Image-guided cochlear implant programming

Jack Noble, PhD, René Gifford, PhD, Benoit Dawant, PhD, and Robert Labadie, MD, PhD
Overview

The position of implanted electrodes relative to stimulation targets can be used to aid programming

- Individualized determination of electrode-to-neural interface (distance based)
- Can be used to determine programming relevant characteristics
- Significant improvement in hearing outcome compared to traditional programming (n = 65)
Background

In vivo electrode position identification

CT imaging approaches\(^1,2\)
- High quality images of electrodes
- Basilar membrane, spiral ganglion, etc. not visible

- Rigid registration with high resolution model image of a specimen\(^3\)
- Small scale soft tissues visible in aligned model
- Does not account for non-rigid variation in cochlear anatomy
- Time per case may be prohibitive for clinical use


Background

**In vivo electrode position identification**

- Extend our recently presented methods for identifying ST & SV to identify SG in pre-op CT²
  - Automatic—based on statistical shape modeling
  - Accounts for non-rigid variations in cochlear anatomy
- Register to post-op CT in which electrodes are visible
- Permits computation of programming relevant characteristics


Creation of SSM of Cochlea from microCT
Pre-op CT

Coronal slice

posterior to anterior
Post-op CT
Coronal slice
posterior to anterior
MicroCT model → SG in pre-op CT → EA and SG → EA in post-op CT
Electrode Position Analysis

Electrode Distance-Vs-Frequency Curves

Programmed Cochlear Implant Vanerbilt University
DVF-based Deactivation Strategy

**Image Guidance**

**DVFs of Traditional Map**

**DVFs of Experimental Map**

**SG Characteristic Frequency (Hz)**
PARTICIPANTS

- n = 65
- Mean age = 61.2 years
  - range 18.9 to 90.5 years
- Experienced adult CI users
  - Mean of 3.7 years of CI experience
- 29 bilateral, 36 unilateral
PARTICIPANTS

- 16 AB, 37 Cochlear, 12 MED-EL
- Mean # of deactivated electrodes = 5.9
  - AB: 5.7
    - Proportion: 0.36
  - Cochlear: 7.1
    - Proportion: 0.32
  - MED-EL: 2.4
    - Proportion: 0.20
**METHOD**

- Measure patient's hearing performance with clinical map
  - CNC
  - AzBio (Quiet & Noise)
  - BKB-SIN
  - Spectral Modulation Detection
  - APHAB, SSQ

- Switch patient to experimental map 3-6 weeks

- Re-measure hearing performance
METHOD

• CI reprogrammed by deactivating recommended electrodes

• Parameters held constant:
  • Stimulation rate
  • Frequency allocation table
  • Strategy

• Parameters adjustable:
  • PW (AB only)
  • Global M/C levels for loudness
  • Maxima for Cochlear
HYPOTHESES

- ID electrodes with greatest channel interaction based on individualized anatomy, electrode location, and electrode-to-modiolus distance →
- Deactivate electrodes →
- Increase spatial selectivity →
- Improve spectral resolution →
- Improve speech recognition in noise
RESULTS

APHAB

- Aversiveness
- Backdrop Noise
- Ease of Communication
- Reverberation
- Global Score

Benefit (Percentage points)

SSQ

- Spatial Hearing Qualities
- Speech Hearing

Total

Benefit (Percentage points)
• This is how I've wanted it to sound all along.
• It sounds less cluttered.
• It's as if you've unclogged the sound pipe line.
• There is no more 'wamp wamp' sound.
• It’s different. I will have to get used to it.
• It sounds like you took the pillow off my head.
• Everything is so much clearer. It's like I don't have a 'better' ear anymore.

• The improvement shown on your tests doesn't reflect how much better I am doing.

• If I could have heard like this out of the gate, there's no telling how much better I would be hearing even today.

• I do not want my old program back.
DISCUSSION

• Currently, CI programming is completed manually without knowledge of electrode position.

• In this work, we have presented approaches for:
  • Automatically determining electrode position
  • A position-dependent programming strategy that reduces channel interaction.

• Significant improvement for experimental ears on all speech measures and QSMD (spectral resolution)
FUTURE WORK

• Children
  • VUMC grant
  • \( n = 8 \)
• Efficacy for newly activated patients
  • U01 (Labadie and Gifford)
• Automation and software integration
  • R01 (Dawant)
• Investigation of additional parameter manipulation
  • R01 (Noble)
• Investigate the unknowns
  • Neural survival, excitation