Imaging Biomarkers for Early Diagnosis of Traumatic Brain Injury

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Philips Research
Neuroimaging of Mild-Moderate TBI

- Majority of conventional imaging studies in mTBI are normal
  - CT scan
  - Conventional MRI
- Some emerging techniques show promise:
  - Diffusion weighted imaging (e.g. DTI)
  - MR spectroscopy
- Emerging technologies are labor intensive, not always reliable and not readily available
- Real-time volumetric measures would be of interest
Shape-constrained Deformable Brain Model
Fully Automatic Adaptation

Model

Shape Detection  Parametric Adaptation  Deformable Adaptation

Patient’s Scan

Model Adapted to Patient’s Shape
Segmentation Example
Quantitative evaluation

- K-fold cross validation
Comparison with FIRST and Freesurfer

- 10 healthy volunteers scanned twice within a week
- Quantitative scan, re-scan reproducibility

FIRST 5.0
Freesurfer 5.1
Methods

• 44 patients with mild TBI (mTBI) and 29 healthy control subjects were imaged with MR (T1-weighted) at 2 time points

• The fully automatic shape-constrained deformable brain model was applied to each group at both time points

• Volumetric measures were examined for significant differences using multivariate analysis of covariance (MANCOVA) with age and relative intracranial volume as covariates
mTBI vs. Controls

- 44 patients with mTBI
  - (ACRM criteria; GCS score 13-15)
  - studied ~ 1 month and ~ 1 year after their injury
- 29 demographically-equated healthy controls

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mild TBI</th>
<th>Control</th>
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<tbody>
<tr>
<td>Age</td>
<td>31.0 ± 13.9</td>
<td>29.4 ± 11.7</td>
</tr>
<tr>
<td>Sex</td>
<td>26M + 18F</td>
<td>18M + 11F</td>
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<tr>
<td>Scan-scan interval</td>
<td>322-490 days (384.3 ± 38.9)</td>
<td>336-437 days (383.9 ± 30.0)</td>
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Two-tailed t = 0.50, p = 0.62

X² = 0.065, p = 0.80

Two-tailed t = 0.05, p = 0.96
### TBI Injury-Scan Interval

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
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<tr>
<td>Injury to scan 1</td>
<td>19-113 days (59.9 ± 20.6)</td>
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<tr>
<td>Injury to scan 2</td>
<td>376-537 days (444.2 ± 41.7)</td>
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### mTBI Cohort: Clinical Features

<table>
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<tr>
<th>Loss of Consciousness (minutes)</th>
<th>Glasgow Coma Scale Score</th>
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<tr>
<td>1.95 ± 1.89 (max 7.5 min)</td>
<td>14.7 ± 0.6 (13-15)</td>
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<tr>
<td>(n=31; 13 had no LOC or unknown)</td>
<td>(n=34)</td>
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Results

Regional Brain Volumes One Month after Mild TBI

$p(0.0027;0.0010;0.0025;0.0016;0.0671;0.0049)$
Results

Regional Brain Volumes One Year after Mild TBI

$V_{[\text{mm}^3]}$:

- Controls
- mTBI

$p (0.0013; 0.0006; 0.0001; 0.0002; 0.0148; 0.0060; 0.0009; 0.0303; 0.0872; 0.0819)$
Results

- **LCaudate**: $p = 0.032$
- **LAmygdala**: $p = 0.050$
- **Brainstem**: $p = 0.013$
- **Cerebellum**: $p = 0.006$
Visual Volumetric Differences

green: controls (mean mesh)
red: mTBI patient

Putamen

Thalamus
Conclusions

- mTBI is associated with small but detectable and statistically significant reduced volume in key subcortical structures one month after injury
- The differences persist at one year but are reduced in magnitude suggesting the possibility of normalization over time
- MBS provides sensitive measure of structural brain change after mTBI
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