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.
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
Case 1
acute

ventricular system
edema
hemorrhage
Case 1
chronic

- ventricular system
- lesion
- bleed
Case 1 longitudinal comparison

- Red: acute
- Green: chronic
Case 2

Gunshot victim
Case 2
acute

ventricular system
edema
hemorrhage
Case 2
chronic

- ventricular system
- lesion
- bleed
Case 2
longitudinal analysis

- Acute
- Chronic
Case 3

Blunt force trauma
Case 3
acute

- ventricular system
- edema
- hemorrhage
Case 3
chronic

- ventricular system
- lesion
- bleed
Case 3
longitudinal analysis

- red: acute
- green: chronic
Acute/Chronic Multimodal Registration in TBI
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.

**Sliding organ registration**
- Handle sliding motion (ex. between brain and skull).
- Validation evaluated in abdomen:

Kitware, UNC, UCLA, Utah
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

Andrei Irimia et al.
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
Conference Presentations

Automatic Segmentation of Traumatic Brain Injury MRI volumes using Atlas Based Classification and 3D Slicer
Andrei Irimia, Misha C. Chambers, John D. Van Horn
Laboratory of Neuro Imaging
University of California, Los Angeles
andrei@imaging.ucla.edu
213-247-6801
http://www.imaging.ucla.edu
NAMIC Tutorial Context: Summer 2011

NAMIC DBP
Traumatic Brain Injury
UCLA
Jack Van Horn, A. Irimia, M. Chambers, A. Toga, J. Alger, P. Vespa,
D. Hovda UCLA LONI, Neurology, Neurosurgery
Guido Gerig, M. Prastawa, S. Gouttard
University of Utah and SCI Institute
Stephen Aylward, Kitware

Clinically-Driven Multimodal Imaging of Traumatic Brain Injury Using Semi-Automatic Segmentation in 3D Slicer

[Image of a poster and a presentation slide related to traumatic brain injury research]
TBI DBP Presentations

• Conference Proceedings

• Conference Abstracts & Posters
NA-MIC Winter Project
Week 2012 TBI Activities

1. 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)

2. 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)

3. 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)

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

5. 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)

6. 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