QUANTIFICATION OF OPHTHALMIC CHANGES AFTER LONG-DURATION SPACEFLIGHT, AND SUBSEQUENT RECOVERY

S. H. Sater[1], J. J. Rohr[1], A. M. Sass[1], B. R. Macias[2], K. Marshall-Goebel[2], R. J. Ploutz-Synder[3], S.S. Laurie[2], S. Greenwald[2], M. B. Stenger[4], B. A. Martin[1]

BACKGROUND

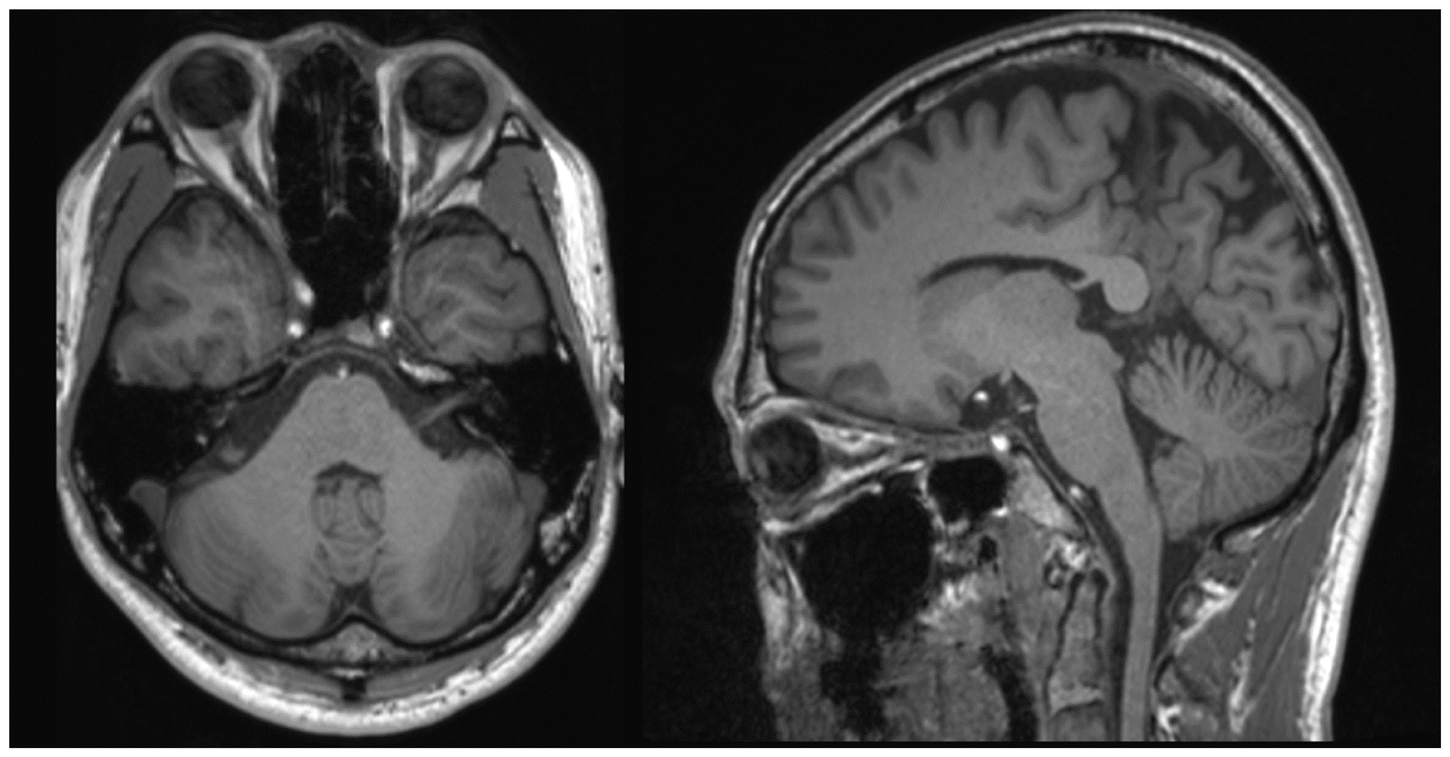

Fig.1: T1 MR image of ophthalmic structures.

A subset of crewmembers are subjected to ophthalmic structure changes due to long-duration spaceflight (>6 months). Crewmembers who experience these changes are described as having Spaceflight Associated Neuro-Ocular Syndrome (SANS). Characteristics of SANS include optic disk edema, cotton wool spots, choroidal folds, refractive error, and posterior globe flattening.

SANS remains a major obstacle to deep-space and planetary missions, requiring a better understanding of its etiology. Quantification of ocular, structural changes will improve our understanding of SANS pathophysiology. Methods were developed to quantify 3D optic nerve (ON) and ON sheath (ONS) geometries, ON tortuosity, and posterior globe deformation using MR imaging.

METHODS

Study Design: MRIs of 10 long-duration crewmembers (mission duration = 167 ± 17 days) were acquired at up to 6 time points; 1 preflight MRI, and 5 postflight MRIs (R+1-3, R+30, R+90, R+180, and R+360 days).

3D ON and ONS Geometry: A semiautomated, threshold-based segmentation method was applied to MR images to extract ON and ONS contours (**Fig. 2a**). Linear interpolation was applied to the obtain a contour located 3 mm posterior to the optic nerve head (ONH) (**Fig. 2b**) at which changes in cross-sectional area were quantified (**Fig. 2c**).

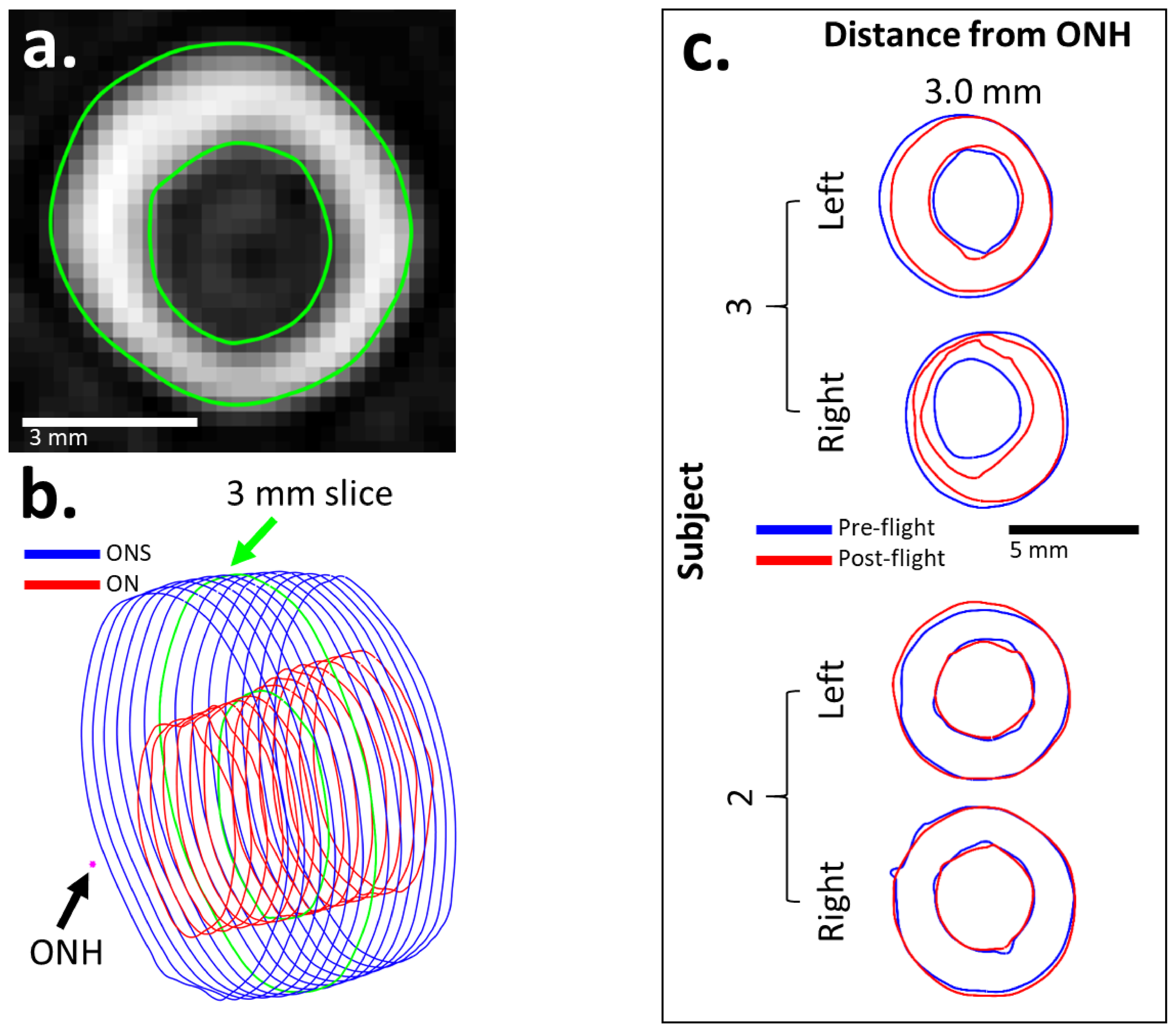

Fig. 2: **(a)** Example contour generation of the ON and ONS boundaries for a slice at 3 mm posterior to the optic nerve head. **(b)** Combined ON (red) and ONS (blue) contours for multiple slices including 3 mm slice contours (green), and **(c)** an example of pre- versus post-flight contours for two subjects.

METHODS CONT.

Tortuosity Assessment: ON tortuosity was manually assessed using T1 weighted MRI. Pre and postflight ON trajectories were generated using 3D curved, multiplanar reconstruction (**Fig. 3a**). Tortuosity was defined as the maximum orthogonal distance between the curved ON trajectory and a corresponding Euclidean line from optic nerve head to final point along ON pathway (**Fig. 3b**).

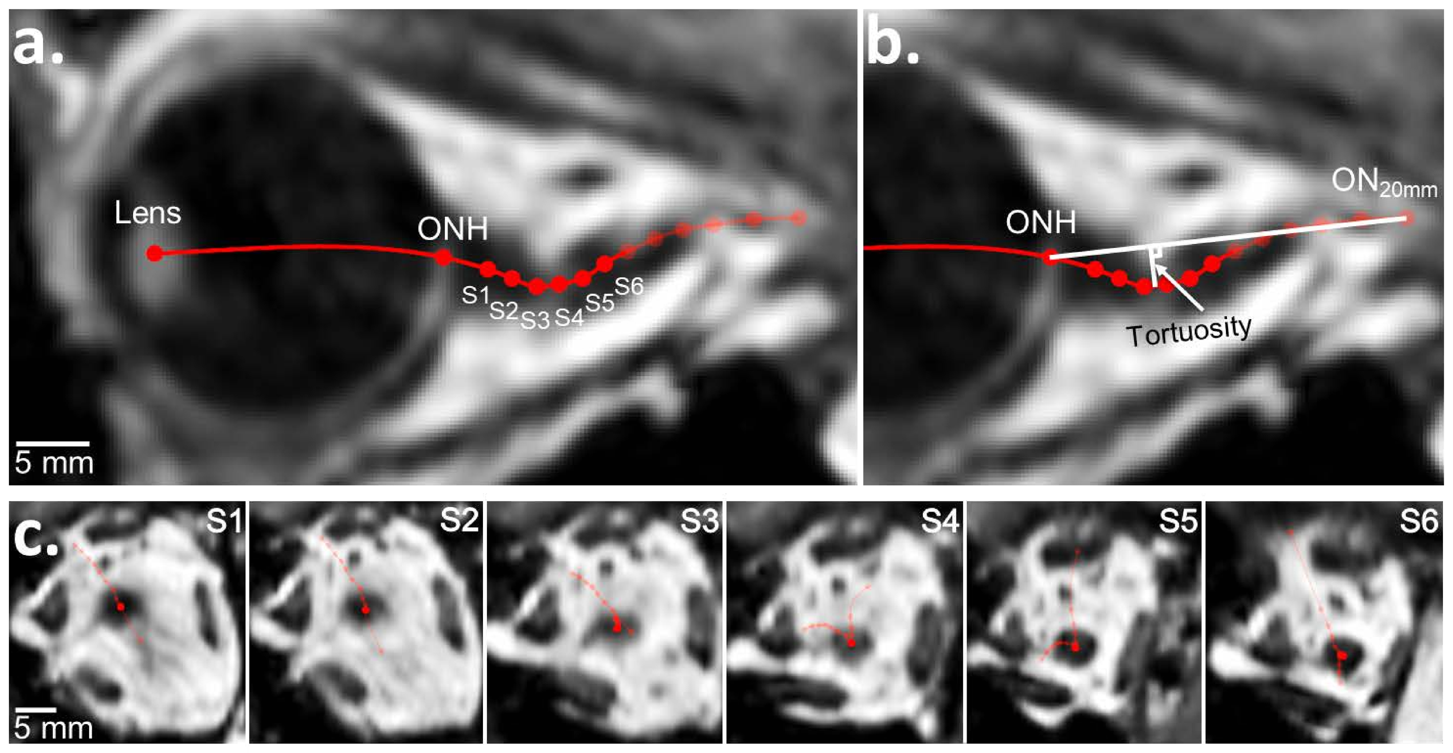

Fig. 3: **(a)** Visualization of ON pathway selections (red). **(b)** Visualization of the tortuosity parameter (white arrow). **(c)** 3D multi-planar reconstruction showing coronal view of each selection (S1-S6) along the same ON trajectory .

Optic Globe Deformation: MR images were radially resliced about a rotational axis at 1-degree intervals (**Fig. 4a**). Threshold-based segmentation of each rotational slice was performed to generate 3D point clouds (**Fig. 4b**). The resulting point clouds were aligned pre versus postflight using an iterative closest point algorithm (**Fig. 4c**). Volumetric deformation of the posterior globe was computed for a localized region within 4 mm of the ON head (ONH).

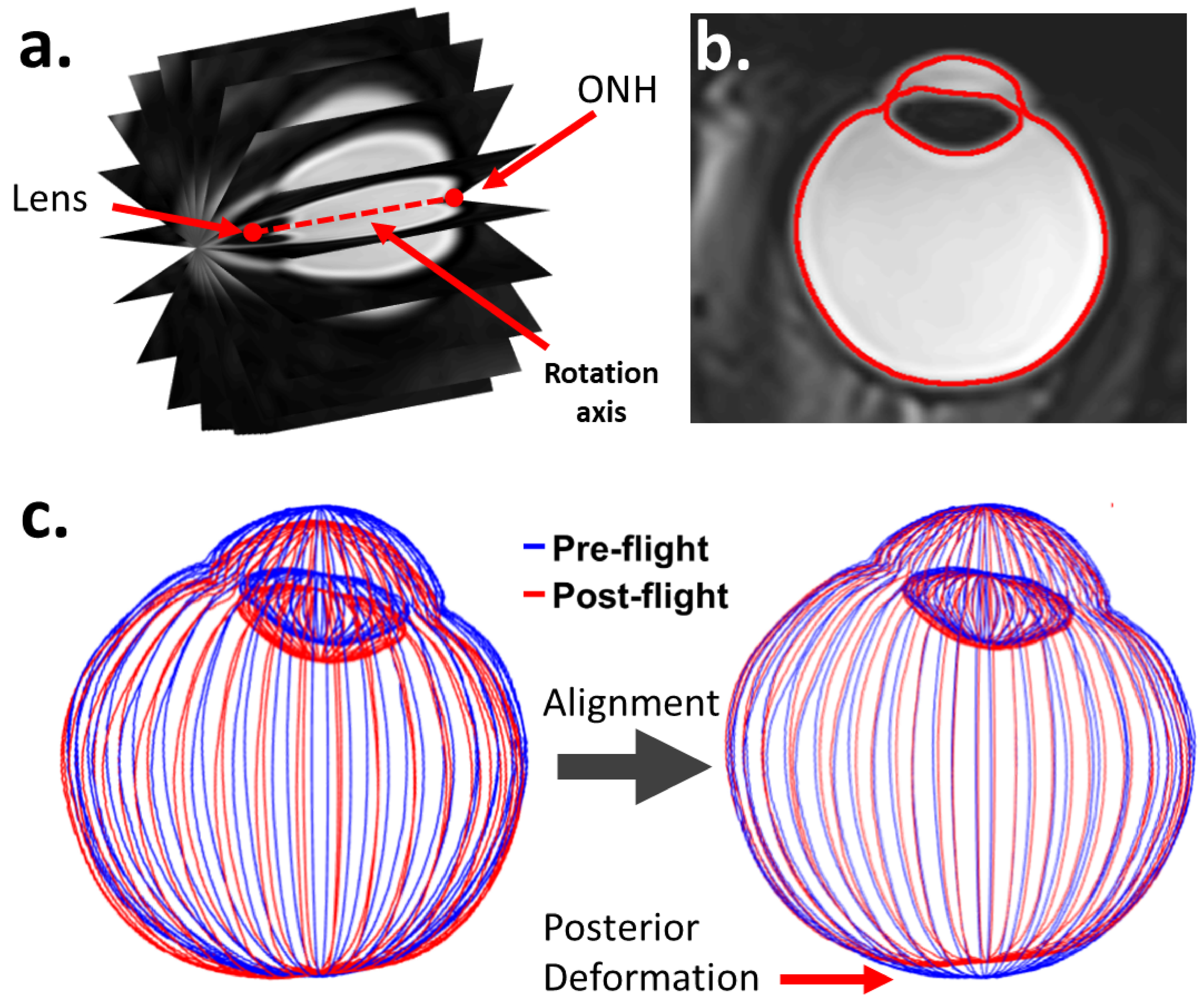

Fig. 4: Methods for segmenting T2-weighted axial MRI including **(a)** radial re-slicing, **(b)** segmentation, and **(c)** alignment of point clouds.

AFFILIATIONS & ACKNOWLEDGEMENTS

[1]Department of Biological Engineering, University of Idaho, Moscow, ID;
[2]Cardiovascular and Vision Laboratory, KBR, Houston, TX;
[3]Applied Biostatistics Laboratory, University of Michigan, Ann Arbor, MI;
[4]NASA JSC, Houston, TX

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RESULTS

Very little change was observed in the ON and ONS immediately post-flight, however, significant posterior globe deformation was identified (**Table 1**). Time series plots (**Fig. 5**) indicate that the most notable trend was observed in volume deformation wherein the deformation was most severe immediately postflight but subsided over time (**Fig. 5d**). It was also revealed that the subject with the greatest volume deformation was clinically diagnosed grade 1 optic disc edema via fundus imaging.

Table 1: Average change in key parameters with p-values between pre-flight baseline and immediate postflight values.

Parameter	Average Change	P-value
ON Cross-sectional Area	0.13 mm^2	1.00*
ONS Cross-sectional Area	-0.22 mm^2	1.00*
ON Tortuosity	-0.14 mm	1.00*
Posterior Globe Volume Deformation	10.76 mm^3	0.01

*Bonferroni adjusted

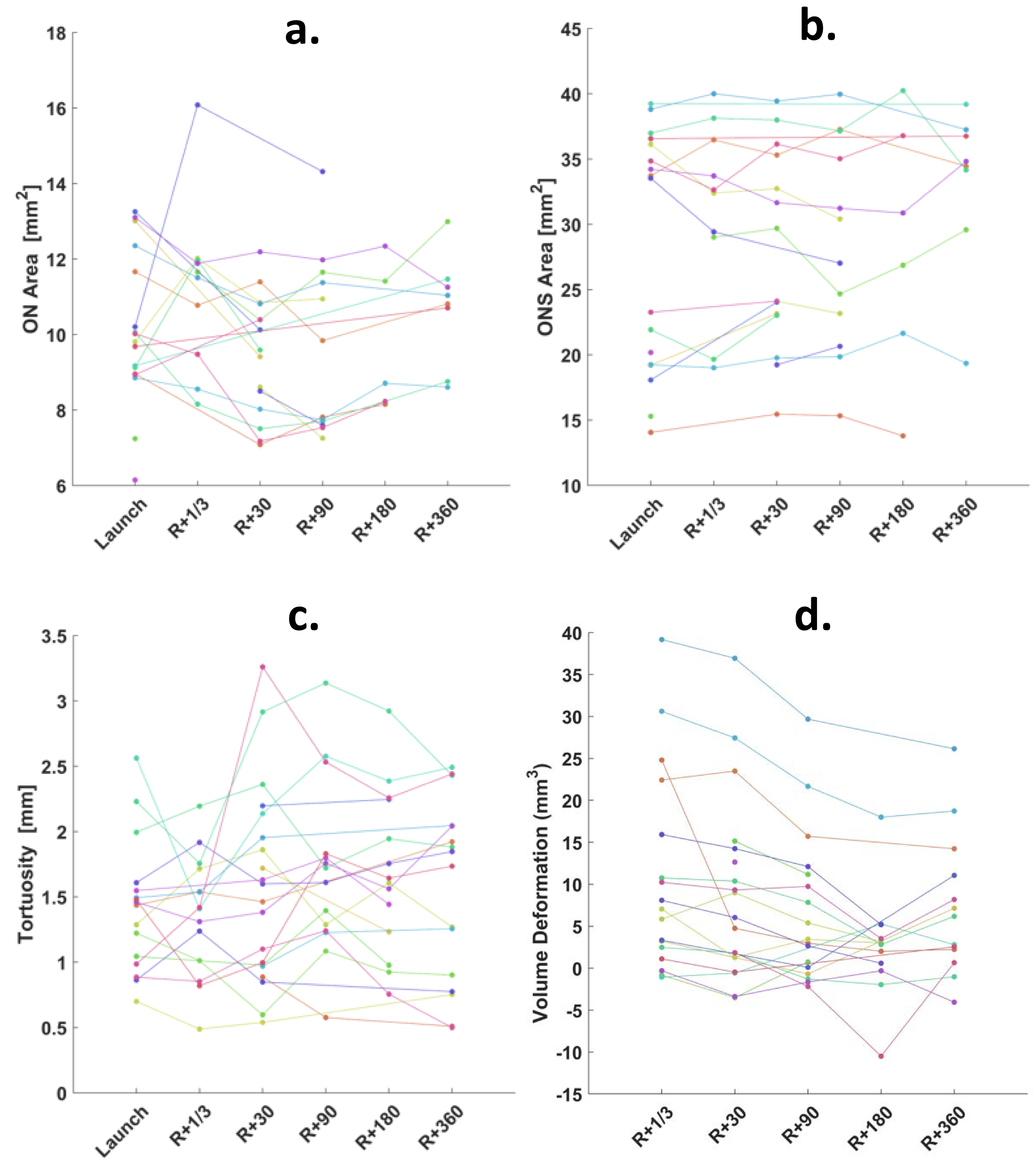

Fig. 5: Time series plots of **(a)** ON cross-sectional area, **(b)** ONS cross-sectional area, **(c)** ON tortuosity, and **(d)** posterior globe volume deformation within a 4 mm radius of the ONH.

CONCLUSION

ON tortuosity as well as ON and ONS cross-sectional areas remained largely unchanged after spaceflight while globe deformation was almost always present immediately postflight but diminished over time. The small sample size used in this study represents a major limitation. Thus, applying these methods to more crew members and a healthy control population is imperative for making more informative comparisons.