Detecting atrophy in chronic moderate and severe traumatic brain injury using an automated volume-based morphometry toolbox

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Purpose: Traumatic brain injury (TBI) has become a rising epidemic, affecting millions of people each year. However, little is known about underlying pathophysiology changes of the progressive and long-term consequences of TBI. Although neuroimaging is essential for management of traumatic brain injury (TBI), there is a lack of robust methods for the visualization and assessment of TBI pathophysiology. TBI presents significant segmentation challenges, due to the need to account for tissue classes other than healthy appearing gray matter (GM) and white matter (WM). Until now, the application of automated segmentation algorithms to TBI in a clinical setting has remained an elusive goal because existing methods have been insufficiently robust to detect TBI-related changes in brain anatomy. The goal of this study is to evaluate the performance of an automated volume-based morphometry package further referred to as MorphoBox[1] to assess atrophy in chronic moderate and severe TBI.

Methods: A total 24 TBI patients and 12 demographically-matched healthy controls (HC) subjects were studied. All TBI participants had a moderate to severe injury (PTA>24 hours and LOC>30 minutes) and were an average of 13.6 years post-injury (range: 2-36 y). At screening, participants were evaluated for facial affect recognition (DANVA Faces)[2]. These scores were used to classify TBI participants as impaired (TBI-I) or unimpaired (TBI-N) in facial affect recognition. There were a total of 12 TBI-I and 12 TBI-N patients included. T1-weighted 3D MPRAGE was acquired for all participants on a 3T scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) using the ADNI2[3,4] (Alzheimer's Disease Neuroimaging Initiative) MPRAGE protocol with an acceleration factor of 2 (GRAPPA). All MPRAGE images were processed through MorphoBox pipeline that includes atlas registration, bias field inhomogeneity correction, calculation of probabilistic maps for GM, WM and CSF and binary maps for a number of key brain structures along with their absolute and relative volumes, which were computed by integration over class-specific regions and normalized by the total intracranial volume (TIV), respectively[1]. Scores for overall image quality and segmentation quality (correlation of extracted GM probability map with GM prior probability atlas ranging from 0 to 1) were also provided [5]. Volumetric measures derived from MorphoBox and those generated using the widely used volume-based morphometry package FreeSurfer 5.1 [6] were compared in their ability to detect diseased subjects.

Results: After excluding subjects with segmentation quality scores lower than 0.7 (two TBI and one HC), all individual absolute volumes provided by MorphoBox were analyzed by MANCOVA using age, sex and TIV as covariates. TBI patients showed significantly smaller volume of total GM, WM, insula, bilateral frontal and temporal WM, right temporal lobe GM, cingulate GM, pallidum and putamen ($p<0.05$). In post-hoc comparison (table 1), TBI-I patients demonstrated less global GM and WM, cingulate GM, frontal and temporal WM volumes compared to HC subjects, while the TBI-N group showed intermediate changes between TBI-I and HC groups. Only right temporal WM showed significant TBI-N > TBI-I. Except ventricles, no region was found to be of greater volume in TBI than HC group. Same significant group differences were found while using volumes provided by FreeSurfer.

Tab. 1.

Regions	*post-hoc* Comparison
Total GM	HC > TBI-I
Total WM	HC > TBI-N, TBI-I
Left Insula	HC > TBI-I
Right Insula	HC > TBI-N, TBI-I
Bilateral Frontal Lobe WM	HC > TBI-N, TBI-I
Left Temporal Lobe WM	HC > TBI-I
Right Temporal Lobe GM	HC > TBI-I
Right Temporal Lobe WM	HC, TBI-N > TBI-I
Cingulate GM	HC > TBI-N, TBI-I
Pallidum	HC > TBI-N, TBI-I
Putamen	HC > TBI-I
Ventricles	HC < TBI-N, TBI-I

Discussion: Identification of structural abnormalities in chronic TBI remains challenging because the brain often appears quite normal on conventional CT and MRI scans. Our preliminary data suggests usefulness of the newly developed automated segmentation tool in detecting atrophy in chronic moderate and severe TBI. Although the widely used FreeSurfer can provide detailed volumetric information of more brain structures, this study indicates that MorphoBox achieves comparable ability to detect diseased subjects using a particular brain structure volume. It therefore opens perspectives towards a more extensive use of tools such as MorphoBox in clinical practice for fast volumetric analysis without complex post-processing steps.

Conclusion: Patients with chronic moderate and severe TBI often have impaired facial affect recognition. Our initial results indicate that underlying structural abnormalities may provide a substrate for this cognitive deficit, and such alterations could be easily assessed using an automated volume-based morphometry toolbox such as MorphoBox.

References

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