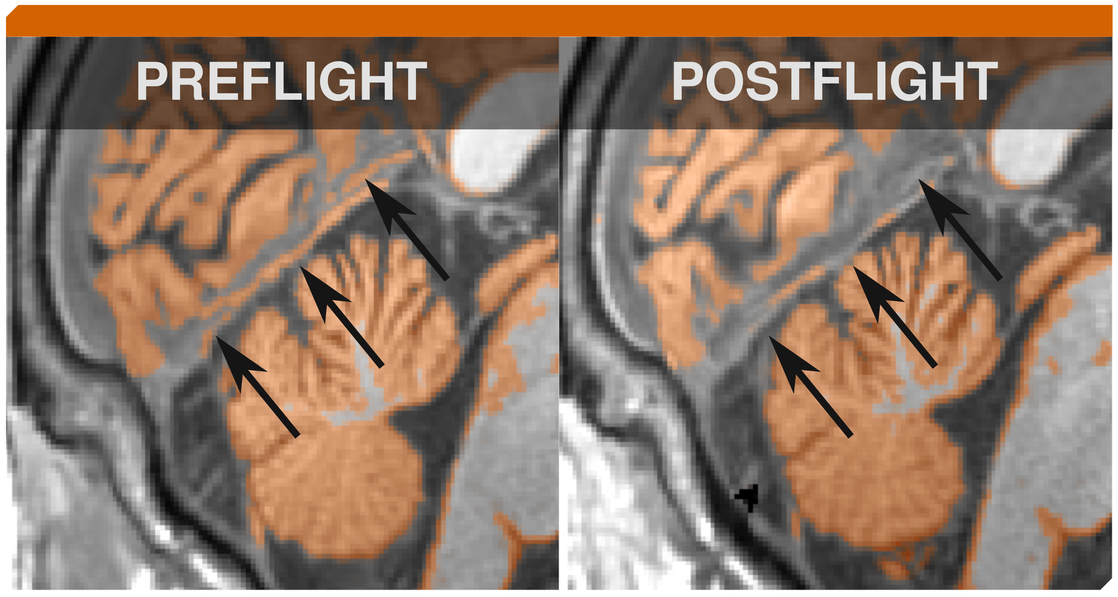
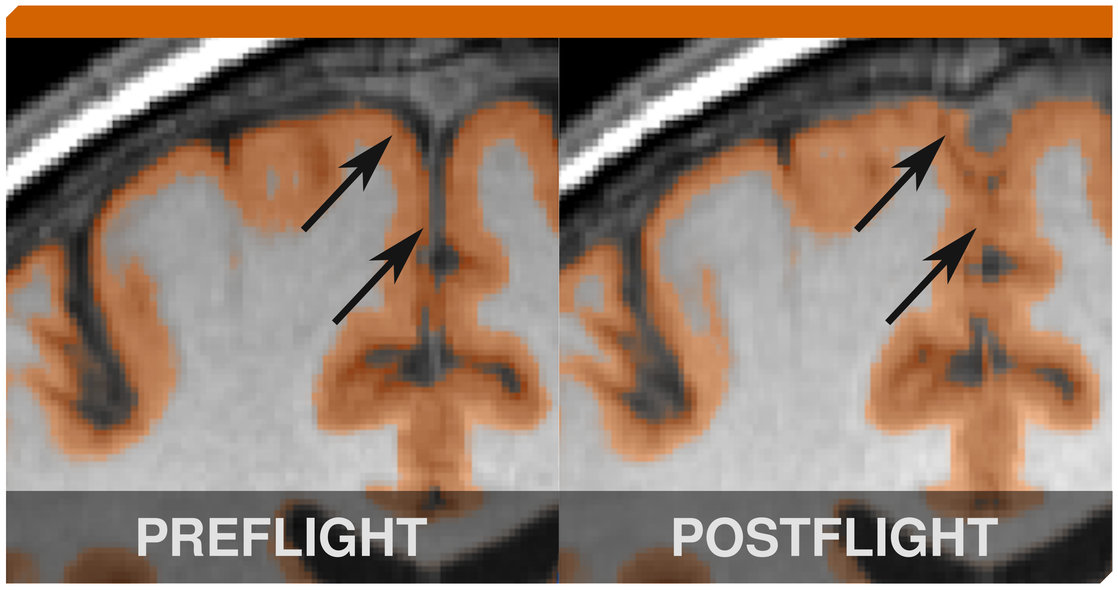
Errors cloud what we know about brain volume changes in spaceflight

Volumetric analyses of grey matter using common software packages are corrupted with spatially-biased errors distinguishing grey matter from other tissues, ostensibly due to the redistribution of cerebrospinal fluid within the skull. Generally, studies have reported increased grey matter volume in dorsal portions of the brain, and decreases in some ventral portions. These effects are largely artifactual, and are **not evidence of the brain neuroplastically adapting to spaceflight**.

Decreases in segmentation errors at ventral sites produce artifactual grey matter losses.



Increases in segmentation errors at dorsal sites produce artifactual grey matter gains.



These changes are not evidence of the brain neuroplastically adapting to spaceflight.

THE UNRESOLVED METHODOLOGICAL CHALLENGE OF IDENTIFYING NEUROPLASTIC CHANGES IN ASTRONAUTS

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INTRODUCTION

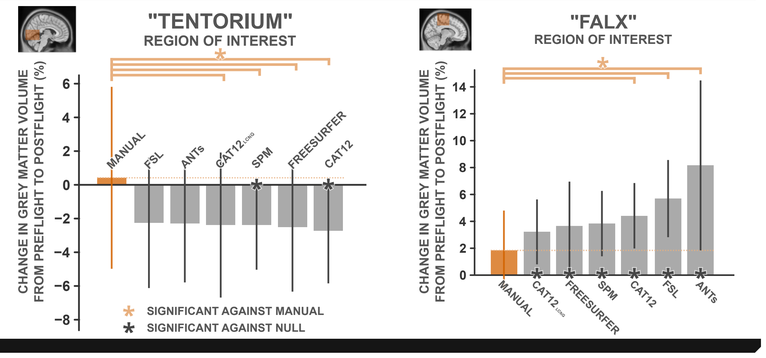
After spaceflight, astronauts display a salient upward shift in the position of their brain within the skull. This positional shift is accompanied by changes in cerebrospinal fluid (CSF) distribution[1-8]. CSF is not functional brain tissue, and changes in CSF volume are not directly interpretable as functional changes to the brain. Some previous studies have reported changes in grey matter volume[2,3,5,7,9], which could be interpreted as neuroplastic adaptations to spaceflight[10,11]. Here, we found evidence that the grey matter changes identified by typical automated processing pipelines are partially driven by misclassification of dural structures (i.e., connective tissue) as grey matter, as well as other sources of erroneous tissue identification.

METHODS

We analyzed structural MRI data from 43 astronauts, sourced from NASA's Lifetime Surveillance of Astronaut Health Program and the CSA 'Wayfinding' Project. Initial volumetric analyses in SPM12 revealed a pattern of results typically seen in previous studies of individuals who underwent spaceflight: increases in grey matter volume in dorsal portions of the brain, and decreases in ventral portions. We selected two regions of interest (ROIs) representative of these two general effects, a ventral ROI centered about the cerebellar tentorium (depicted in the top figure), and a dorsal ROI about the cerebral falx (depicted in the bottom figure). In a subset of our data (n = 10), we manually segmented the grey matter in these ROIs. We compared the change in grey matter volume in these ROIs agains that detected from typical automated pipelines in commonly-employed software packages (i.e. SPM12, CAT12, Freesurfer, ANTs, and FSL).

RESULTS

We found that manual segmentation identified negligible changes in grey matter volume due to spaceflight (Tentorium $p = .095$, Falx $p = .822$), whereas automated procedures occasionally identified changes in grey matter volume in the ventral Tentorium ROI ($.024 < ps < .131$), and regularly identified changes in the dorsal Falx ROI ($ps < .009$).



IMPLICATIONS

Our findings suggest that the brain volume changes detected using standard automated processing pipelines for neuroimaging analyses are contaminated by errors in identifying different tissue types. These errors prevent the valid interpretation of the results of such analyses as direct evidence of neuroplastic adaptation. While less susceptible to the types of errors depicted on the left, manual segmentation is far too labour-intensive to feasibly address these issues on whole-brain datasets, and it is also poorly equipped to address other sources of error, such as partial volume effects. Novel or alternate acquisition, preprocessing, or experimental paradigms are needed in order to resolve this important issue in space health research.

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