Robotic transcranial magnetic stimulation mapping of the motor cortex in the intact developing brain

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ROBOTIC TMS INTRODUCTION

- Wilder Penfield first described the motor and sensory homunculus in 1950 that showcased the topographic arrangement of muscle representations of the human cortex
- New robot transcranial magnetic stimulation (TMS) technology has been developed to non-invasively assess functional cortical topography in vivo (Axilum robotics, Strasbourg, France)
- The robot corrects for potential head movement in 3-dimensional space to enhance precision and reproducibility of procedures by eliminating human error – the robot arm features 7 moving joints for improved accuracy
- Here, a study using robotic TMS is undertaken to understand the primary motor cortical M1 representations in healthy pediatric participants

OBJECTIVES

Primary Aim: Determine the feasibility of robotic TMS in a pediatric population and characterize the cortical motor maps in typically developing children

Additional aims:
- Localize the mean coordinate of maximal activation (hotspot) and centre of gravity (CoG)
- Quantify typical cortical motor map area and volume

METHODS

- Surface EMG simultaneously recorded 4 distal forelimb muscles bilaterally, including:
  - first dorsal interosseous (FDI)
  - abductor pollicis brevis (APB)
  - abductor digiti minimi (ADM)
  - abductor pollicis longus (APL)
- The site generating an MEP of maximal amplitude ≥50 µV on ≥2 /4 pulses was used to find the resting motor threshold (RMT)
- Motor mapping involved delivering 4, 1 Hz single pulses at 120% RMT at each site
- A responsive site was defined as a site generating an MEP ≥50 µV on ≥5 /10 single pulses
- Motor map bordering consisted of surrounding responsive sites
- The CoG is an MEP amplitude weighted mean coordinate position of the map, calculated as follows:
  \[ x_{\text{CoG}} = \frac{\sum x \cdot a_{\text{MEP}}}{\sum a_{\text{MEP}}} \]
  \[ y_{\text{CoG}} = \frac{\sum y \cdot a_{\text{MEP}}}{\sum a_{\text{MEP}}} \]

RESULTS

Mean TMS Coordinate Localizations of the FDI Muscle Warped to MNI Space

<table>
<thead>
<tr>
<th>Hemisphere</th>
<th>Hotspot X</th>
<th>Hotspot Y</th>
<th>Hotspot Z</th>
<th>Centre of Gravity X</th>
<th>Centre of Gravity Y</th>
<th>Centre of Gravity Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left (n=8)</td>
<td>-37</td>
<td>-12</td>
<td>58</td>
<td>-35</td>
<td>-16</td>
<td>61</td>
</tr>
<tr>
<td>Right (n=8)</td>
<td>43</td>
<td>-15</td>
<td>57</td>
<td>43</td>
<td>-15</td>
<td>58</td>
</tr>
</tbody>
</table>

SIGNIFICANCE

- High resolution cortical motor maps can be generated in pediatric participants using robotic TMS
- Localization of the primary motor cortex in individual children will enable personalized precision targeting for neuromodulation
- Motor map quantification in children with brain injury will better inform clinicians of plastic reorganization and regions of altered excitability

FUTURE DIRECTIONS

- Robotic TMS motor maps will be co-registered with fMRI-derived activation maps to understand the spatial congruency between modalities
- Robotic TMS motor maps will be used as an outcome measure for motor neuromodulation interventions in both normal and hemiparetic children