Brain Biomechanics Data

(updated 07/18/2023)

Site: Washington University in St. Louis (**WUSTL**)

Data Type: Magnetic Resonance Elastography (**MRE**)

Datasets Available: 52

Overview

Each dataset corresponds to a structural imaging acquisition (T1-w, T2-w, DWI), and a single multi-frequency (20, 30, 50, 70, 90 Hz) MRE data set acquired with an EPI sequence using 3 mm isotropic voxels. Skull vibration was induced by either a lateral or occipital actuator. All images were acquired on a Siemens Prisma Fit 3T scanner using a 20 channel coil. Detailed description of the data processing and acquisition of raw data can be found in Bayly et al. (2021) and Okamoto et al. (2023).

Information about each subject within the datasets are documented in a csv file in the data repository: U01_NITRC_subject_info_v04.csv

Description of Data Folders

The name of each folder consists of the subject ID (e.g. U01_WUSTL_0001), followed by the visit number. Four types of processed data are included for each subject.

A. Anatomy: "*_SLANT" (0.8 mm isotropic voxels, registered rigidly to MNI-152)

- *_ MPRAGEPre_norm_deface.nii.gz: the processed, defaced T1-weighted MPRAGE in MNI space.
- *_ 3DT2_norm.nii.gz: processed T2-weighted image in MNI space.
- *_ MPRAGEPre_norm_slant.nii.gz: segmented brain regions using SLANT-CRUISE.
- *_ brainmask.nii.gz: binary brain mask
- *_ falx.nii.gz: segmented falx
- *_ tentorium.nii.gz: segmented tentorium

B. Diffusion: "*_DWI" (0.8 mm isotropic voxels, registered rigidly to MNI-152)

- *_ DT.nii.gz: the processed diffusion tensor
- *_ DT_EV.nii.gz: the eigenvectors of the diffusion tensor.
- *_ DT_FA.nii.gz: the fractional anisotropy

C. MRE data (folder for each frequency, generally 20, 30, 50, 70, 90 Hz).

- All data is defined using the LPS (or RAI) scanner coordinate system. The first coordinate is –R/+L, second coordinate is –A/+P, and the third coordinate is –I/+S. Spatial coordinates are provided in mm.
- * _disp_re.nii and *_disp_im.nii: contain the complex lagrangian displacement components over time along the x-, y-, and z-axis, respectively. Values are in microns and represent the total displacement (see Badachhape et al.2017; Okamoto et al., 2023) determined from MRE phase after spatial and temporal unwrapping.

- *_strain_re.nii and *_ strain_im.nii: contain the real and imaginary parts of the Cartesian components of the complex lagrangian strain tensor in order Exx, Eyy, Ezz, Exy, Eyz, Ezx.
- *_strain_OSS.nii: contains the octahedral shear strain as calculated in McGarry et al. 2011.
- *_anat.nii: contains a T2-like anatomical image in the MRE data space.

D. **Anatomical Data in MRE Space**: “*_register_to_MRE” (3 mm isotropic voxels, registered rigidly to MRE data space)
   - This folder contains the same files in folders (A) and (B), but rigidly registered and downsampled to the MRE data space. These images allow for a one-to-one correspondence between the voxels in the MRE data and the anatomical segmentations. The ‘moving image’ is defined as the “*_3DT2_norm.nii.gz” image from the data in (A). The ‘fixed image’ is defined as the 50 Hz “*_anat.nii” from the MRE data in (C). The rigid transformation from the fixed image to the moving image is provided in the “*_RigidTransform.mat” file, which is generated from ANTs. The anatomical images in (A) and (B) are then transformed to the MRE space using ANTs. The T1w and T2w images are transformed using 5th order B-spline interpolation. Binary images use nearest neighbor interpolation, while the SLANT segmentation used the ‘multilabel’ interpolation. The diffusion data uses a 4D tensor transformation within ANTs. Example registration and transformation code is given in the appendix below.

Notes and Updates

- (July, 2022) In the datasets uploaded Oct-2021, the values in the *disp_im.nii” files at all frequencies were incorrect (values were stored in rad rather than microns). Updated versions of the *disp_im.nii files have been uploaded for subjects U01_WUSTL_0001_01 through U01_WUSTL_0010_01. The *disp_re.nii files and the strain files had the correct values and have not been updated.
- (July, 2022) The 50 Hz displacement and strain MRE results have been updated for subject U01_WUSTL_0010_01. The previous results contained a temporal unwrapping error which has been corrected.
- (July, 2022). The 90 Hz MRE results for subject U01_WUSTL_0009_01 have been removed due to low data quality.
- (July, 2022). There are no 90 Hz MRE results for subject U01_WUSTL_0018_01.
- (July, 2022). The MRE sequence used for 20 Hz MRE data was modified, which shortened TE from 100 ms to 72 ms. 20 Hz MRE data for subjects U01_WUSTL_0001_01 through U01_WUSTL_0012_01, U01_WUSTL_0002_02, and U01_WUSTL_0016_01 were collected prior to the sequence change.
- (July, 2022) Note that for subjects scanned at multiple sites, a column has been added to identify “cross-site IDs."
- (July, 2023) 18 datasets have been added. Four datasets (U01_WUSTL_0005_02, U01_WUSTL_0008_02, U01_WUSTL_0042_01, U01_WUSTL_0045_01) contain MRE data for 20, 30, 50 Hz only. There are no 30 Hz MRE results for subject U01_WUSTL_0047_01. There are no 90 Hz data for subject U01_WUSTL_0044_01.

References:

Bayly PV, Alshareef A, Knutsen AK, Upadhyay K, Okamoto RJ, Carass A., Butman JA, Pham DL., Prince JL, Ramesh KT, Johnson CL, 2021, MR Imaging of Human Brain Mechanics in Vivo: New Measurements to Facilitate the Development of Computational Models of Brain Injury. Ann. Biomed. Eng., **49**(10), pp. 2677–2692. doi: 10.1007/s10439-021-02820-0. PMCID: PMC8516723.

Badachhape AA, Okamoto RJ, Durham RS, Efron BD, Nadell SJ, Johnson CL, Bayly PV. The Relationship of Three-Dimensional Human Skull Motion to Brain Tissue Deformation in Magnetic Resonance Elastography Studies. J Biomech Eng. 2017 May 1;139(5):0510021–05100212. doi: 10.1115/1.4036146. PMCID: PMC5444212.

McGarry MD, Van Houten EE, Perriñez PR, Pattison AJ, Weaver JB, Paulsen KD. An octahedral shear strain-based measure of SNR for 3D MR elastography. Phys Med Biol. 2011 Jul 7;56(13):N153-64. doi: 10.1088/0031-9155/56/13/N02. PMCID: PMC3172714.

Okamoto RJ, Escarcega, JD, Alshareef A, Carass A, Prince JL , Johnson CL, Bayly PV, 2023, Effect Of Direction And Frequency Of Skull Motion On Mechanical Vulnerability Of The Human Brain, J. Biomech. Eng., online before print. doi: 10.1115/1.4062937. PMID: 37432674

Appendix 1: ANTs registration and transformation

Rigid Registration

- antsRegistration -d 3 -o [$outputName, $outputName_Warped.nii.gz, $outputName_InverseWarped.nii.gz] -a 1 -z 1 -r [${FixedImage}, ${MovingImage}, 1] -t Rigid[0.1] -m MI[${FixedImage}, ${MovingImage}, 1, 32, Regular, 0.25] -c [1000x500x250x100,1e-6,10] -f 8x4x2x1 -s 3x2x1x0vox --float 1 –verbose

Rigid Transformation

(change the -n option for interpolation method)

- antsApplyTransforms -d 3 -i $*_MPRAGEPre_norm_slant_macruise.nii.gz -o $outputName_macruise.nii.gz -r ${FixedImage} -n MultiLabel -t [$outputName_Composite.h5] --verbose