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

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INTRODUCTION

- an estimated 1.7 million Americans sustain a traumatic brain injury (TBI) every year [1]
- the use of automatic segmentation for the clinical investigation of TBI remains an elusive goal because such methods are insufficiently robust to accurately capture TBI-related changes in brain anatomy
- despite recent progress in image analysis, it remains difficult to quantify TBI-related brain insults multi-modally, especially for improving clinical outcome metrics
- to address the urgent need for clinically-oriented TBI analysis tools, we have used multimodal, automatic TBI analysis methods with a focus toward assessing clinical improvement

METHODS

- we employ the NA-MIC Kit and 3D Slicer platforms [2, 8, 9] to obtain metrics of pathology and changes due to therapy and/or recovery
- processing includes segmentation of lesions, homorhage, edema and other pathology using Atlas Based Classification (ABC)
- ABC is a robust automatic segmentation framework which includes multimodal image registration, model-based bias field correction, tissue classification and outlier detection [2, 4, 7]
- the ABC paradigm is considerably more suitable for TBI volume segmentation compared to standard methodologies
- longitudinal changes are assessed by registration and joint segmentation of baseline and follow-up data for the ultimate purpose of performing longitudinal analysis
- our tools allow cross-correlation of multimodal metrics from structures imaging (cortical thickness, volume, lesions) and DTI with clinical outcome variables (time since injury, age, gender, etc.)
- neuroimaging data are drawn from the LONI Image Data Archive (IDA), a comprehensive archive comprised of a number of funded projects [3]

RESULTS

- 3D Slicer and the NA-MIC Kit are applicable to the analysis of TBI neuroanatomy to investigate alterations in cortical thickness and white matter changes
- Slicer software tools being developed allow us to obtain multimodal results for the analysis of neurological concommitants associated with TBI
- metrics can be extracted for uni- and multivariate modeling to provide additional insights about neuro-anatomical changes and clinical outcome variables
- multimodal data processing solutions are to be made openly available, with accompanying training materials via the NA-MIC web site, and compliant with the NA-MIC open-source policies

CONCLUSIONS

- we envision NA-MIC Kit workflows to be suitable for TBI clinical practice and patient monitoring, particularly for assessing TBI damage and measuring neuroanatomical change over time
- with knowledge of location, extent, and degree of change, metrics can be associated with clinical measures and subsequently used to suggest viable treatment options for individual patients with patterns that are typical TBI populations

REFERENCES


Figure 1. First row: Axial rendering of a TBI volume in 3D Slicer. (B) Image quality is low, due to motion artifacts, poor contrast, etc. White, black and gray image volumes (D, orange) are overlaid to the native T1 volume (A). (C) Lesions are defined as regions where T1 25% T1 > T1 30% T1 > T2 18%. (D) White matter (gray), ventricles (white) and lesions (cerebral contusions, red). Finally, the T1 models are created in IDA Slicer.

Figure 2. Second row: Axial rendering of a TBI volume in 3D Slicer. Challenges associated with this volumetric segmentation include large variability in size, shape, location and number of lesions. (A) As with the TBI volume in Figure 1, the TBI segmentation was performed manually, followed by semi automatic lesion segmentation of the TBI lesions and lesions. (B) Three different segmentation tools are shown in color: T1 25% T1 > T1 30% T1 > T2 18% (gray), white matter (white), ventricles (yellow). All models are then automatically exported into 3D Slicer.

Figure 3. Transmodality and point cloud display of segmented objects and MRI. The ABC algorithm performs the coregistration of structural modality to DTI (B) before image registered to T2 (A), which allows the residual T2 and structural images to be made available in the same coordinate system.

Figure 4. Simulated white matter and lesion segmentation, showing opaque models (left) of the white matter (red), with lesion (yellow) and transparent models (right).

Figure 5. Lesion and point cloud display of segmented objects and MRI. The ABC algorithm performs the coregistration of structural modality to DTI (B) before image registered to T2 (A), which allows the residual T2 and structural images to be made available in the same coordinate system.