Prediction of Children's Language Outcome Using Diffusion Tensor Imaging and Machine Learning

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- Surgical Advisory Board, MED-EL Corporation
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- SING Registry Board, Akouos
- US provisional patent application No. US20190192285A1 Neural predictors of language-skill outcomes in cochlear implantation patients
Variability of Outcome of Young Implanted Children

- Despite young age at CI, only a minority of children did as well as normal hearing peers.
- Prediction of high vs low performers not possible
  - Age at CI and residual hearing alone do not adequately account for variance

Niparko, et al 2010
Prediction to Develop Precision Brain Based Therapy to Improve Language

- Auditory deprivation’s impact on brain development must be taken into account
- Neural predictors based on brain structure & function to forecast **individual** outcome
Neural Predictors of Post-implant Language Based on Pre-surgical MRI

Measure language outcomes every 6-12 months

- T1 Neuroanatomical Imaging
- Diffusor Tensor Imaging (DTI)
T1 Neuroanatomic: Binary Classification Prediction on Individual Level

**Graph A:**
- SRQ Improvement vs. Age (Month)
- High improvement region
- Low improvement region

**Graph B:**
- Table of features and their accuracy (Acc), sensitivity (Sens), specificity (Spec), and AUC
- Features: Age at implant, Residual hearing
- GM: Affected = 49%, Sens = 50%, Spec = 47%, AUC = 49%
- GM: Unaffected = 73%, Sens = 80%, Spec = 71%, AUC = 78%
- GM: Whole-brain = 73%, Sens = 80%, Spec = 65%, AUC = 76%
- WM: Affected = 68%, Sens = 75%, Spec = 59%, AUC = 70%
- WM: Unaffected = 78%, Sens = 80%, Spec = 76%, AUC = 84%
- WM: Whole-brain = 76%, Sens = 80%, Spec = 71%, AUC = 82%

GM = Grey matter
WM = White matter

*Feng...Young, Wong. Proceeding of the National Academy of Sciences, 2018*
Brain regions unaffected by auditory deprivation are the most predictive.
- Mostly higher level auditory and cognitive regions engaged in speech perception.

Preservation of higher level processing regions is predictive of higher improvement
Diffusion Tensor Imaging (DTI)

- Non-invasive MRI
  - Additional scan time
- Tracts & connections
- Diffusion indexes
  - Fractional anisotropy (FA)
  - Radial diffusivity (RA)
    - Sensitive to myelination
  - Axial diffusivity (AD)
    - Sensitive to axonal injury
Prediction Based on MVPS Comparison Enabled by Machine Learning

- Subjects:
  - CI candidates (bilat mode to severe/profound) < 3.5 years at CI (6 – 41 months)
    - Excluding children with complicating conditions, developmental delay, brain & significant cochlear malformations
  - MRI of 31 normal hearing from NIH brain bank
    - Matched by age at MRI, sex, SES
  - Prediction of pre-CI speech perception and improvement at 6-month:
    - 52 at baseline
    - 32 at 6-month
  - Outcome measure at 6-month:
    - Speech Recognition Index in Quiet (MAIS/IT-MAIS)
MVPS Group Difference Maps (Axial) Between Normal & CI Candidates
High vs Low Performance: Classification Accuracy

Baseline Score

6-month Improvement
Predicted Regions of 6-month Improvement Overlapped with Group Difference
DTI Prediction Findings Summary

• Regions *unaffected* by auditory deprivation were most predictive of 6-month improvement

• Provides complimentary information to confirm hypothesis that *brain regions unaffected by auditory deprivation are predictive of outcome after CI*
**Predict-to-Prescribe - A Conceptual Framework To Improve Language Outcome**

- Brain based prediction - the first step toward personalized language learning for children with hearing loss
- Prediction is a powerful tool that may permit determination of optimal type and dose of therapy
  - Should not be used to deny care
    - Benefits to hearing beyond speech perception & language
- New approach to clinical care:
  - Improved counseling pre-CI
  - Improve language of at risk children
- Applicable to other developmental disorders
Future Pediatric Cochlear Implant Research Using Machine Learning

• Expand prediction window to 5 years, enabling hypothesis testing of theory of *Neural Readiness for Spoken Language Development*

• Compare predictive models of English learning children to Spanish learning children

• Evaluate whether Parent-Implemented Communication Treatment (PICT) can lead to larger language gains in children predicted to have poorer language outcome
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