Cortical Control of Hand Movement: Impact on Clinical Care of People with Cerebral Palsy

Kathleen M. Friel, Ph.D.
Cortical Control of Hand Movement

• Primary methods of evaluating cortical control of hand movement in people with CP
  – Single pulse transcranial magnetic stimulation (TMS)
  – Diffusion tensor imaging (DTI)

• Who cares?
  – What is the clinical relevance of this information?
  – How does cortical wiring impact hand function, responsiveness to therapies?

• How can this information be assessed meaningfully in the clinic?
Hemiplegic (Unilateral) Cerebral Palsy

• Motor deficits primarily on one side of the body.
• Hand function is most impacted impairment.
• As children with hemiplegia age, they often fail to develop good motor skills on one side of body.
• Affects ability to perform activities of daily living.
Cortical Control of Hand Movement

- Best understood in children with unilateral CP.
- Most studied in older children (age >6yr).
- Assessments challenging for more severely impaired children and younger children.
- Much work still needs to be done: different types of CP, different parts of body, different ages (very young children, adults, age related changes across lifespan).
Motor System Dysfunction in Children with Unilateral CP

- Single-pulse TMS to map brain circuits
- Repetitive TMS to change activity of brain circuits

Inga et al., 2009

NIMH
TMS with Kids: A Collaborative Effort!

• [VIDEO]

Videos are shared with consent of participants & their families.
Using TMS to Study CP Neurophysiology

• How does motor system develop after perinatal brain injury?

"Contralateral"

Staudt et al, 2002
Using TMS to Study CP Neurophysiology

• How does motor system develop after perinatal brain injury?

"Contralateral"

"Ipsilateral"

Staudt et al, 2002

Ipsi, contra -> Same latency
Using TMS to Study CP Neurophysiology

- How does motor system develop after perinatal brain injury?

“Contralateral”  “Bilateral”  “Ipsilateral”

Staudt et al, 2002

Ipsi, contra --> Same latency
How does CST pattern impact hand function?

- **Contralateral**
  - ~20% of kids
  - Jebsen-Taylor Test of Hand Function: Time taken to complete fine motor tasks (higher score --> more impaired)

- **Bilateral**
  - ~40% of kids

- **Ipsilateral**
  - ~40% of kids

Kids with ipsilateral CST have poorer hand function than other groups (p<0.05).
Using TMS to Study CP Neurophysiology

Ipsilateral projections:
- Maladaptive after stroke in adults.
- Previously assumed to only control proximal gross movements.
- Marker of poor function/prognosis?

High variability: Why??

~40% of kids
Ipsilateral projections in CP:

- Possibly adaptive after developmental brain injury.
- Can control fine motor (digit/wrist) movements.
- Motor maps of both hands share the same cortical space.
- In many kids, the maps of the two hands are highly overlapped.
- More overlap → better hand function (r=0.51, \( p<0.05 \)).
- “Adaptive yoking” of motor control of the two hands.
Alternative to TMS for determining CST laterality

- TMS equipment is expensive, contraindicated for children who have seizure disorders.
- Diffusion Tensor Imaging (DTI) can be used to visualize brain pathways.
DTI: Alternative to TMS for determining CST laterality

- Can be done on most MRI scanners (~6min).
- Is accurate surrogate measure of CST laterality (Kuo et al., 2017).

Contralateral  Bilateral  Ipsilateral
Mirror Movements: A Quick Clinical Assessment of CST Laterality?

• Even though DTI is more accessible to most kids than TMS, it still requires an MRI, and interpretation of scans.

• Mirror movements (MMs) → when child moves one hand voluntarily, the other hand involuntarily mirrors the movement.

• Severe MMs associated with ipsilateral CST.

• Most kids have mild/moderate MMs – unclear how mild MMs relate to CST laterality.
Summary: Neurophysiology in Children with Unilateral CP

• Connection pattern of CST is related to severity of hand function deficits.
• Single Pulse TMS and DTI can be used to assess CST laterality.
• Severe mirror movements may point to an ipsilateral CST.
Activity-Based Treatments for Unilateral CP

- Unimanual training: sling over “good” arm, intensive training of impaired arm- game-playing, arts/crafts, practicing functional movements. (Gordon et al.)

- Bimanual training: children use both hands intensively, efficacy not different from unimanual training, better translates into improvement of functional goals. (Hand-Arm Bimanual Arm Training, HABIT) (Gordon et al.)
High Variability in Treatment Response

![Graph showing percent improvement in affected hand function for Unimanual and Bimanual therapy types. The graph indicates a high variability in treatment response.]
High Variability in Treatment Response-Why??

- Single pulse TMS - determine corticospinal tract (CST) organization
- 90 hrs. of unimanual or bimanual therapy
- Goal: Determine if CST organization relates to improvements in dexterity following unimanual vs. bimanual therapy
High Variability in Treatment Response - Why??

- Constraint therapy – drives down activity in the hemisphere controlling the less-affected arm.
- If both hands are controlled by the less-affected hemisphere, driving down activity may not be best.
- Bimanual therapy → “yoking” of both hands.
Children with contralateral CST improve more than children with ipsilateral CST in CIMT (unimanual therapy)

Children with ipsilateral and contralateral improve equally in HABIT (bimanual therapy)
Understanding an individual’s brain wiring can help prescribe the most effective therapy.
Upper Limb Rehab in People With CP: Lessons and Future

• TMS and DTI effective tools for measuring CST laterality.

• CST laterality affects hand function:
  – Contralateral CST associated with better hand function.
  – Ipsilateral CST associated with poorer hand function.

• CST laterality appears to impact efficacy of intensive hand therapy:
  – CIMT best for kids with contralateral CS.

• Much is still unknown!
Early Brain Injury Recovery Program

Funding: NINDS, NICHD, Burke Foundation, Carvel Foundation, Blythedale Children’s Hospital

Lab Members:
Talita Campos
Karen Chin, MS
Claudio Ferre, PhD
Disha Gupta, PhD

Collaborators:
Andy Gordon, PhD
Marom Bikson, PhD
Dylan Edwards, PT PhD
Yannick Bleyenheuft, PhD
Jason Carmel, MD PhD
Susan Duff, EdD PT OT/R CHT
Bernadette Gillick, PhD PT