Translating Research into Clinical Practice for Children with Cochlear Implants

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  - Jongmin Jung, Doctoral Candidate
  - Diana True-Kloiber, Au.D.
  - Denise Bradford, M.S.
Part 1: Two Technologies to Increase Spoken Language in Deaf Children

- Multi-channel Cochlear Implants
- Newborn Hearing Screening
Multichannel Cochlear Implants

- Cochlear implants: Surgically implanted electronic devices that bypass damaged hearing hair-cells to stimulate the auditory nerve directly
- Three main manufacturers in the US
  - Advanced Bionics
  - Cochlear Americas
  - MED-EL
- Recommended for children 1;0 or older
- Approximately 30,000 deaf or severely hard of hearing children have received CIs in US
- Bilateral CIs are becoming more common
Example of CI Components

MED-EL cochlear implant
How a Cochlear Implant Works
Expected Threshold Range for CI Users
How does speech sound?

(courtesy of Xin Luo)

1ch  2ch  4ch  8ch  16ch
In sum, CIs provide ...

- increased access to conversational-intensity speech and auditory feedback, thereby increasing opportunities to develop phonological abilities through incidental learning.

- access to a wide range of spectral information to support the development of a complete inventory of phonemes.

BUT auditory and speech intervention usually needed because ...

- of a relatively late start in auditory-guided speech development
- CI thresholds not within normal hearing sensitivity limits.
- speech is represented electronically, not naturally
Newborn Hearing Screening

- 2 – 3 children per 1,000 are born deaf or hard of hearing
- 43 states have mandated Newborn Hearing Screening (NHS)
- Common interventions:
  - Hearing Aids
  - Cochlear Implants if HA trial indicates limited audition
  - Family-centered intervention
- Best spoken language results
  - identified <6 months of age (Yoshinaga-Itano, 1998)
  - Intervention started by 11 months of age (Moeller, 2000)
Vocal Development:
A process by which infants and toddlers begin to produce phonetically diverse, structurally complex, and speech-like vocalizations prior to saying words on a regular basis.
1. Precanonical Vocalizations...
(Range of emergence 0 – 6 months in NH children)

- …lack true vowels and true consonants in combination with a rapid transition between them (Oller, 2000)

- Types
  - Quasi- and fully-resonant nuclei (Oller & Lynch, 1992)
  - Squeals
  - Vowels / vocants in isolation or in series (Kent & Bauer, 1985)
  - Consonants / Closants in isolation or in series (Stark, 1980)
Examples of Precanonical Vocalizations

- Quasi and Fully resonant nuclei
- Squeals
- Vocants and vowels
- Closants
Child at Precanonical level

PRE.wmv
Precanonical Video Examples

- http://www.youtube.com/watch?v=4oNhmbn67c
- http://www.youtube.com/watch?v=IKLQOYMGf1A
characterized by...
- Normal phonation
- Full vocalic resonance (vowel)
- At least one consonant
- Rapid CV transitions
  (Oller & Lynch, 1992)

Types
- CV syllables and disyllables (CVCV)
- Reduplicated and nonreduplicated babbling
- Whispered vocalizations
Basic Canonical Syllables

- CV
- CVCV
- Babbling
  - String of 3 or more CV syllables
- Whispered vocalizations
Child at Basic Canonical Syllable level

• BCS.wmv
Basic Canonical Syllables

- http://www.youtube.com/watch?v=37JxkDNJ0Aw
- http://www.youtube.com/watch?v=WRKKEIUIjegtg
- http://www.youtube.com/watch?v=bt077TOugdA&feature=related
- http://www.youtube.com/watch?v=_JmA2CIUvUY&feature=related
AGE OF ONSET OF CANONICAL BABBLING IN DEAF AND HEARING INFANTS

- Hearing infant
- Deaf infant from present work
- Deaf infant from previous work
- Kent, et al., 1987
- Oller, et al., 1985

FIG 1 — Frequency distribution for ages of onset of canonical babbling in deaf and hearing infants
3. Advanced Forms
(Range of emergence in NH children: 10 – 18 months)

- ... have canonical attributes but are phonetically or prosodically more complex than BCS (Nathani, Ertmer, & Stark, 2002)

- Types
  - Complex syllables (e.g. CCV or CVC)
  - Jargon
    - combinations of different consonants and vowels with changes in stress or intonation
  - Diphthongs
Examples of Advanced Forms

- Complex Syllables
  - CVC, VCV, CCV...

- Diphthongs

- Jargon
Child at Advanced Forms level

► AF.wmv
Advanced Forms

- http://www.youtube.com/watch?v=drMaxN5ohA0
- http://www.youtube.com/watch?v=WdoZ8WkfoAE
- http://www.youtube.com/watch?v=wbrkkyA0F7k
Emergence of Speech–Like Utterances (BCS + AF) after CI (Ertmer, Jung, & Kloiber, 2013)

* $p<.05$, and **$p<.005$


CI PC
CI SL
TD SL
Vocal Development Expectations for Children Without Secondary Disabilities
(Ertemer, Jung, & Kloiber, 2013)

- **Precanonicals** – gradually decrease in quantity during the years 1 and 2 of CI use

- **Basic Canonical Syllables** – increase to about 30–40% of child utterances by 1 year of CI use and remain stable.

- **Advanced Forms** – Increase to 25% by 1 year and 50% by 2 years of CI use.

- **Speech-like utterances (BCS + AF)** – account for at least 60% of utterances by 18 months.
Possible Reasons why Expectations for Vocal Development are Not Met

- 35 – 40% of children with hearing loss have additional disabilities
- Relatively high CI-aided thresholds may slow development
- Difficulty in perceiving speech features
- Limited access to specialized intervention
- Presence of a speech/phonological impairment
- Limited follow-up in wearing CIs and mapping
- Others
Goal – to provide focused stimulation for developmentally appropriate vocalizations and to increase consonant and vowel diversity

Models: vocalizations from the child’s current and next level of vocal development
  ◦ PC – variety of vowels
  ◦ BCS – assorted CV, CVCV, and babbled syllables
  ◦ AF – CVC, diphthongs, jargon

Models presented every 5 seconds for 1 minute, 5 times per day by parents

vocal development.com for more information and video examples

http://www.youtube.com/watch?v=37JxkDNJ0Aw
Phonological Development

CI and TD Children
Consonant Accuracy
CI vs TD Age–peers (Ertmer et al, 2012)

- Word Initial Position
- Word Final Position
Finnish Phonology
CI vs TD
Kunnari & Välimaa data

![Bar chart comparing CI and TD data](chart.png)
Initial Phoneme Accuracy
CI Vs TD Age-peers
Final Consonant Accuracy
CI vs TD Age-peers

Phonemes:
- n (6) p (2) t (5) d (3) k (4) g (2)
- f (1) d (2) tf (3) s (3) v (1)
- j (2) θ (2) l (1) z (2) r (3) n (1)
### Phonological Inventories of Finnish CI and TD Children

**Kunnari & Valimaa data**

<table>
<thead>
<tr>
<th>Group</th>
<th>Vowel inventory (max. 8)</th>
<th>Consonant inventory (initial max. 10)</th>
<th>Consonant inventory (medial max. 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI- use-2</td>
<td>u, o, a, i, y, e, oe, ae</td>
<td>p, t, k, m, h, l</td>
<td>p, t, k, m, n, s, h, l, u, j</td>
</tr>
<tr>
<td>TD-2</td>
<td>u, o, a, i, e, ae</td>
<td>p, t, k, n, h</td>
<td>p, t, k, m, n, l</td>
</tr>
<tr>
<td>TD-3</td>
<td>u, o, a, i, y, e, oe, ae</td>
<td>p, t, k, m, n, s, h, l, u, j</td>
<td>p, t, k, m, n, n, s, h, l, u, j</td>
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(English CI users 70%)
Speech intelligibility outcomes

Percent of Words Intelligible

TD age vs CI Months of Robust Hearing
Summary

- Substantial improvements in the prelinguistic and phonological abilities of deaf children have been observed following cochlear implant activation.
- Receiving a CI before 3 years appears to prime children for steady progress toward age level speech production skills.
- Intervention services are also key for optimizing auditory and spoken language development.
Related Readings


