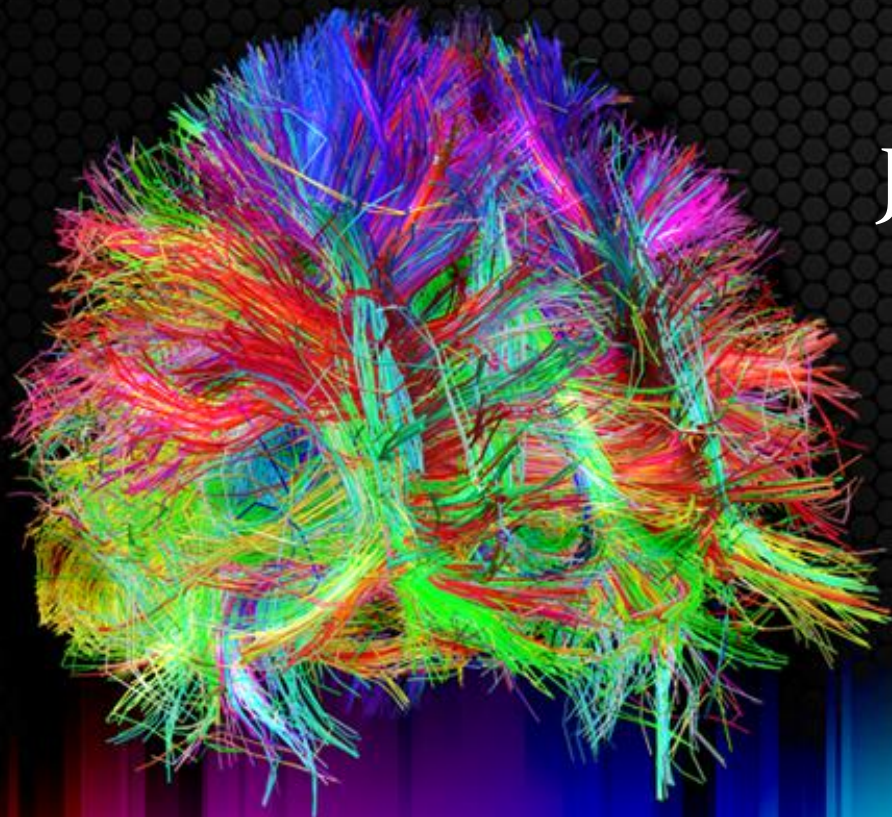# NA-MIC DBP:
Traumatic Brain Injury (TBI)

John Darrell Van Horn, Ph.D.
UCLA

Driving Biological Project on TBI

- **UCLA**
  - **Jack Van Horn**, PhD (PI of the NA-MIC Driving Biological Project)
  - Andrei Irimia, PhD (Postdoctoral Scholar, DBP Engineer)
  - Micah Chambers, MS (UCLA Biomedical Engineering Graduate Program)
  - Paul Vespa, MD, FACN, FAAN (UCLA Neurology & Neurosurgery)
  - David Hovda, MD (UCLA Brain Injury Research Center)
  - Jeffrey Alger, PhD (UCLA Radiology)
  - Arthur Toga, Ph.D. (UCLA Radiology)

- **University of Utah**
  - **Guido Gerig, Ph.D. (Scientific Imaging Institute)**
  - Marcel Prastawa, PhD
  - Bo Wang, BS
  - Sylvain Gouttard PhD

- **Harvard Medical School/BWH**
  - **Ron Kikinis, MD (PI of the NA-MIC Collaboration)**
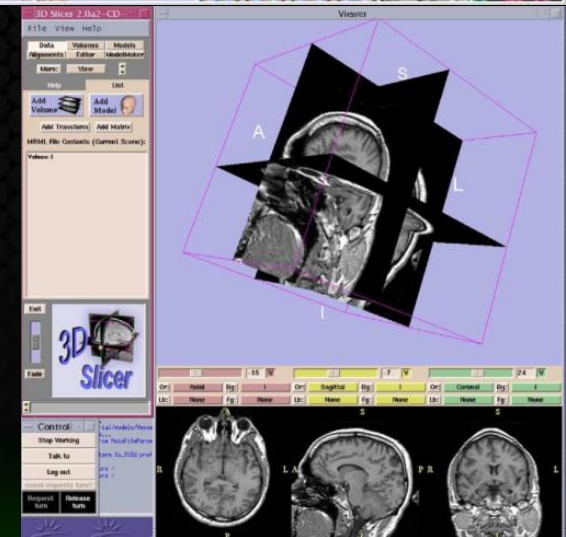 - Sonja Pujol, PhD

- **University of North Carolina, Chapel Hill**
  - **Stephen Aylward, PhD**

- **Georgia Tech, Atlanta, GA**
  - Yifei Lou, Ph.D.
  - Patricio Vela, Ph.D.

- Boston University
 - Allen Tannenbaum, Ph.D.

Motivation TBI Imaging Research

**Traumatic Brain Injury is a Major Health Care and Research Challenge:**

- 1.5 Million TBI cases per year, half are "mild" TBI
- 650,000 hospitalizations for long-term brain injury, known as the "silent death" (unresponsiveness; coma; brain death; eventual patient death)
- $48 billion per year for management and loss to the US workforce
- **Many from automobile accidents and workplace incidents**
- Returning war veterans particularly affected; NFL/NCAA taking seriously
- Neurobiology of TBI is poorly understood
- Not uncommon for patients to suffer from TBI-related epilepsy, paralysis, memory loss, etc
- 85 clinical trials for therapy, all failed
- Few treatment options, no proven rehabilitation, but management
- Management: ~$1 million per case
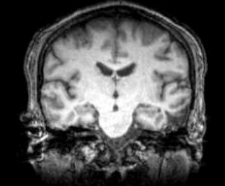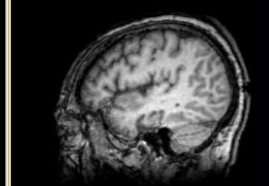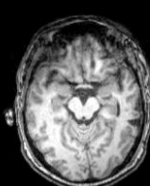- See CDC web-site: http://www.cdc.gov/TraumaticBrainInjury/tbi_concussion.html
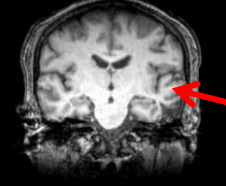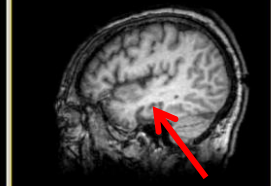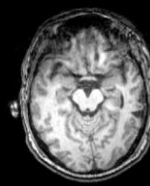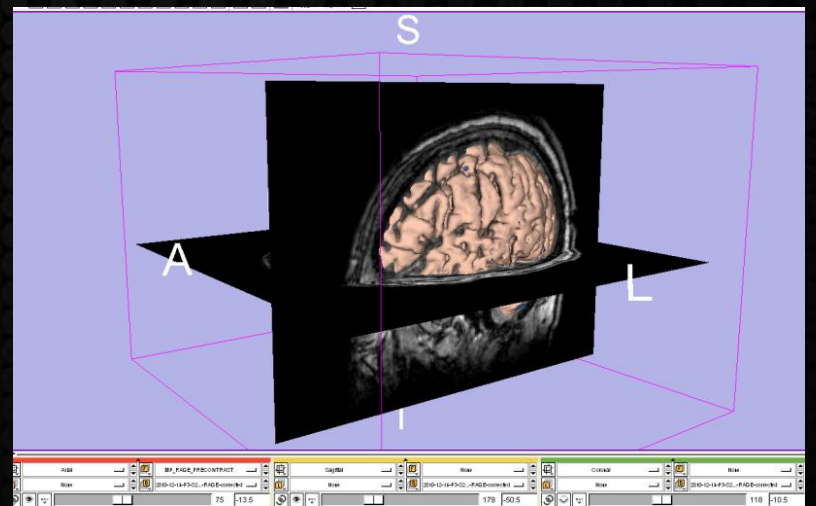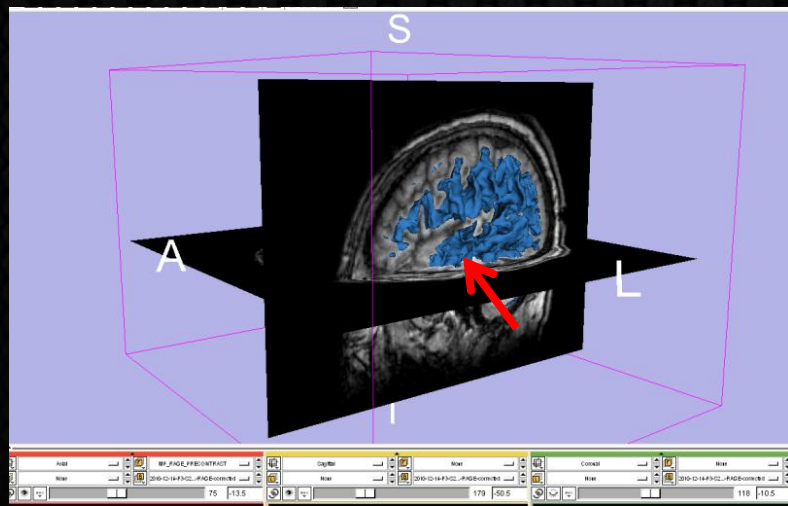
Key Directions

- Quantitative measurements of TBI using new research tools
  - multimodal data integration
  - longitudinal analysis: assess change and trajectories
  - Quantify the degree of atrophy and axonal damage
  - Study the relationship between rates of change and predictors of clinical outcome
- User-supervised, efficient, smart, flexible analysis, registration, parcellation
- Dynamic 3D imaging with multivariate information over time:
  - inform clinicians about damage extent and type
  - assess change over time and guide treatment options with reference to other published studies
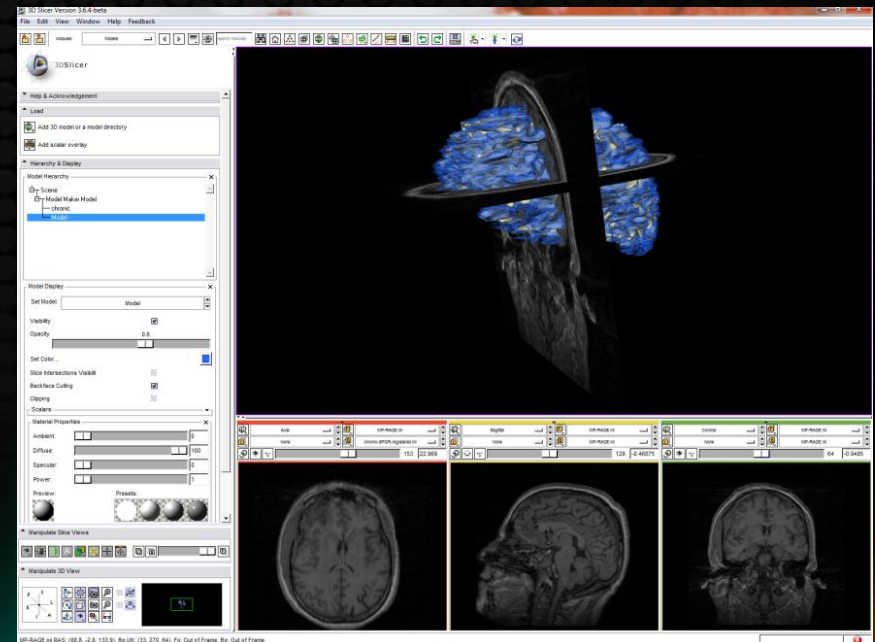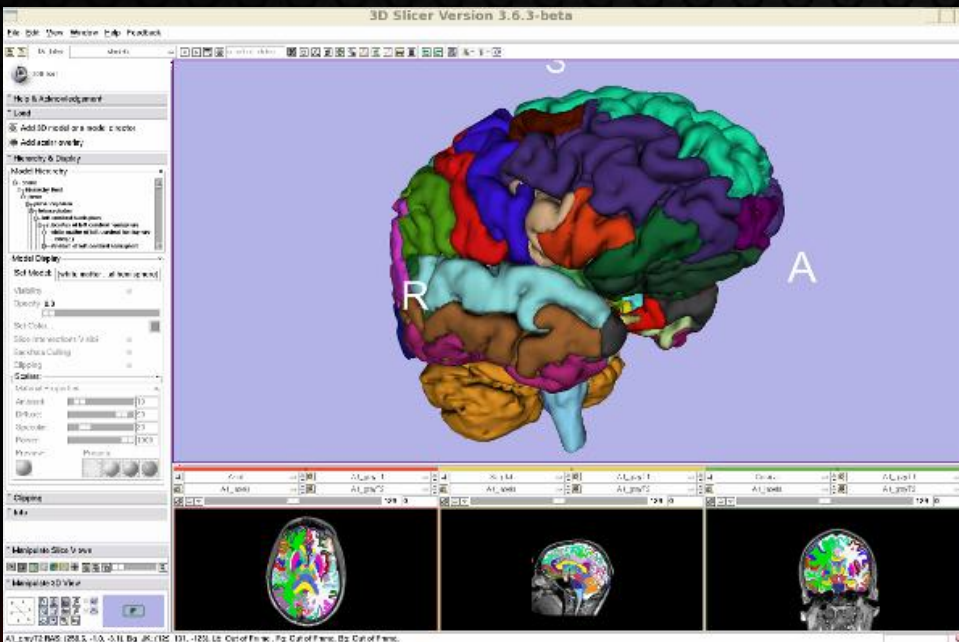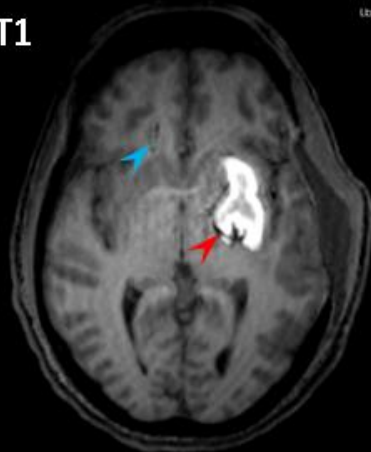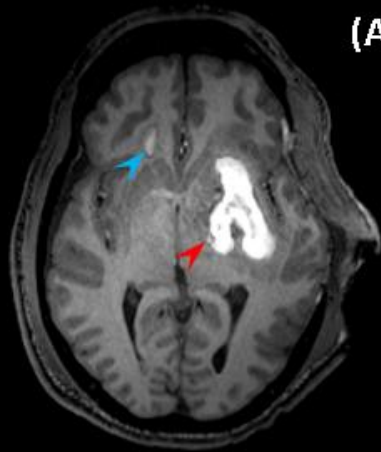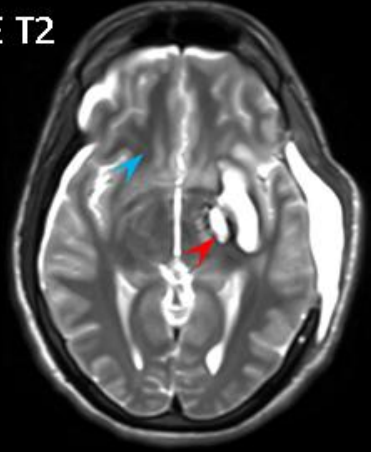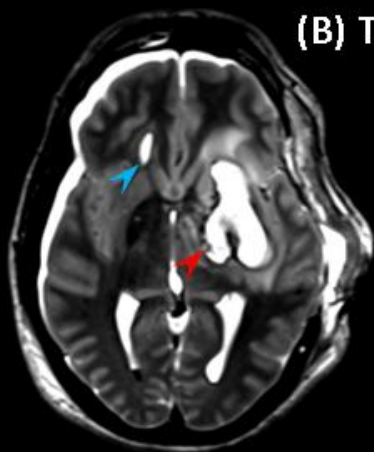
Acute
Baseline
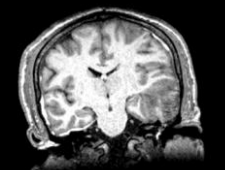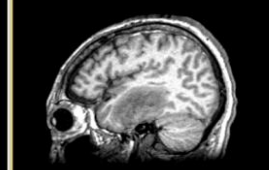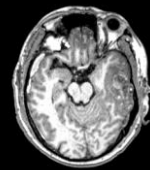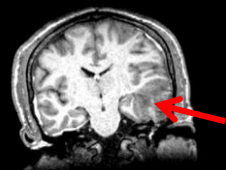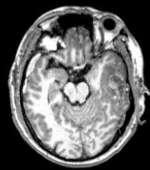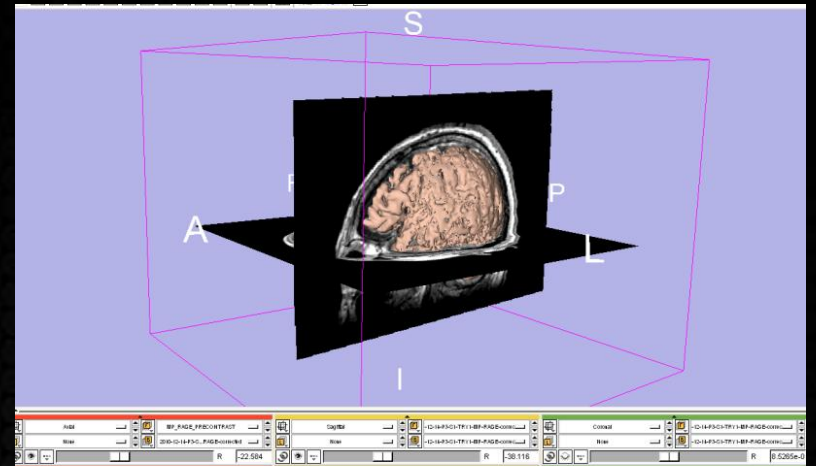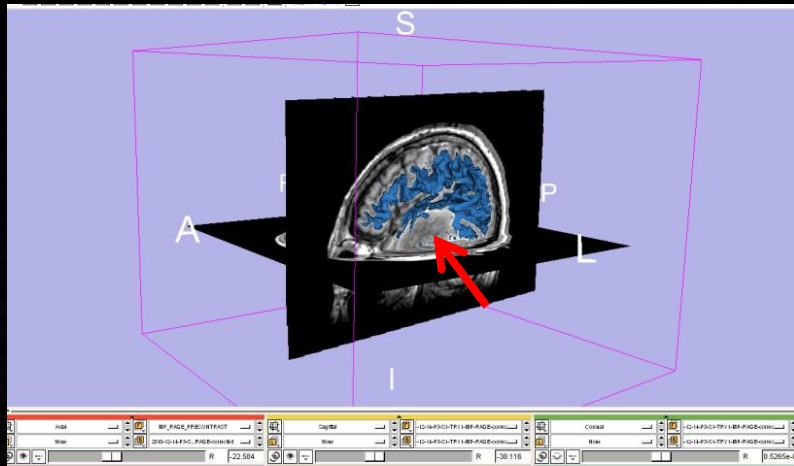
6 Month
Follow-up

ACUTE   CHRONIC

(A) T1

(B) TSE T2
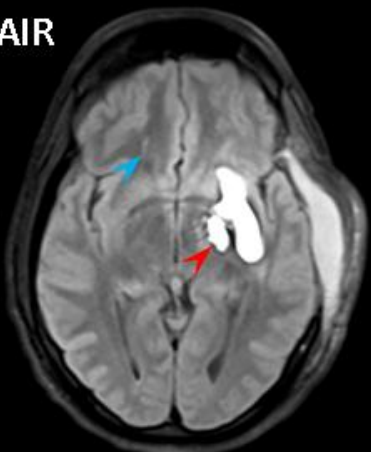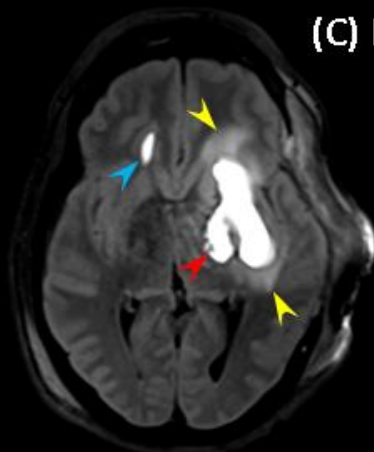
(C) FLAIR

Case 1

(D) GRE T2

(E) SWI

Unknown origin

Case 1 acute

	ventricular system
	edema
	hemorrhage

(A) VENTRICLES   (B) NON-HEMMORRHAGIC LESIONS   (C) HEMORRHAGIC LESIONS   (D) FULL MODEL

RIGHT   LEFT   DORSAL   VENTRAL   ANTERIOR   POSTERIOR

Case 1 chronic

🟪	ventricular system
🟨	lesion
🟥	bleed

(A) VENTRICLES (B) LESIONS (C) BLEEDS (D) FULL MODEL

RIGHT
LEFT
DORSAL
VENTRAL
ANTERIOR
POSTERIOR

Case 1 longitudinal comparison

acute
chronic

Case 2

ACUTE   CHRONIC

(A) T1
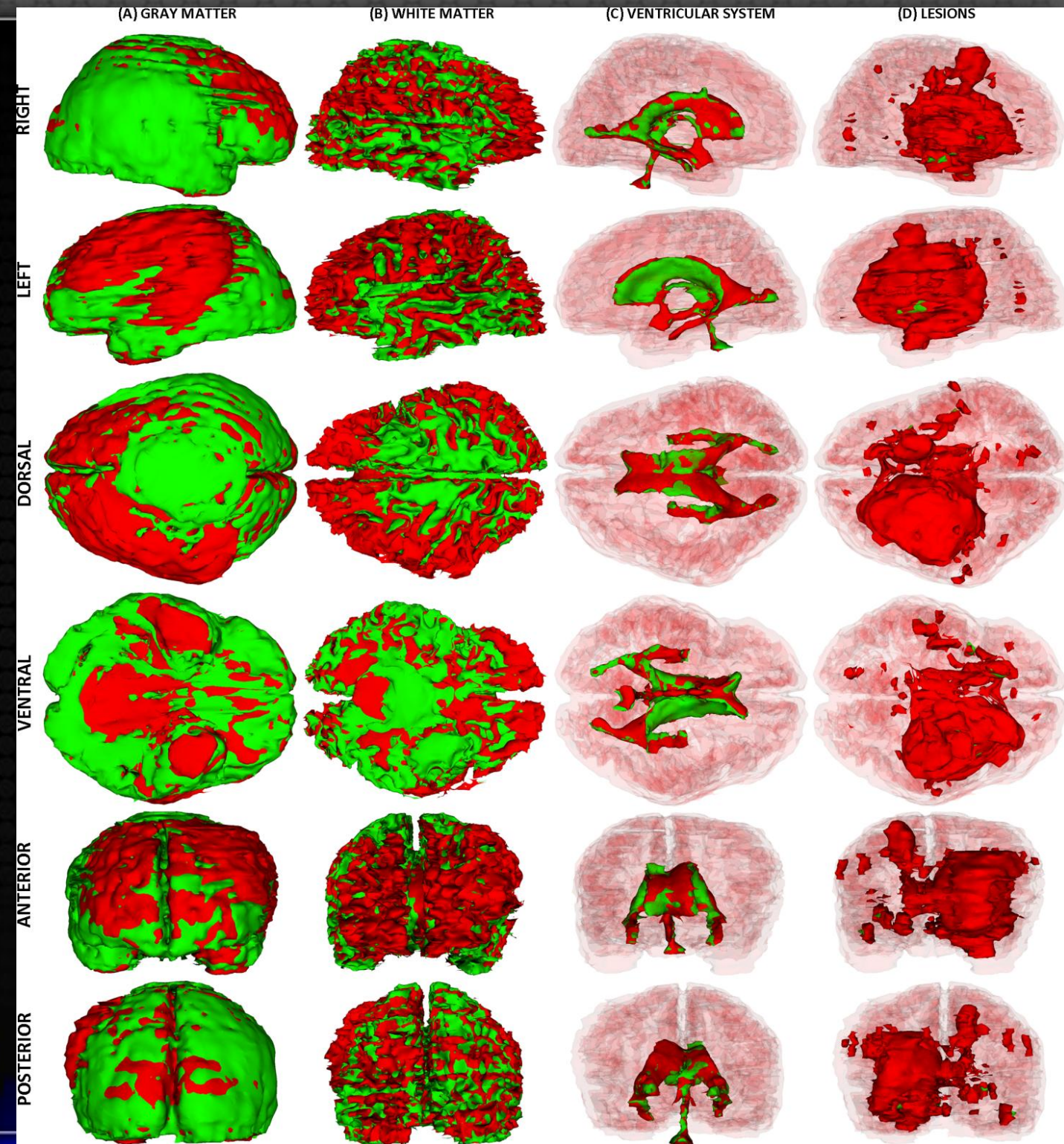
(B) TSE T2

(C) FLAIR

(D) GRE T2

(E) SWI
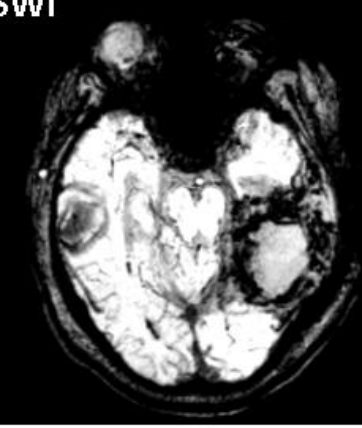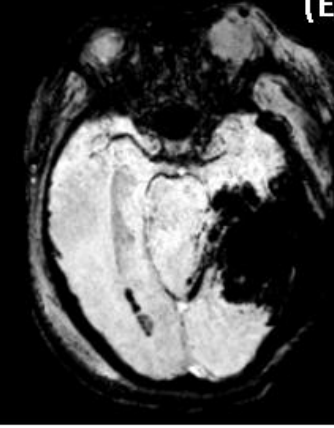
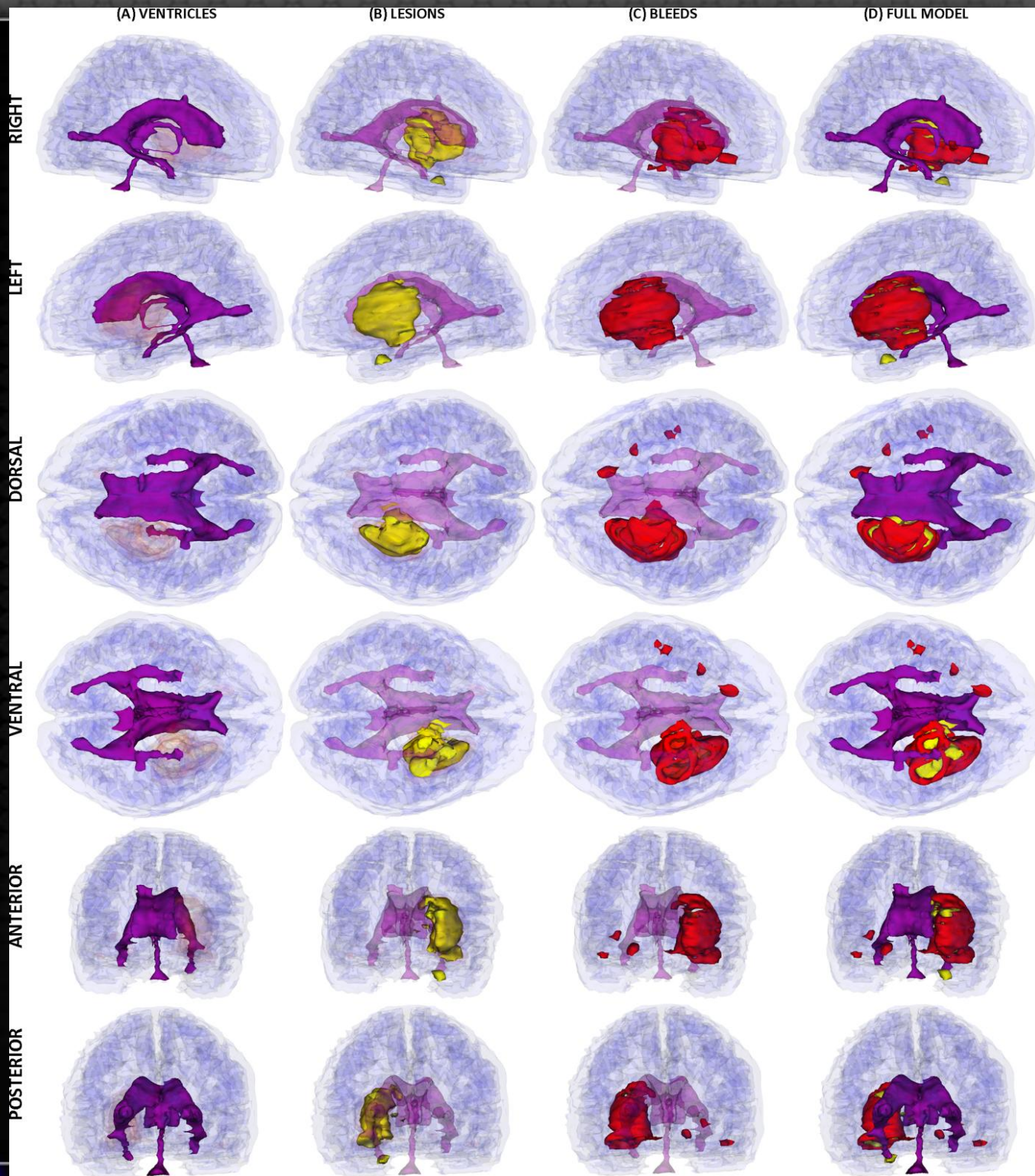Gunshot victim

Case 2
acute

ventricular system
edema
hemorrhage
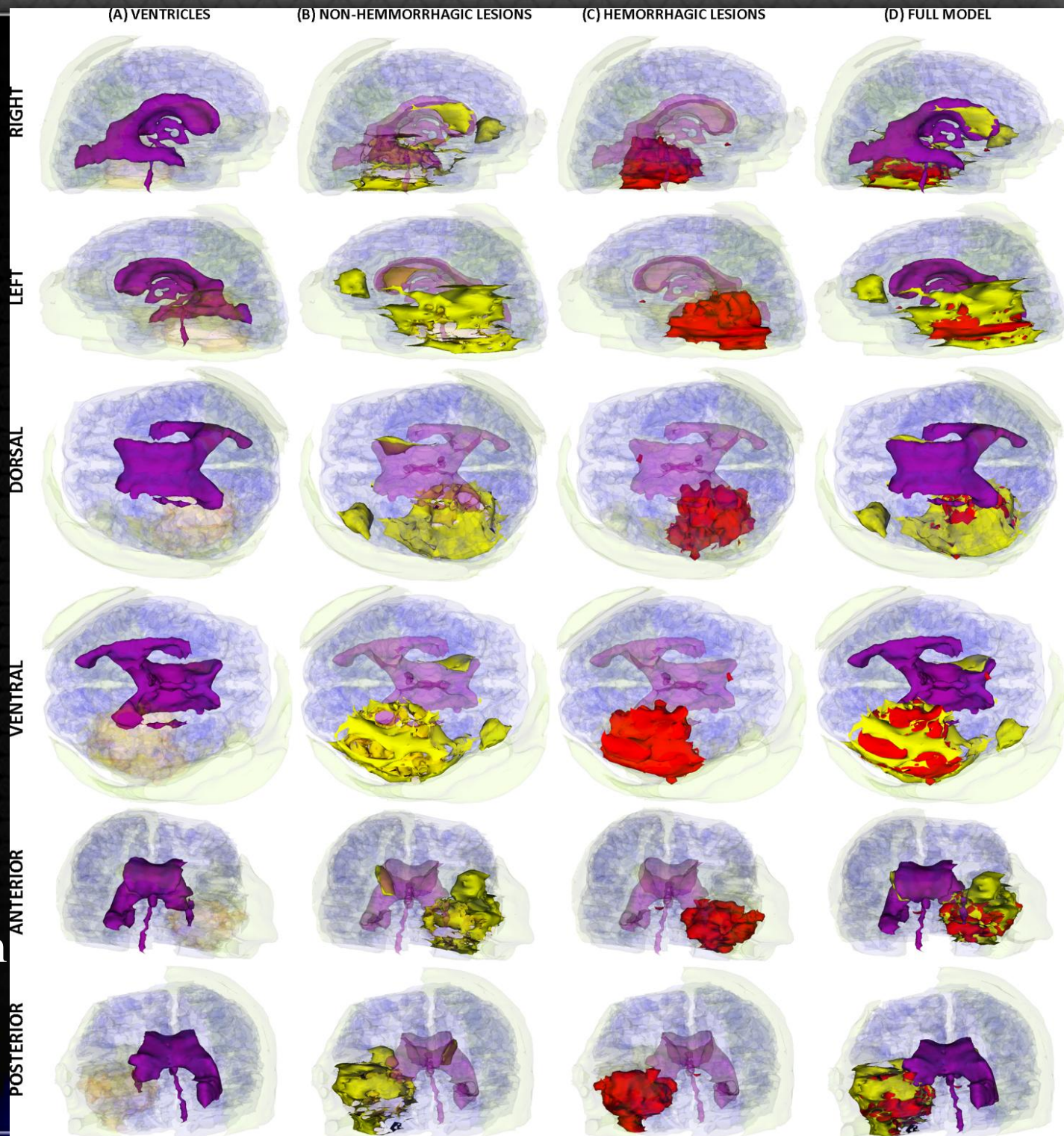
Case 2 chronic

ventricular system
lesion
bleed

Case 2 longitudinal analysis

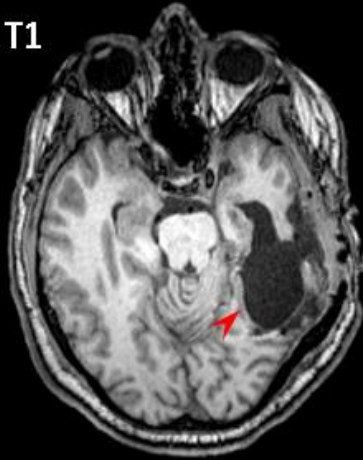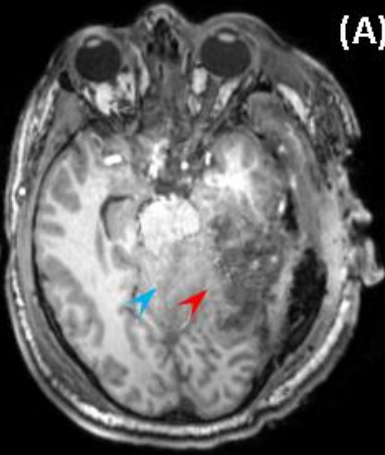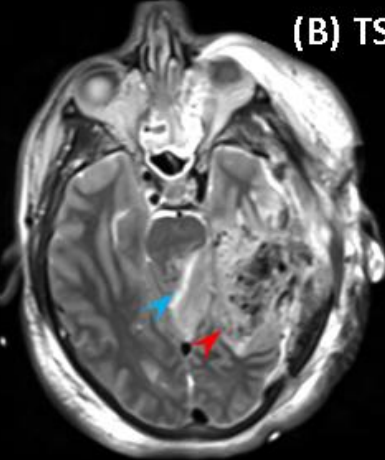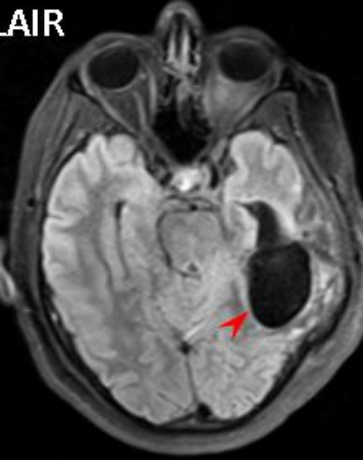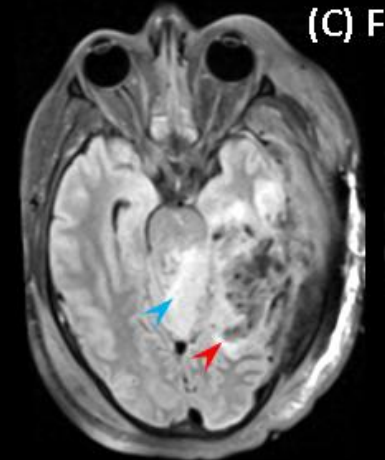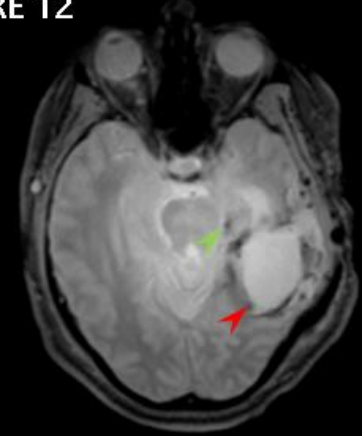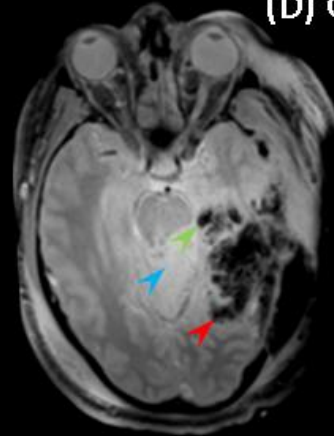(A) GRAY MATTER   (B) WHITE MATTER   (C) VENTRICULAR SYSTEM   (D) LESIONS

RIGHT
LEFT
DORSAL
VENTRAL
ANTERIOR
POSTERIOR

acute
chronic

Case 3

Blunt force trauma

Case 3
acute

ventricular system
edema
hemorrhage

Case 3
chronic

ventricular system
lesion
bleed

(A) VENTRICLES (B) LESIONS (C) BLEEDS (D) FULL MODEL

RIGHT
LEFT
DORSAL
VENTRAL
ANTERIOR
POSTERIOR
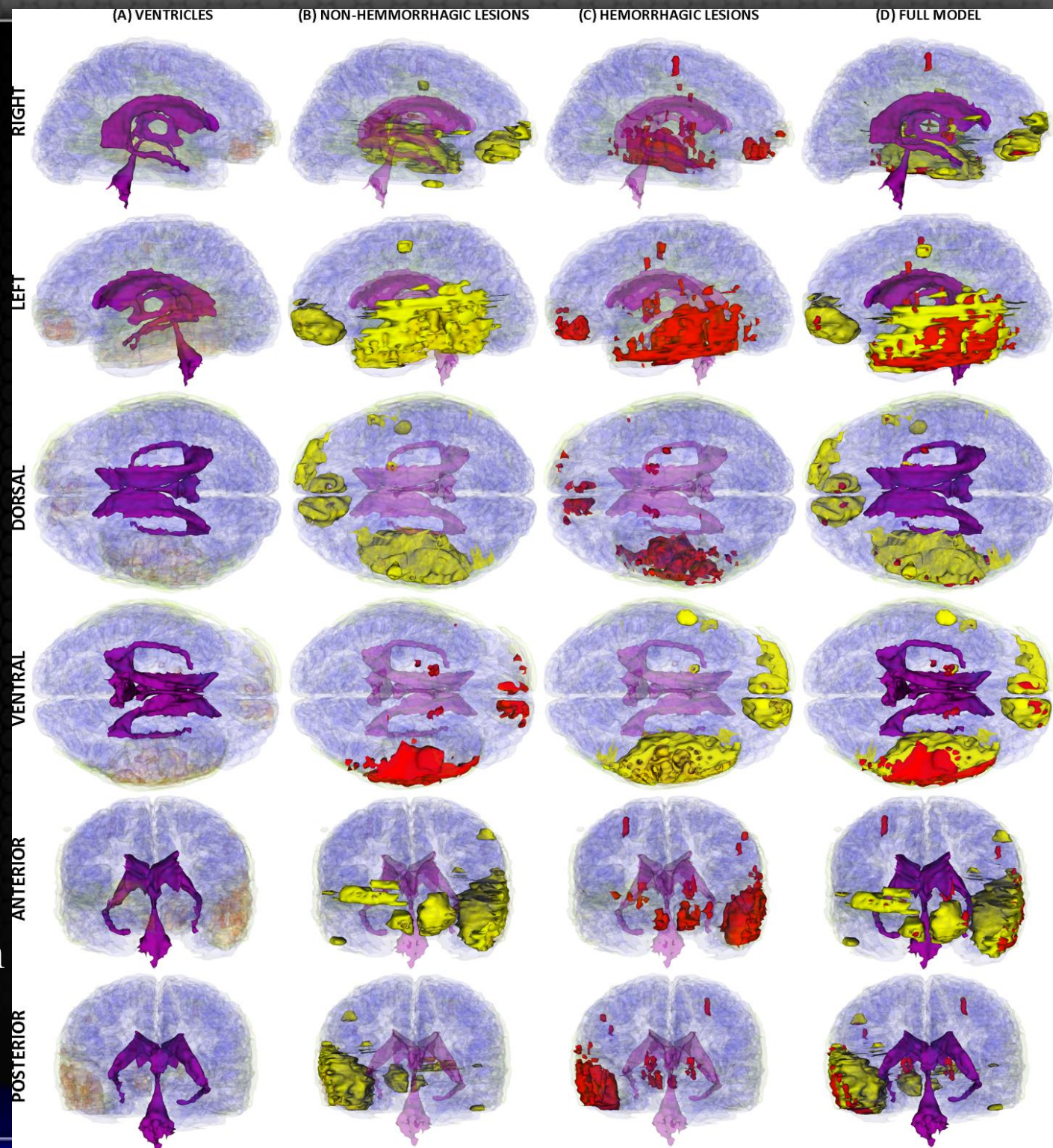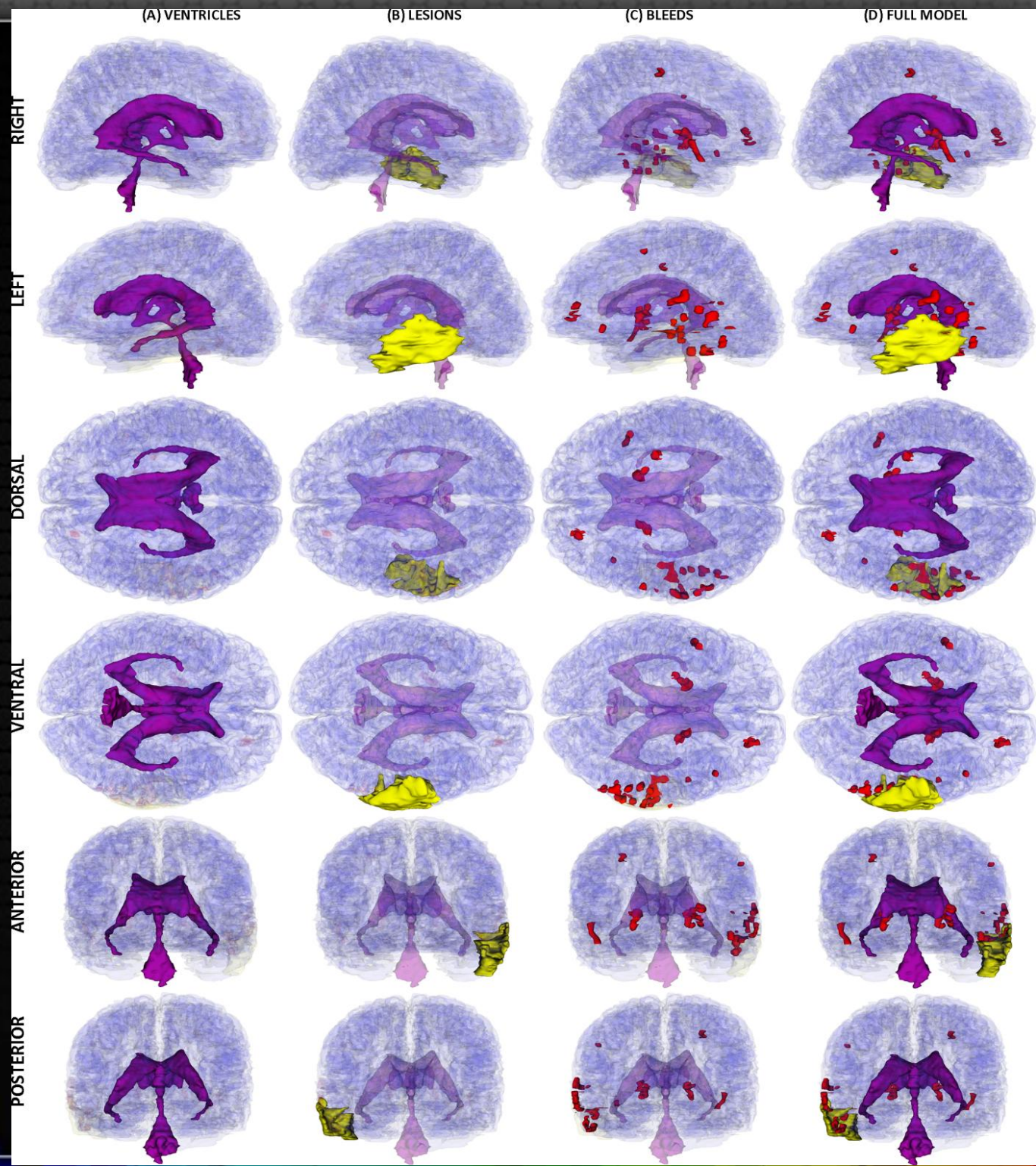
Case 3 longitudinal analysis

acute

chronic

(A) GRAY MATTER (B) WHITE MATTER (C) VENTRICULAR SYSTEM (D) LESIONS

RIGHT LEFT DORSAL VENTRAL ANTERIOR POSTERIOR
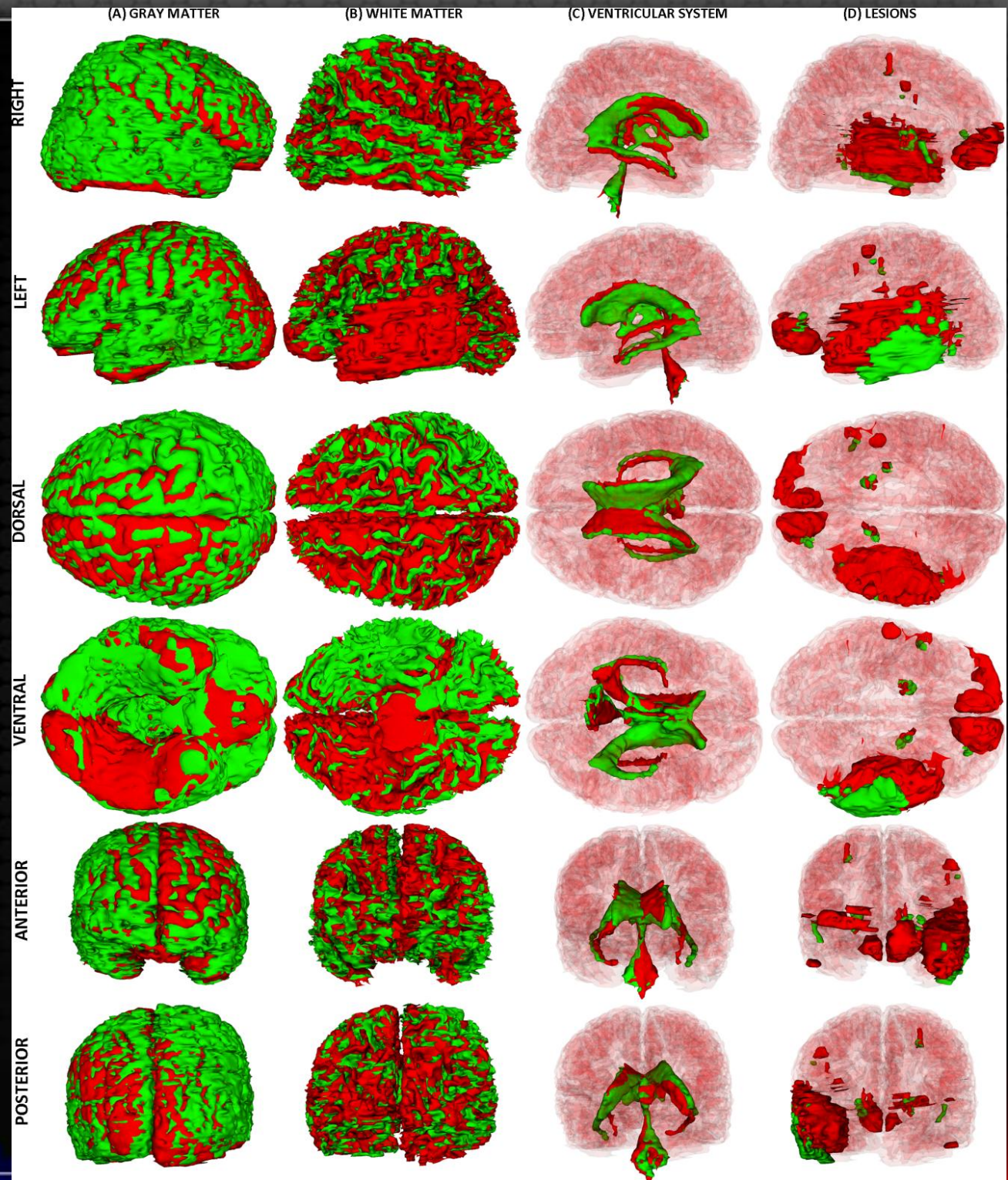
Acute/Chronic Multimodal Registration in TBI
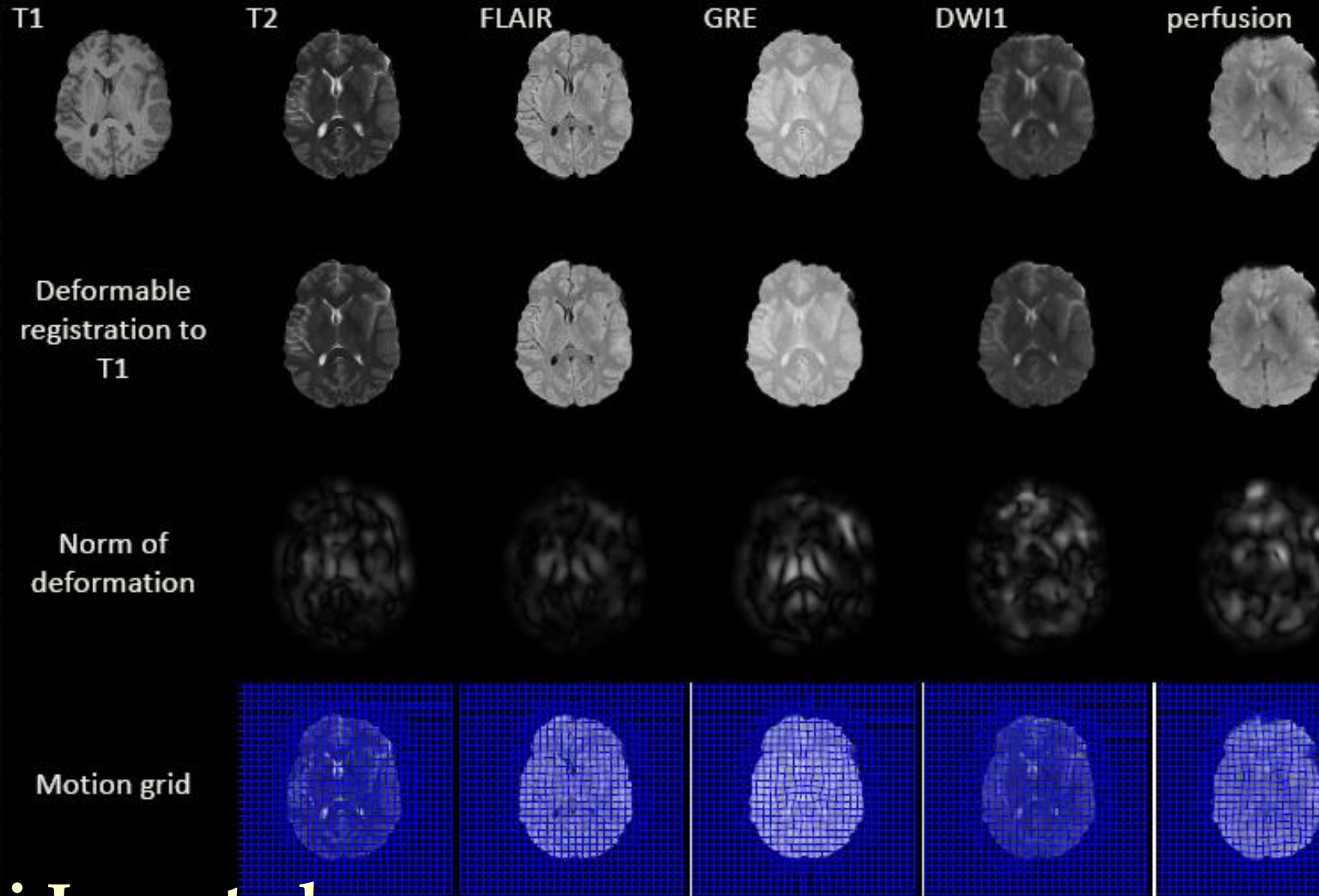
Yifei Lou et al.

TBI Lesion Parcellation
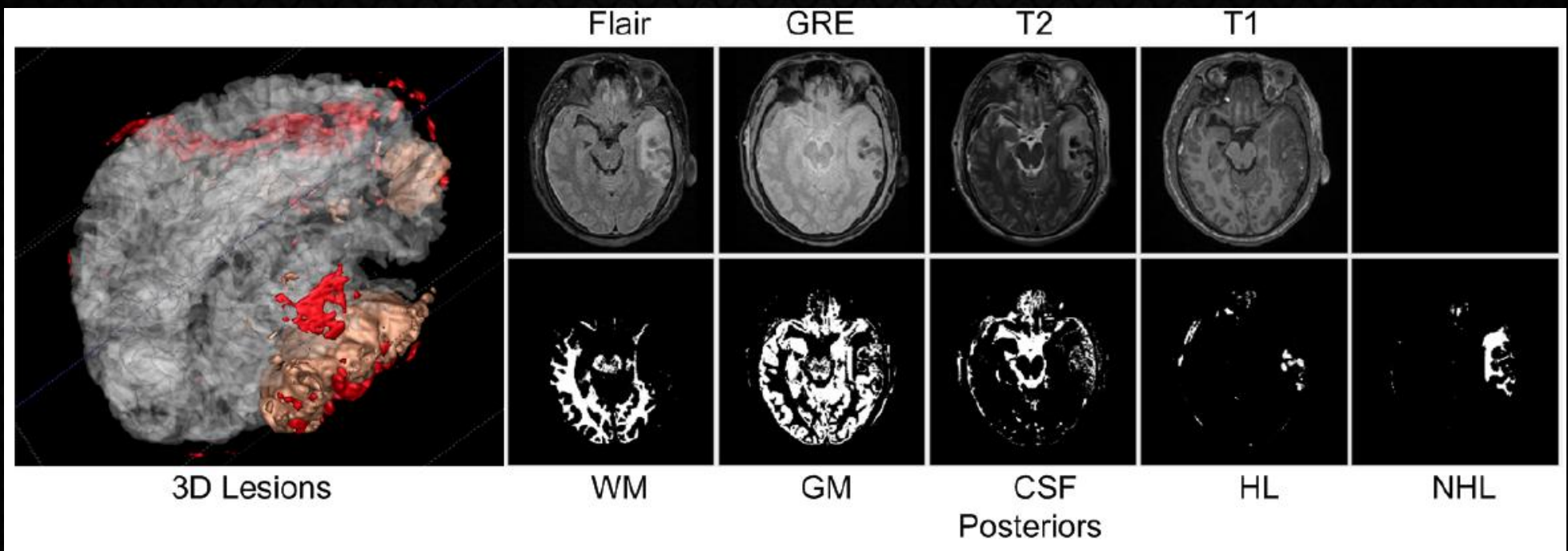
HL = hemorrhagic lesions
NHL = non-hemorrhagic lesions

Bo Wang et al.

TBI Image Registration

Goal: TBI longitudinal change detection and monitoring.
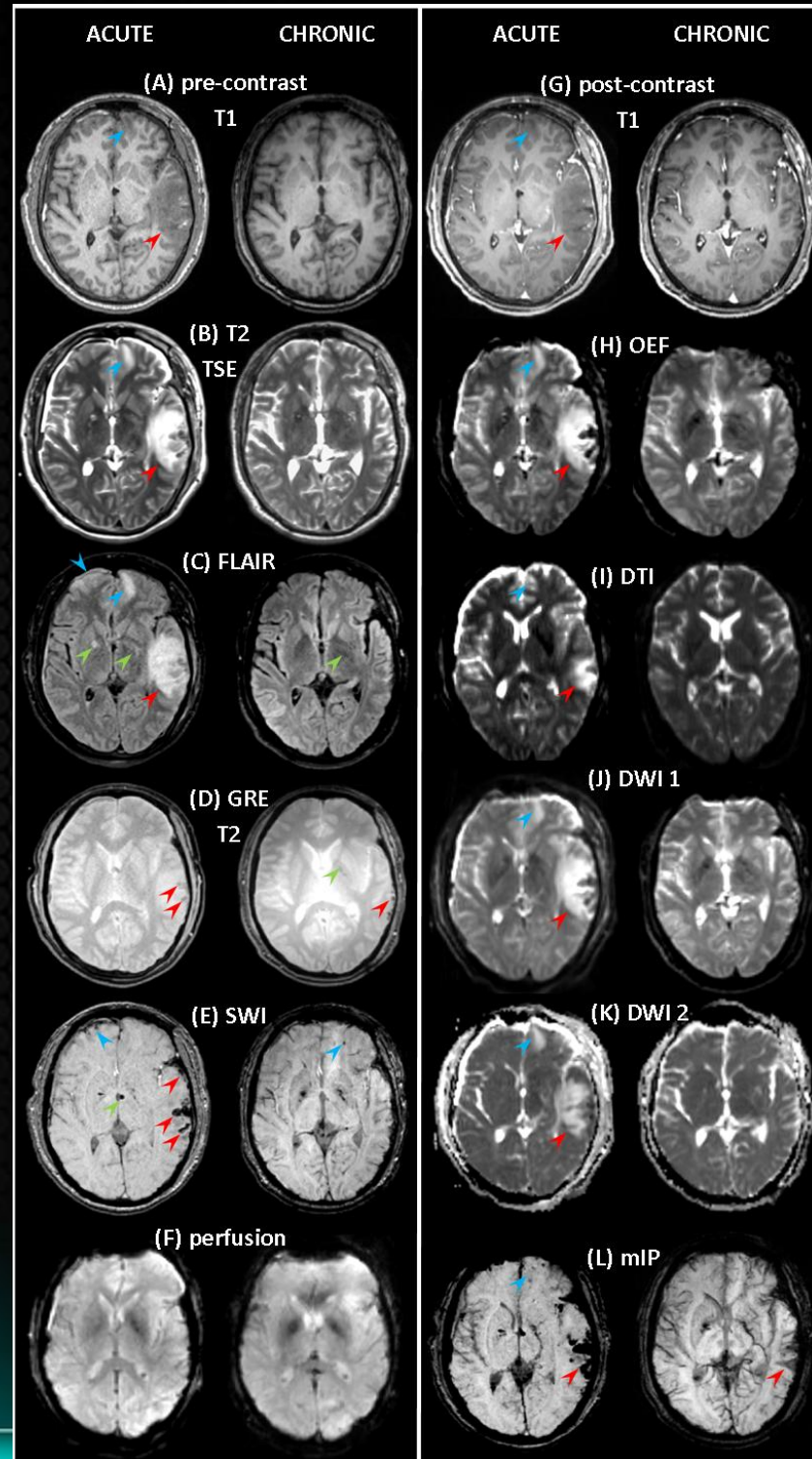
Geometric metamorphosis

- Jointly estimate global background deformation and pathology deformation.
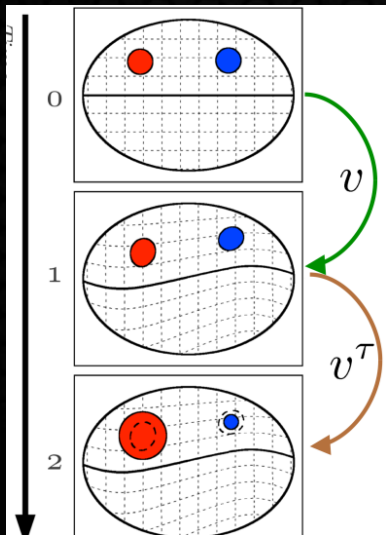
global background motion

pathology grows or contracts
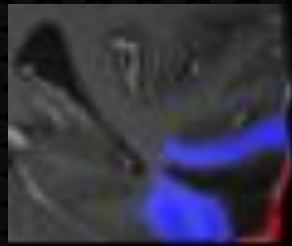
Sliding organ registration

- Handle sliding motion (ex. between brain and skull).
- Validation evaluated in abdomen:
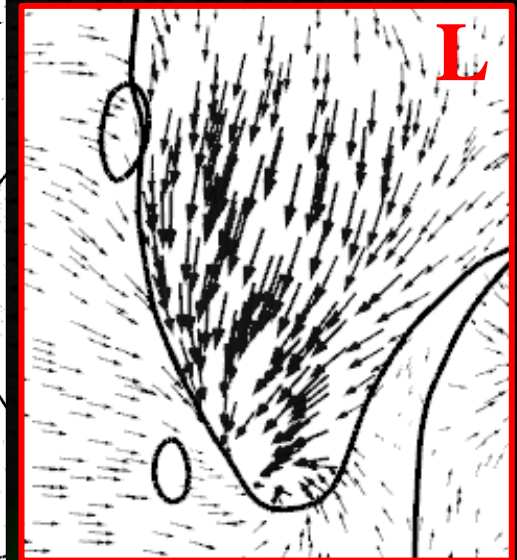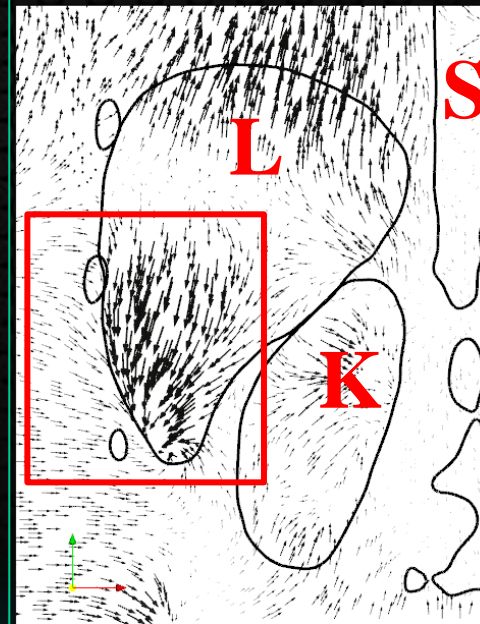
Cortical Parcellation Map

Pial Surface

Inflated Surface
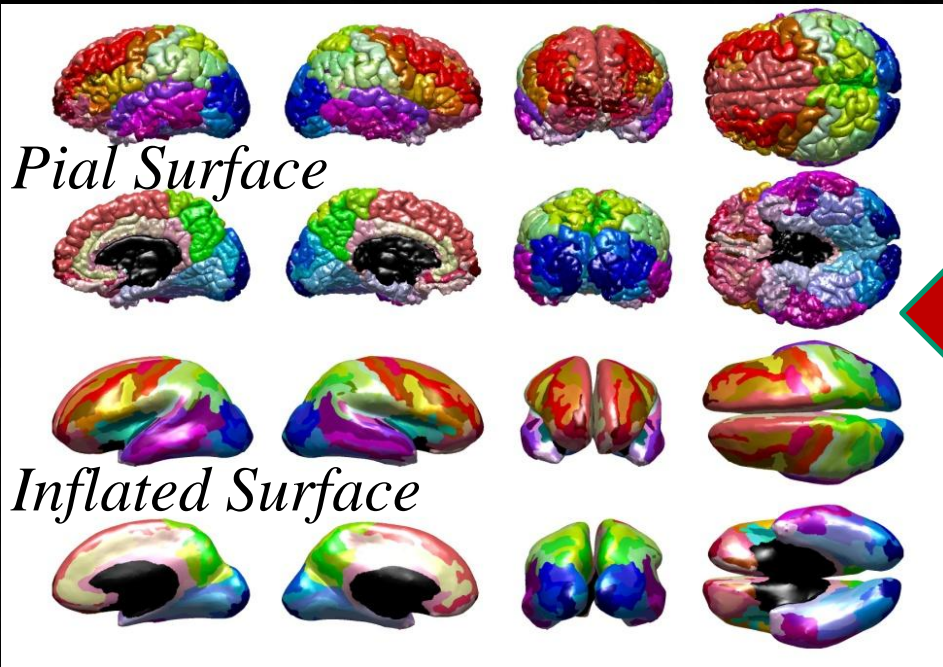
Diffusion Tractography
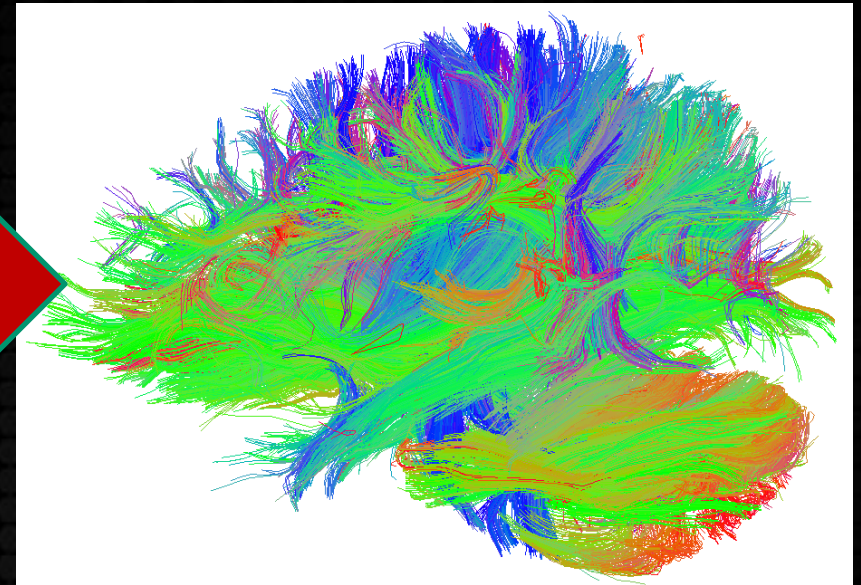
Regional Connectivity Matrix
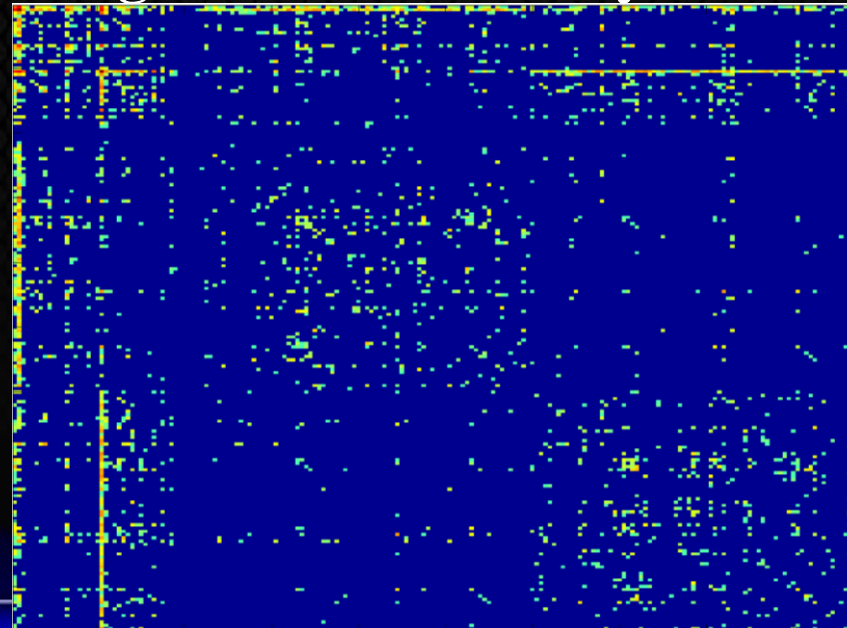
Andrei Irimia et al.
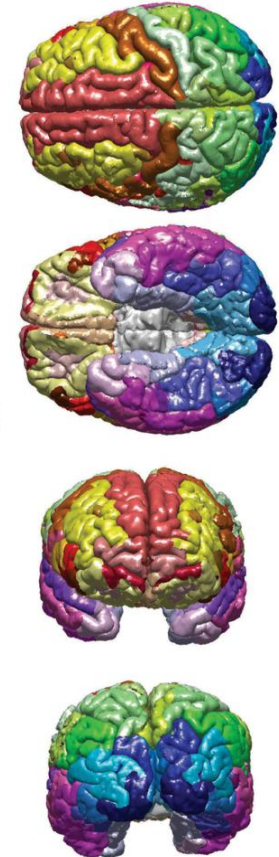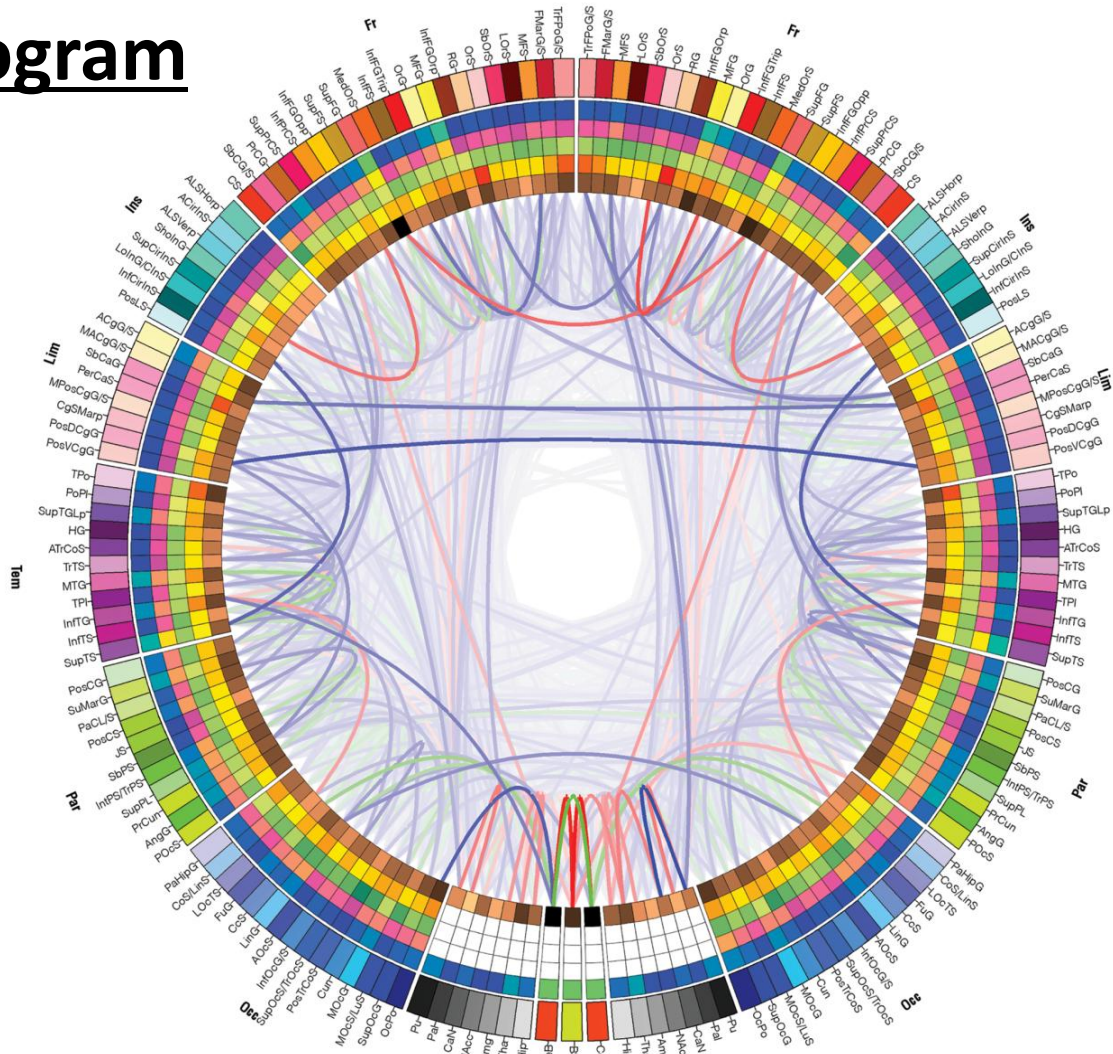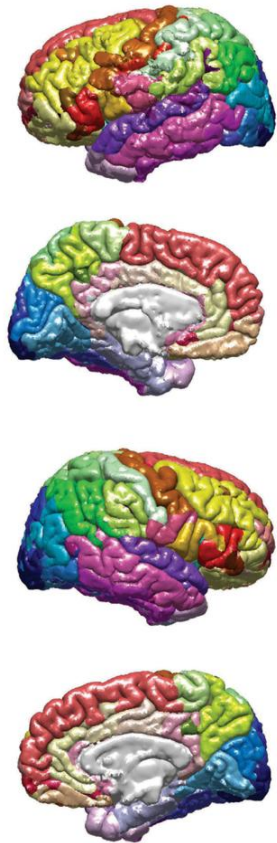
Connectogram

Sample Summary:

N=100
Right handed
Males
25-36 years old
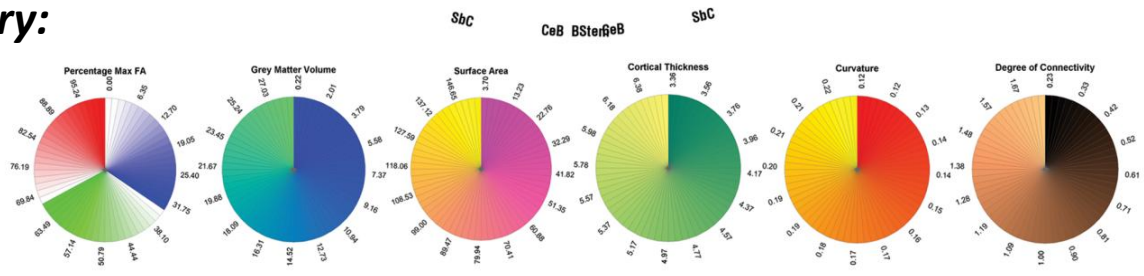
Andrei Irimia et al.

Connectogram Legend
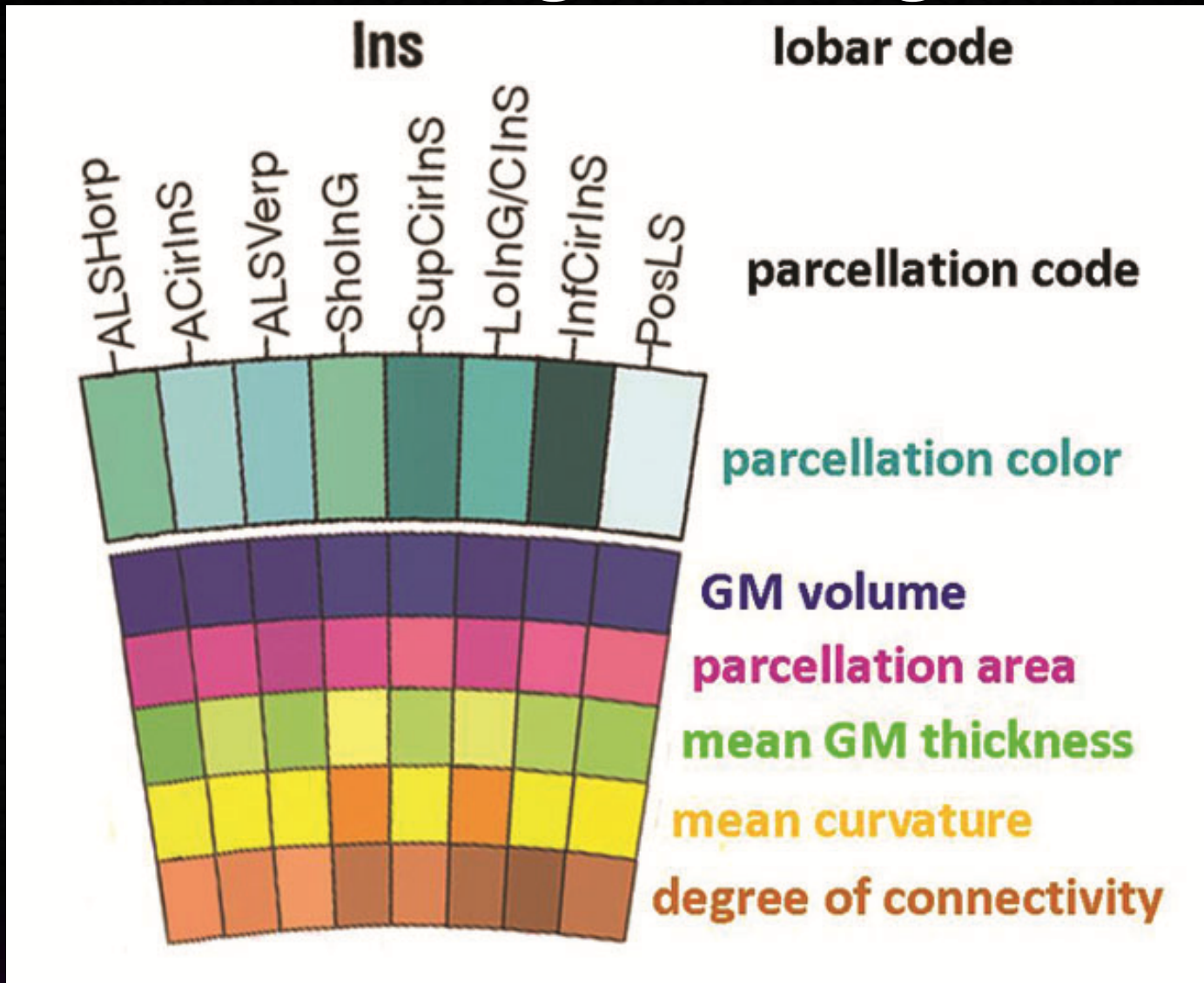
Characterizing Fiber Pathway Damage in TBI
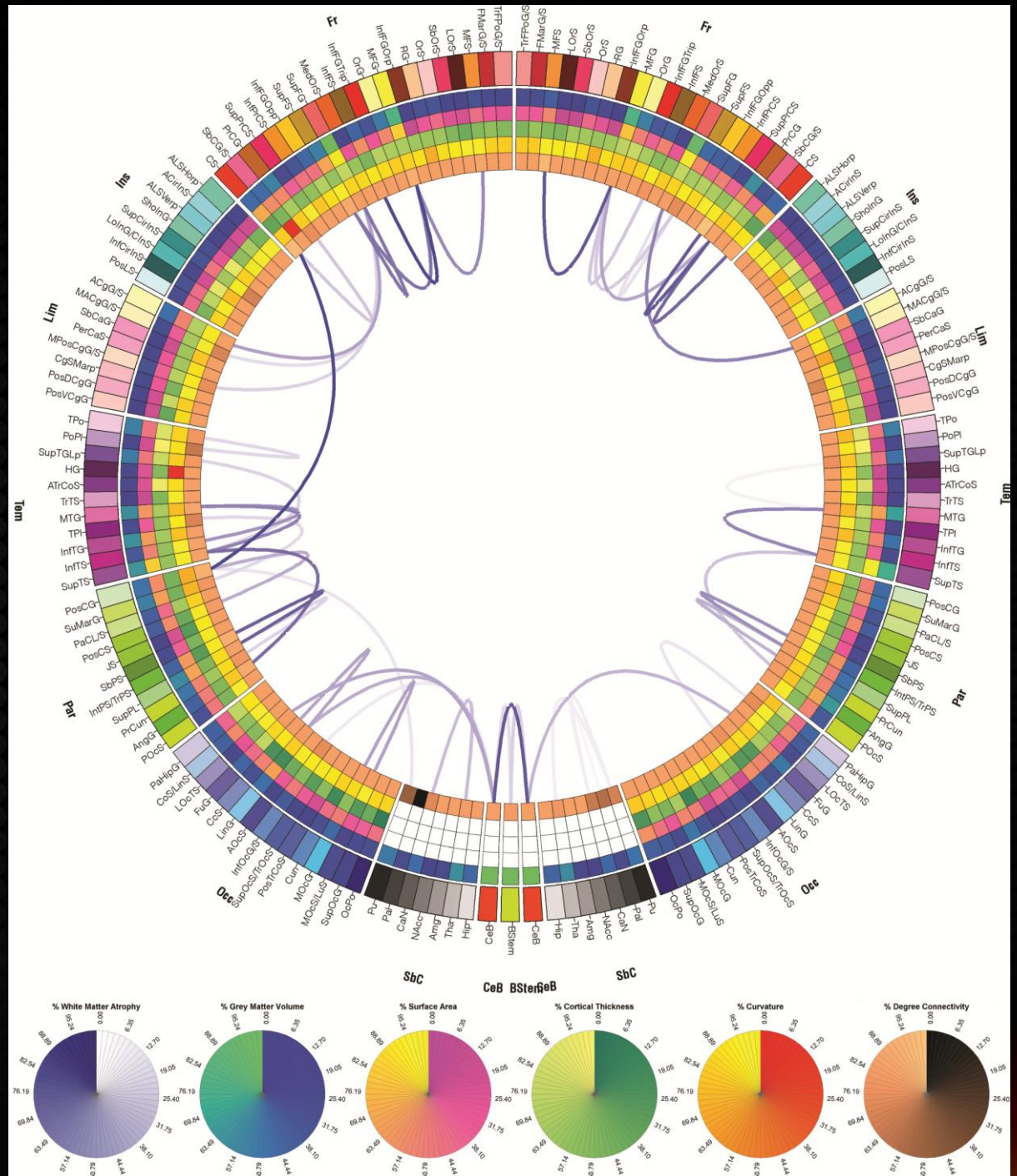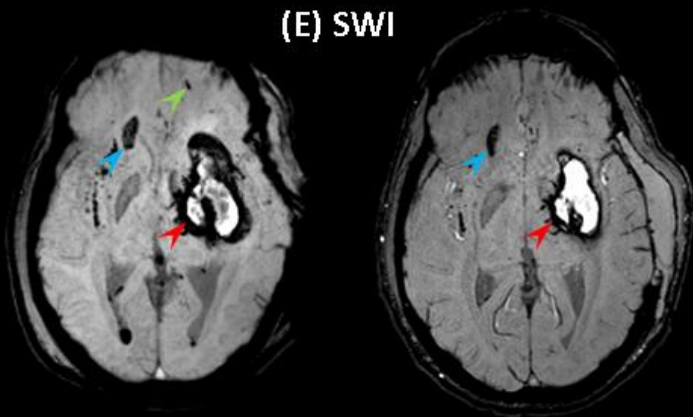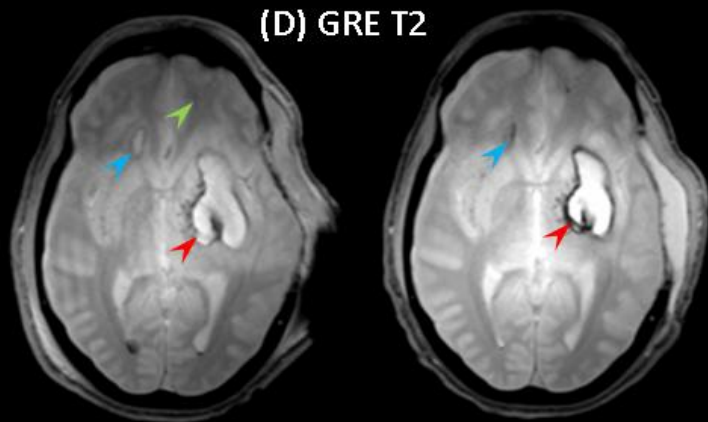
Andrei Irimia et al.

A Famous Case of TBI
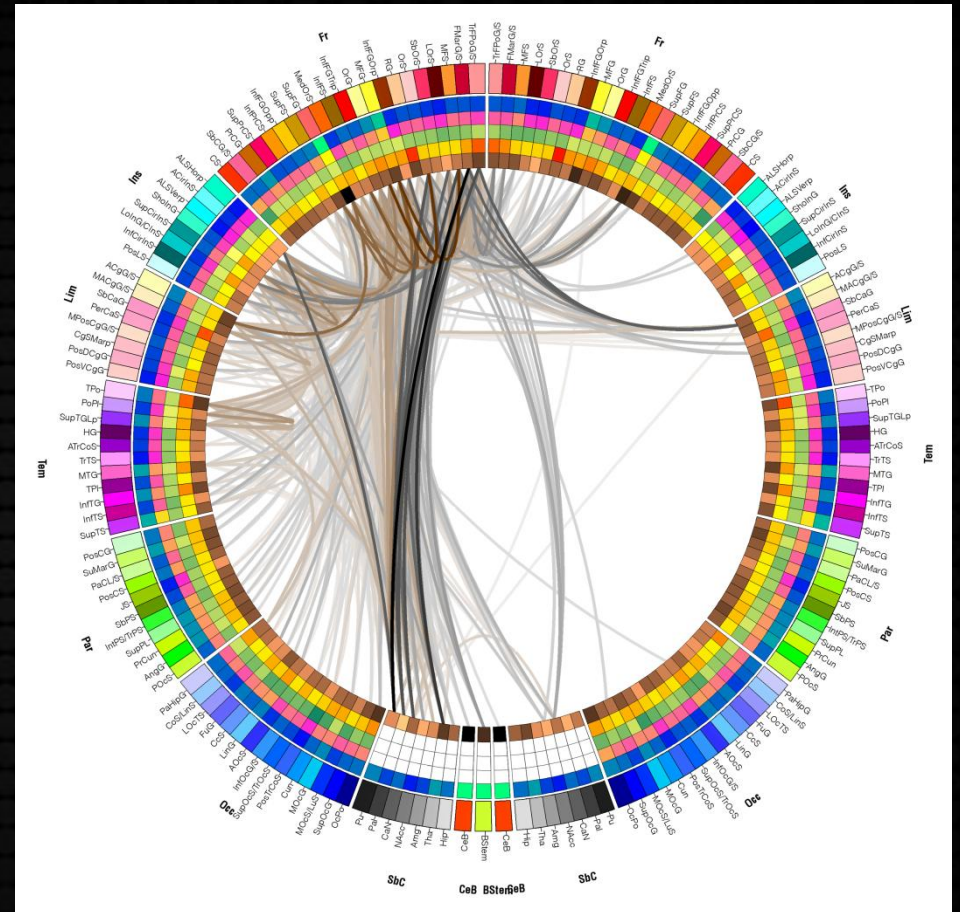
Sample; 110 healthy RH males
25-36 years old
4% grey matter volume loss
11% white matter affected

Van Horn et al.

TBI DBP Publications

- **Journal Papers**

    – A. Irimia, et al. (2011) "Comparison of acute and chronic traumatic brain injury using semi-automatic multimodal segmentation of MR volumes". *Journal of Neurotrauma*

    – *A. Irimia. Et al. (in press) "Patient-tailored connectomics visualization for the assessment of white matter atrophy in traumatic brain injury", **Frontiers in Neurotrauma**.*

    – B. Wang, et al. (accepted) "A Patient-Specific Segmentation Framework for Longitudinal MR Images of Traumatic Brain Injury" **ISBI**.

    – *B. Wang, et al. (submitted) "A Segmentation Framework for Longitudinal MR Images with Traumatic Brain Injury" **SPIE Medical Imaging**.*

    – *M. Niethammer, et al.(2011) Geometric metamorphosis. **Med Image Comput Comput Assist Interv.***

    – D. F. Pace, et al., "Deformable image registration of sliding organs using anisotropic diffusive regularization," **Proc. IEEE International Symposium on Biomedical Imaging**

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AND THE INTERNATIONAL NEUROTRAUMA SOCIETY

Special Issue
Bioengineering in Neurotrauma Research

Mary Ann Liebert, Inc. publishers

Conference Presentations

TBI DBP Presentations

- **Conference Proceedings**
  - M Niethammer, G Hart, A Irimia, PM Vespa, JD Van Horn, SR Aylward (2011) Geometric metamorphosis *Proceedings of MICCAI 2011*
  - *Y. Lou, A. Irimia, P. Vela, M.C. Chambers, J.D. Van Horn, P.M. Vespa, and Al. Tannenbaum (submitted) "Multimodal Deformable Registration of Traumatic Brain Injury MR Volumes using Graphics Processing Units" Workshop on Biomedical Image Registration 2012, Lecture Notes in Computer Science.*

- **Conference Abstracts & Posters**
  - A Irimia, MC Chambers, PM Vespa, AW Toga, JD Van Horn (2011) Cortical network visualization and analysis in traumatic brain injury using multimodal neuroimaging *Proceedings of the Seventeenth Joint Symposium on Neural Computation, June 4, 2011, Institute of Neural Computation, University of California, San Diego*
  - A Irimia, MC Chambers, M Filippou, JR Alger, MW Prastawa, B Wang, S Gouttard, SMA Pujol, SR Aylward, DA Hovda, G Gerig, AW Toga, R Kikinis, PM Vespa, JD Van Horn (2011) Three-dimensional calculation and quantification of morphometric and volumetric cortical atrophy indices of widespread clinical use from MRI volumes of traumatic brain injury using 3D Slicer *Proceedings of the Forty-First Annual Meeting of the Society for Neuroscience (SfN 2011), Washington, DC* **(this work received the First Prize in the Fine Science Tools Contest, UCLA Brain Research Institute)**
  - A Irimia, JD Van Horn, MC Chambers, MW Prastawa, S Gouttard, PM Vespa, DA Hovda, JR Algers, SMA Pujol, G Gerig, SR Aylward, AW Toga, R Kikinis (2011) Automatic multimodal MR image segmentation for the clinical assessment of traumatic brain injury in 3D Slicer *Proceedings of the Seventeenth Annual Meeting of the Organization on Human Brain Mapping (OHBM 2011), Quebec City, Canada*

NA-MIC Winter Project Week 2012 TBI Activities

- ***Segmentation of Serial MRI of TBI patients using Personalized Atlas Construction*** (Bo Wang, Marcel Prastawa, Andrei Irimia, Micah Chambers, Jack Van Horn, Guido Gerig, Danielle Pace, Stephen Aylward)

- ***Registration and analysis of white matter tract changes in TBI*** (Clement Vachet, Anuja Sharma, Marcel Prastawa, Andrei Irimia, Jack Van Horn, Guido Gerig, Martin Styner, Danielle Pace, Stephen Aylward)

- ***Validation, visualization and analysis of segmentation for TBI*** (Bo Wang, Marcel Prastawa, Andrei Irimia, Micah Chambers, Jack Van Horn, Guido Gerig, Danielle Pace, Stephen Aylward)

- ***Geometric Metamorphosis for TBI*** (Danielle Pace, Marc Niethammer, Marcel Prastawa, Andrei Irimia, Jack van Horn, Danielle Pace, Stephen Aylward)

- ***Multimodal Deformable Registration of Traumatic Brain Injury MR Volumes using Graphics Processing Units*** (Yifei Lou, Andrei Irimia, Patricio Vela, Allen Tannenbaum, Micah C. Chambers, Jack Van Horn and Paul M. Vespa, Danielle Pace, Stephen Aylward)

- ***Integration of unscented Kalman filter (UKF) based multi-tensor tractography in Slicer*** (Christian Baumgartner, Yogesh Rathi, Carl-Fredrik Westin)

Discussion and Directions

- Work Accomplished
  - Multi-modal fusion (linear co-registration, ABC)
  - Segmentation of lesions, bleedings, shunt etc.
  - Tissue classification with normal atlas prior, deformable (fluid) atlas to subject registration
  - Several peer-reviewed publications and conference presentations
- In progress and future directions:
  - Get more TBI imaging data and details on case history/outcome
  - White matter damage characterization in acute vs. chronic TBI
  - Robust tissue segmentation with outlier detection and more categories (wm, gm ,csf, hemorrhage, lesions, etc.)
  - Advanced registration via joint surface/volume deformable registration
  - "metamorphosis"-based methods for TBI lesion classification
  - User-guidance to "seed" categories of tissue within Slicer
  - TBI-related informatics wrt the current TBI literature

Thank you