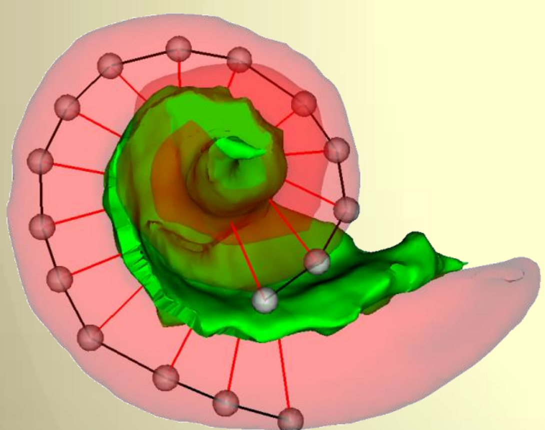
Image-guided cochlear implant programming



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

VANDERBILT UNIVERSITY
MEDICAL CENTER

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

[1]. Verbist, B. M., Frijns, J.H.M., Geleijns, J., van Buchem, M. A., Multisection CT as a Valuable Tool in the Postoperative Assessment of Cochlear Implant Patients. Am. J. Neuroradiol. 26: 424-429, 2005.

[2]. Aschendorff A, Kromeier J, Klenzner T, Laszig R, Quality Control After Insertion of the Nucleus Contour and Contour Advance Electrode in Adults. Ear & Hearing 28, 2007. : 75S-79S.

[3]. Skinner MW, Holden TA, Whiting BR, Voie AH, Brundsden B, Neely JG, Saxon EA, Hullar TE, Finley CC. In vivo estimates of the position of advanced bionics electrode arrays in the human cochlea. Ann Otol Rhinol Laryngol Suppl. 197, 2007. : 197:2-24.

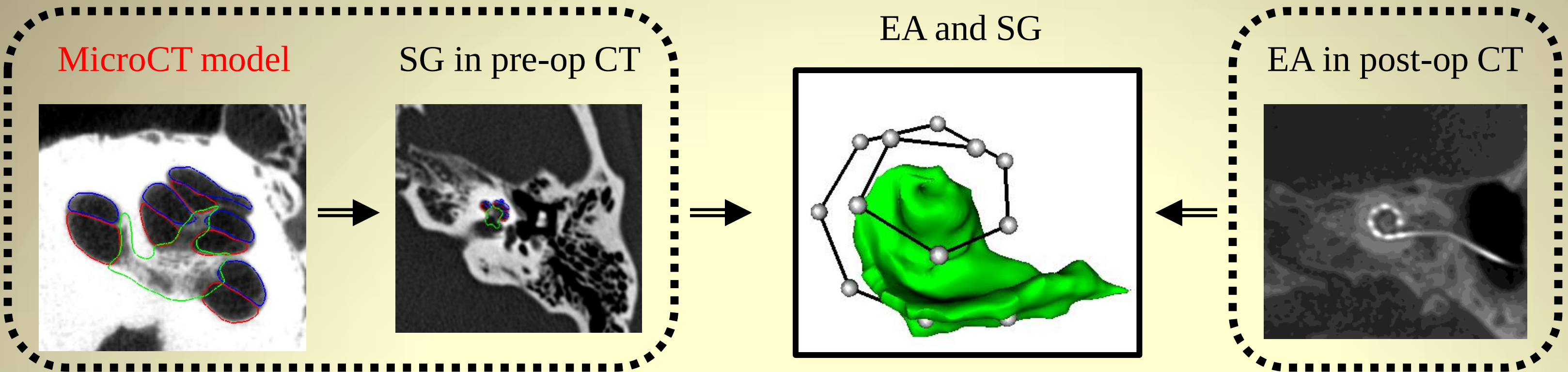
Background

In vivo electrode position identification

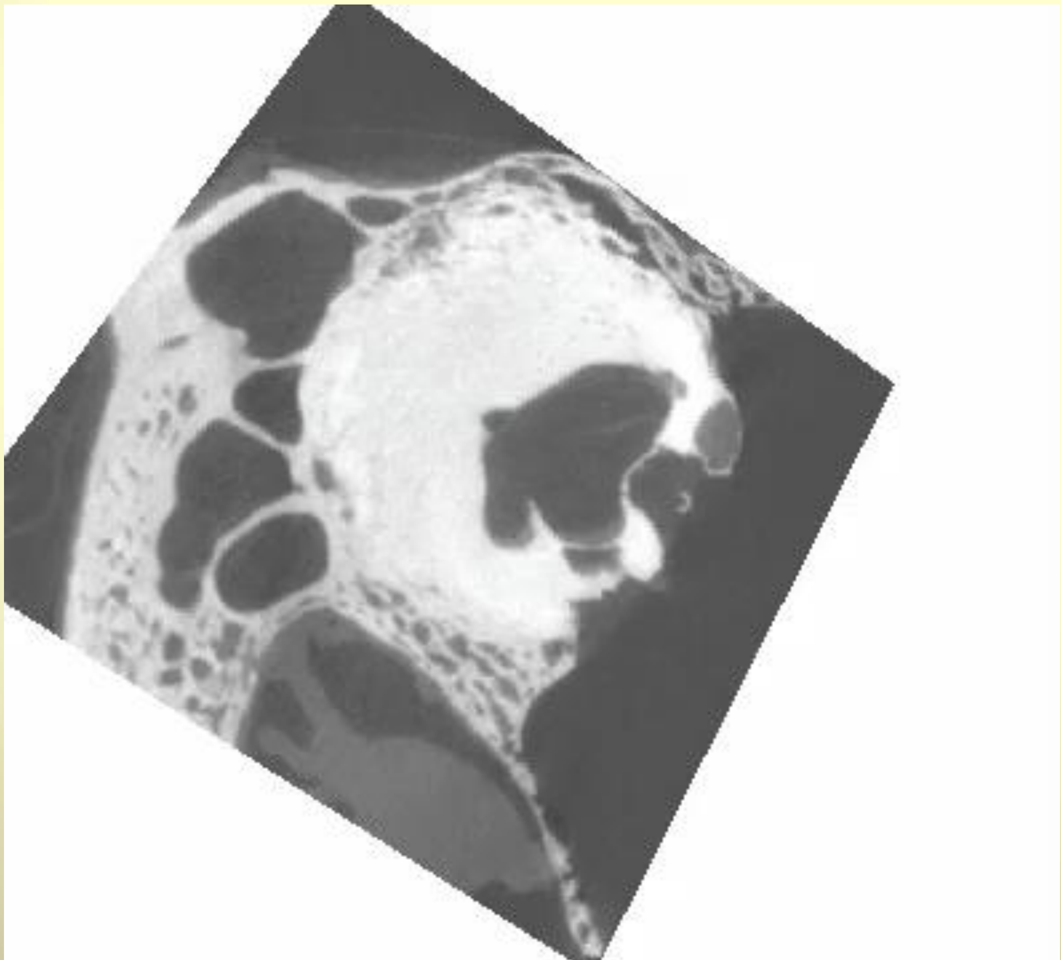
- Extend our recently presented methods for identifying ST & SV[1] to identify SG in pre-op CT[2]
  - Automatic—based on statistical shape modeling
  - Accounts for <u>non-rigid variations</u> in cochlear anatomy
- Register to post-op CT in which electrodes are visible
- Permits computation of programming relevant characteristics

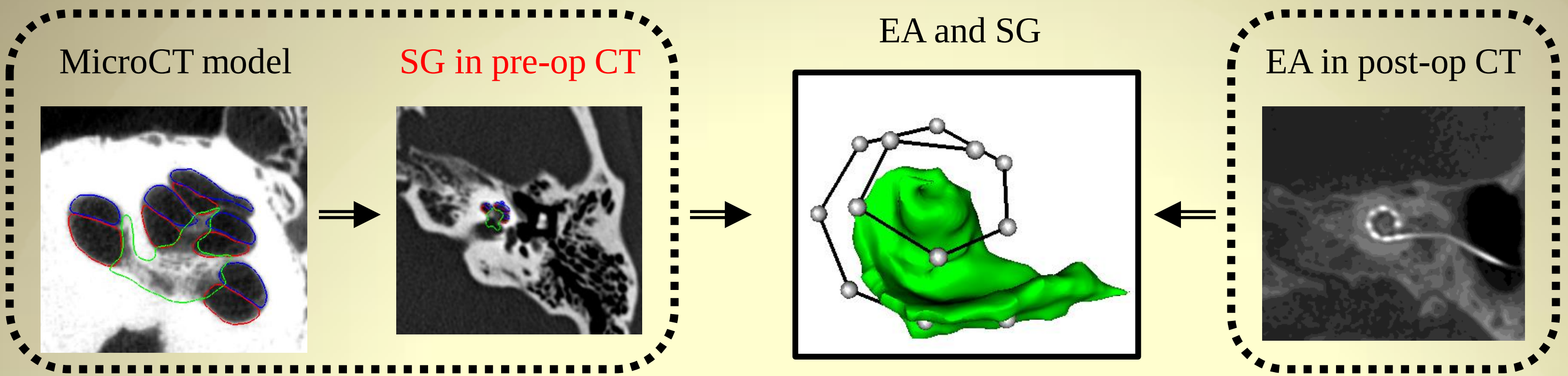
[1]. Noble JH, Labadie RF, Majdani O, Dawant BM,. Automatic segmentation of intra-cochlear anatomy in conventional CT. IEEE Trans. on Biomedical. Eng. 58(9), 2011. : 2625-32.

[2]. Noble, J.H., Gifford, R.H., Labadie, R.F., Dawant, B.M., 2012, "Statistical Shape Model Segmentation and Frequency Mapping of Cochlear Implant Stimulation Targets in CT," Under review for publication in Lecture Notes in Computer Science – Proceedings of MICCAI.



Creation of SSM of Cochlea from microCT

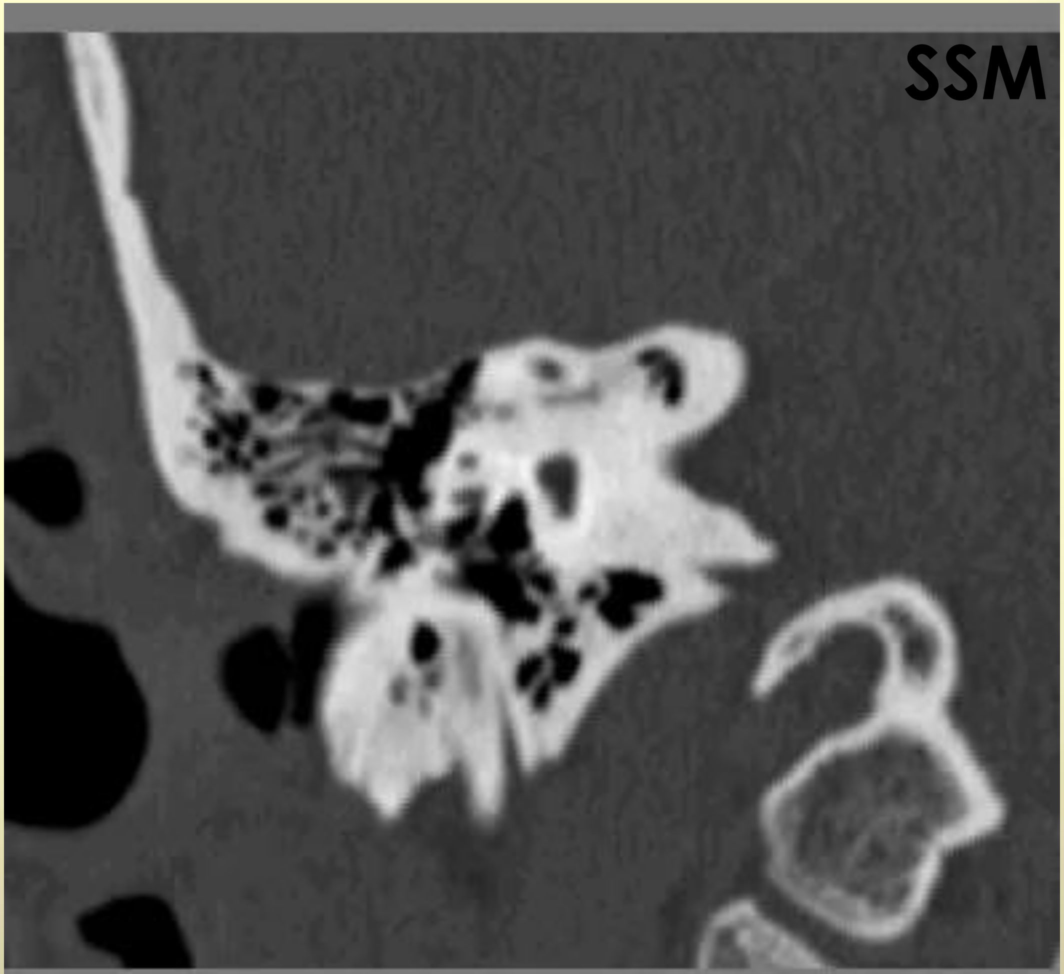


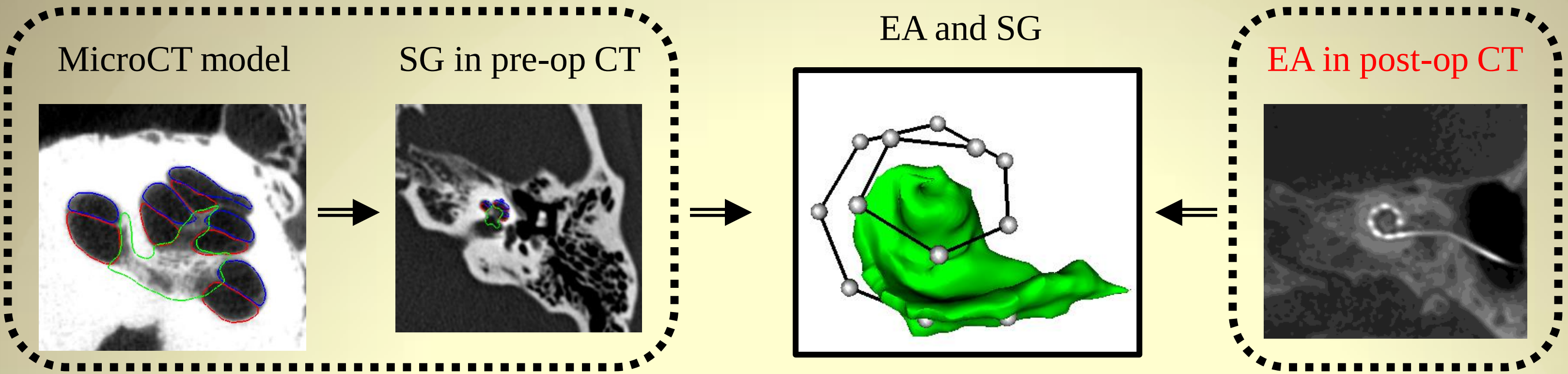


Pre-op CT

Coronal slice

posterior to anterior

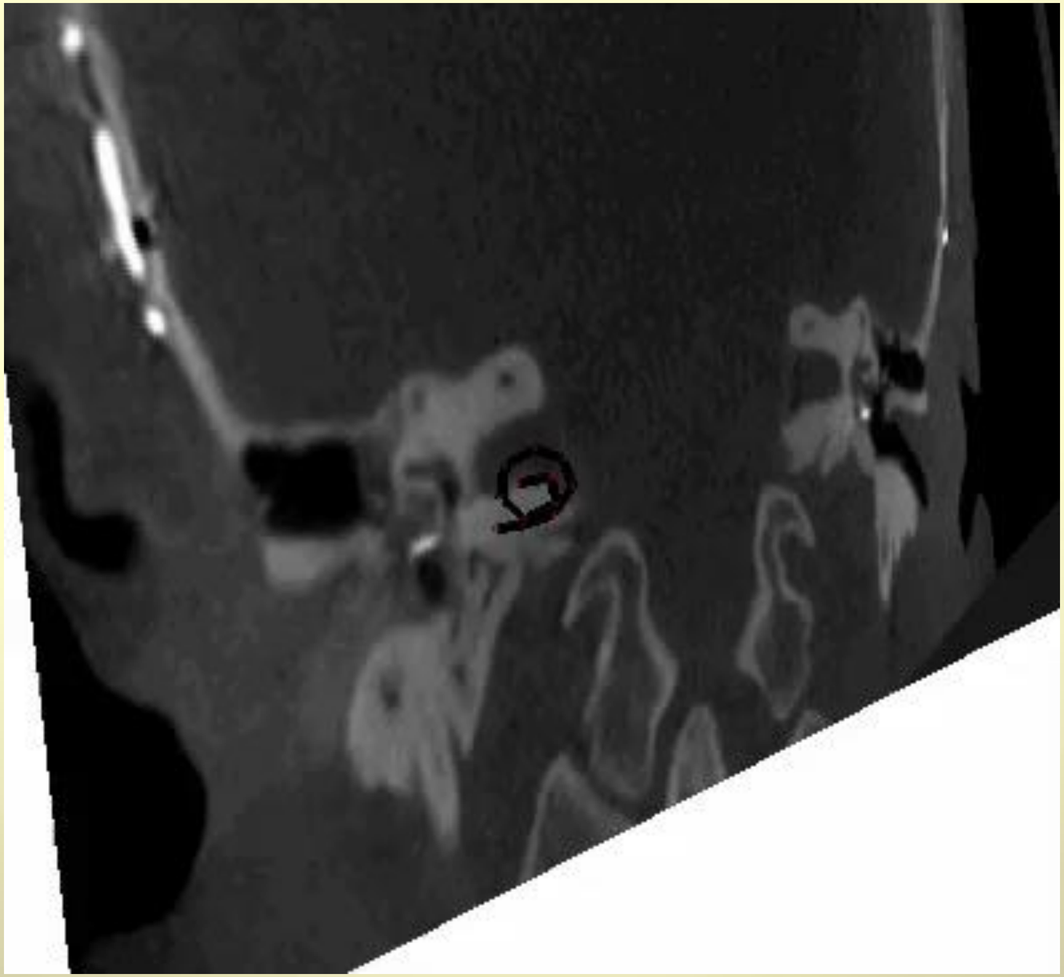


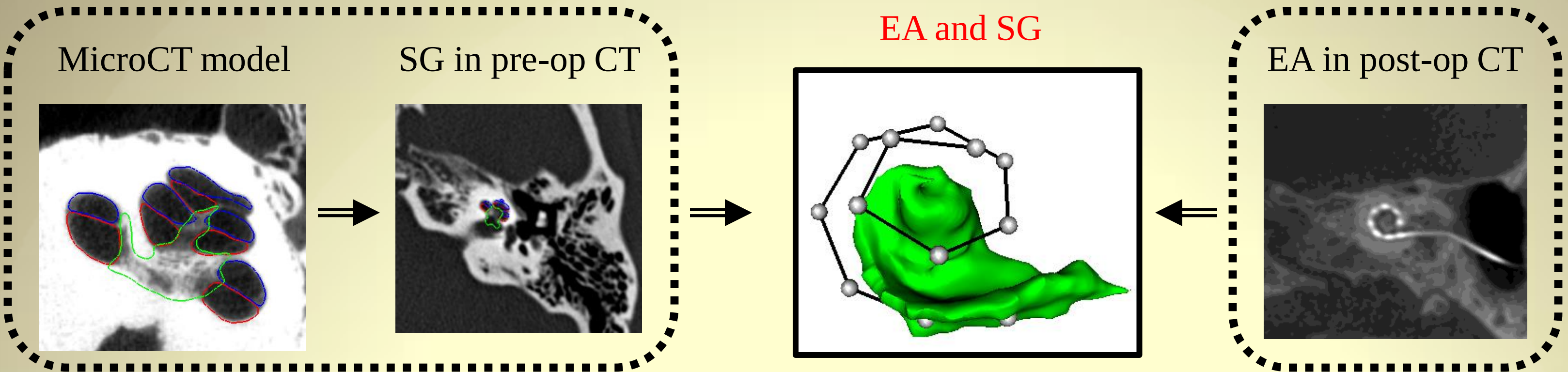


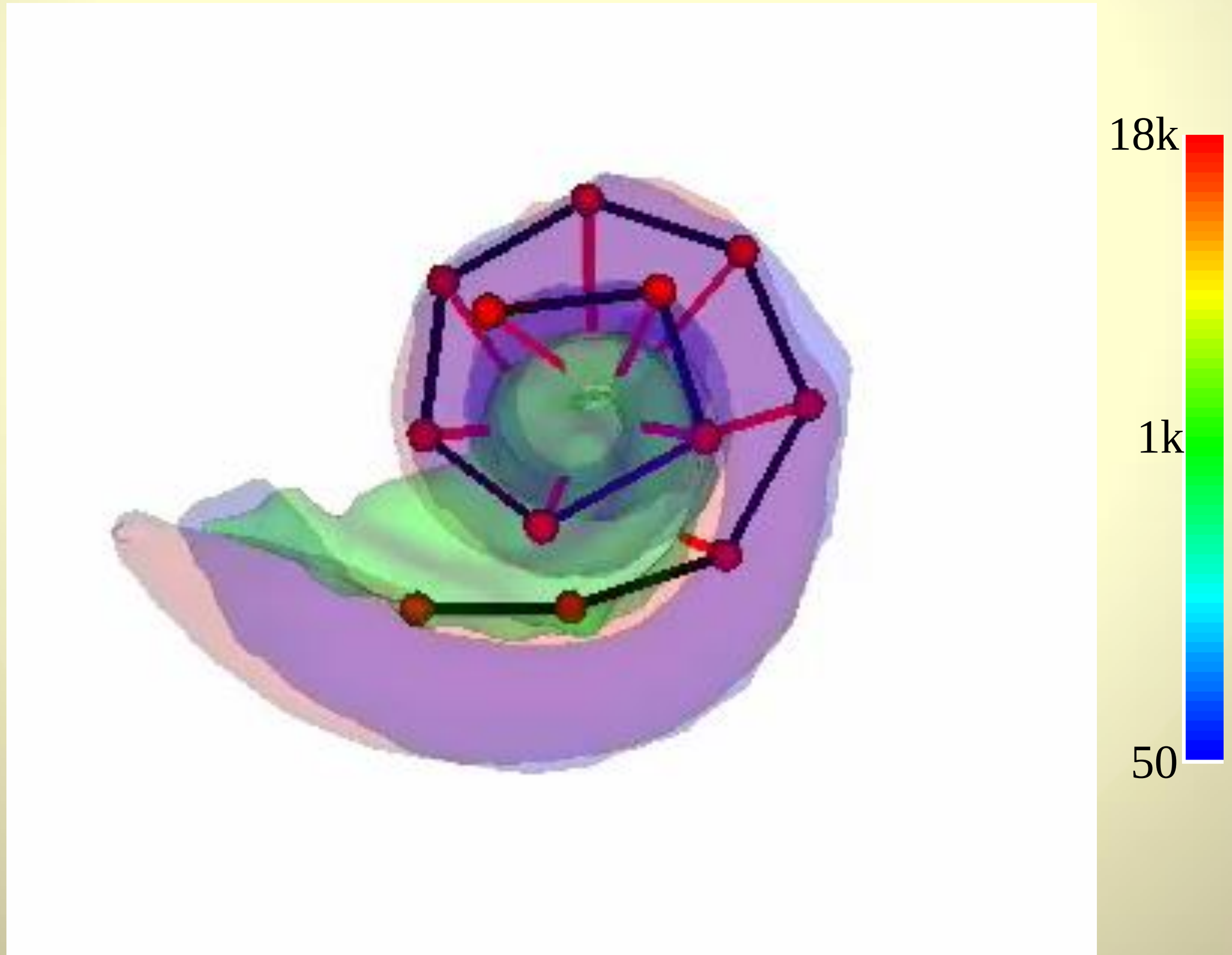
Post-op CT

Coronal slice

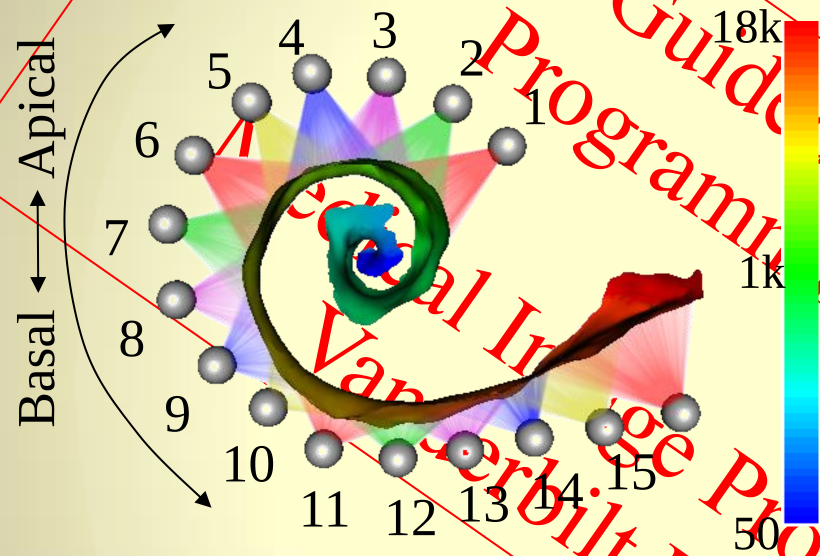
posterior to anterior



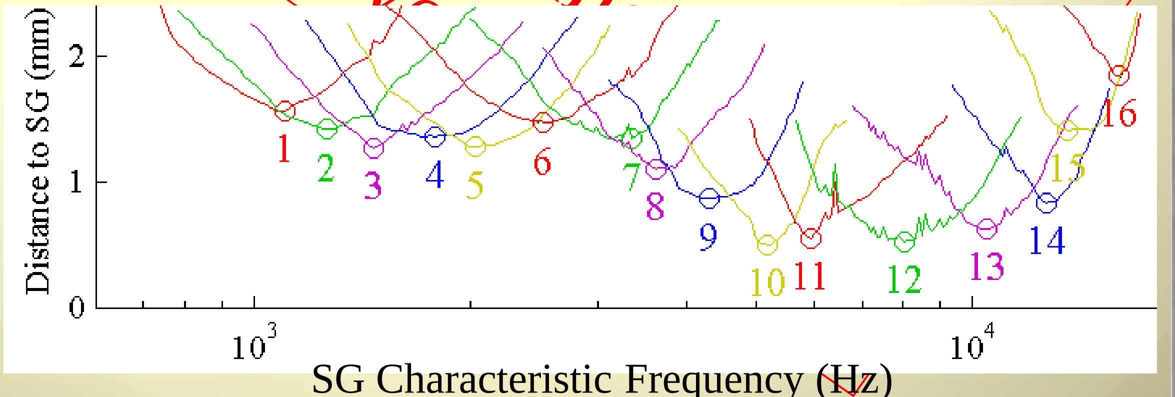

MicroCT model
SG in pre-op CT
EA and SG
EA in post-op CT


18k
1k
50

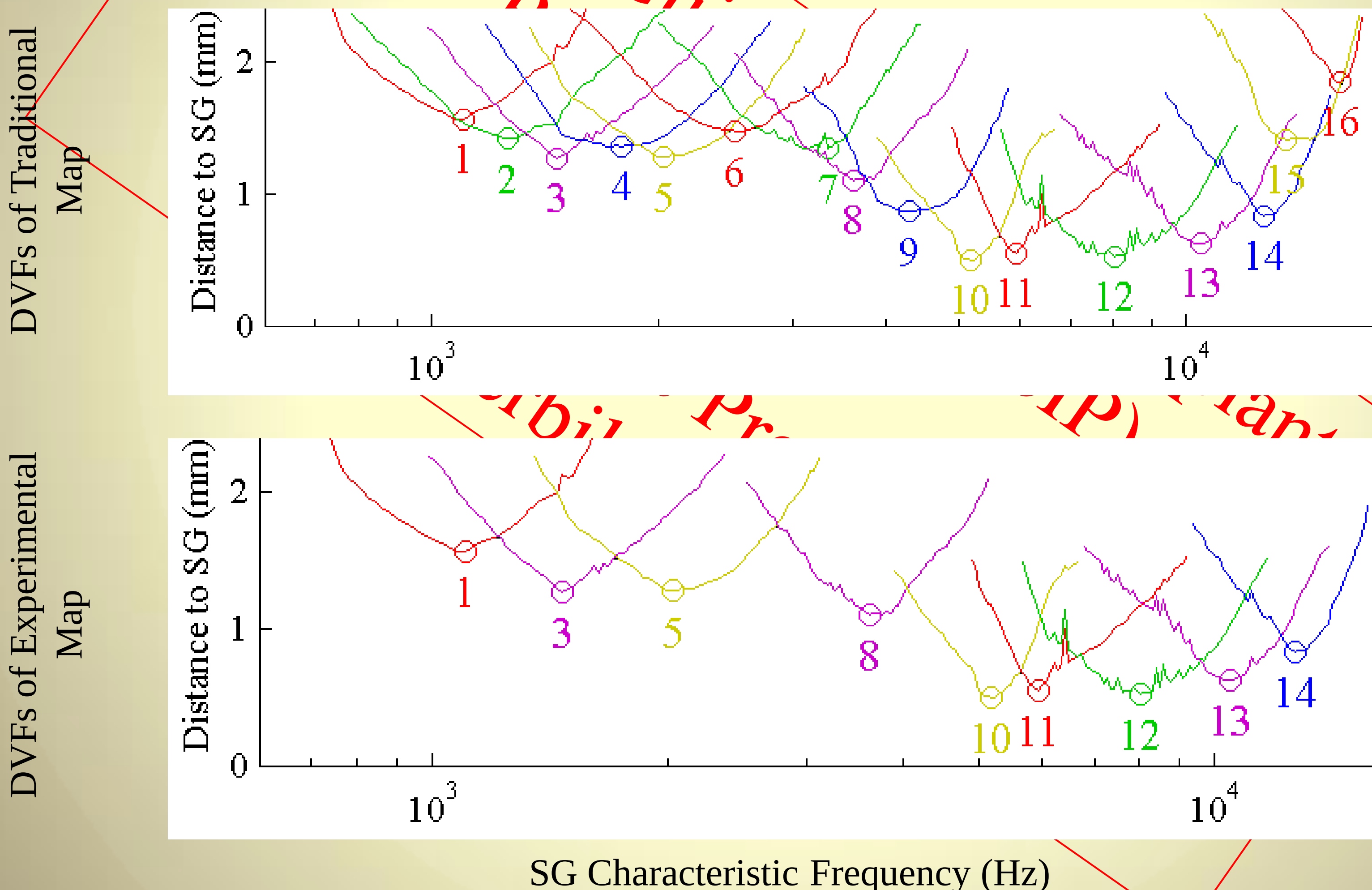
Electrode Position Analysis



Electrode Distance-Vs-Frequency Curves



DVF-based Deactivation Strategy



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

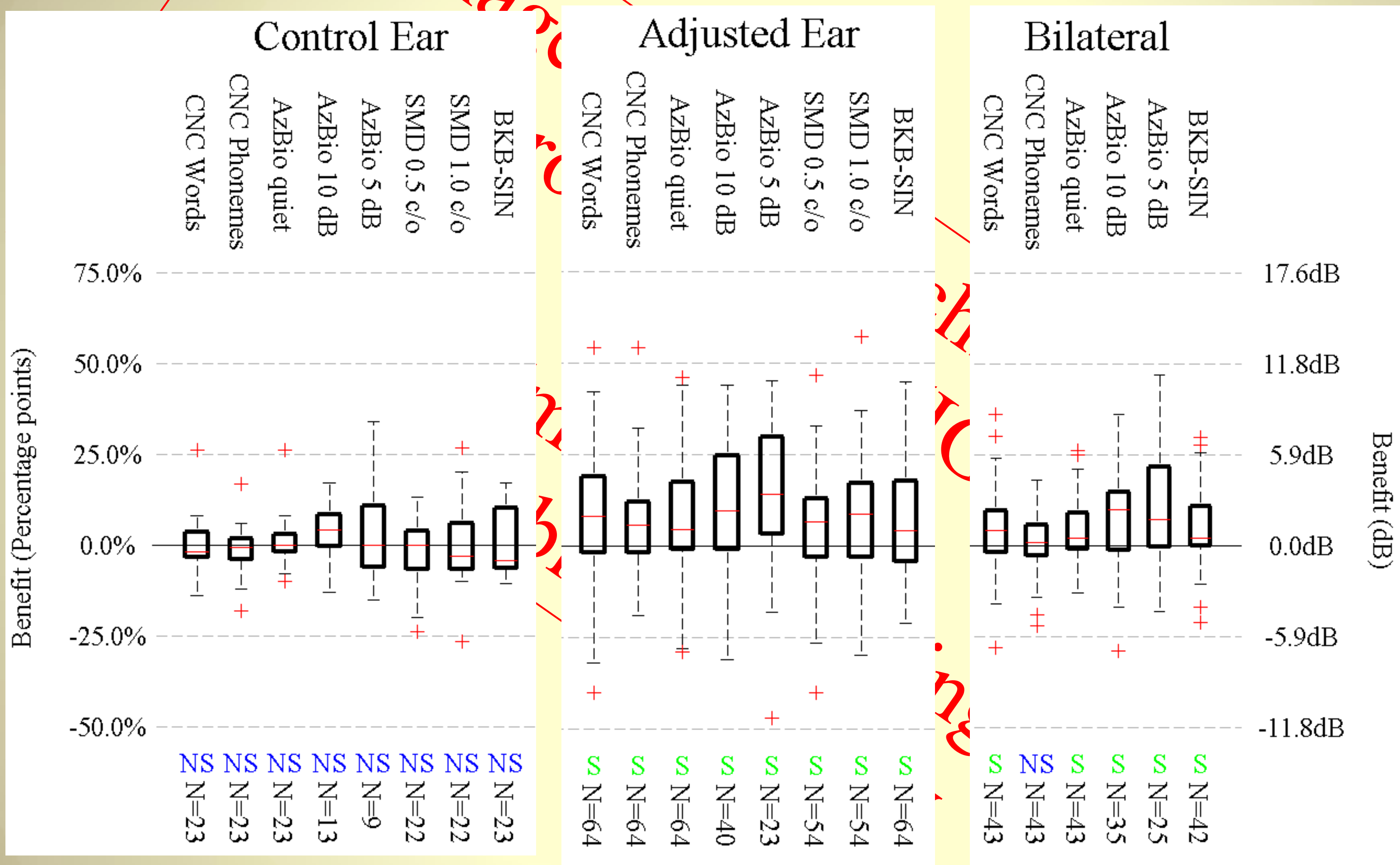
METHOD

- 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

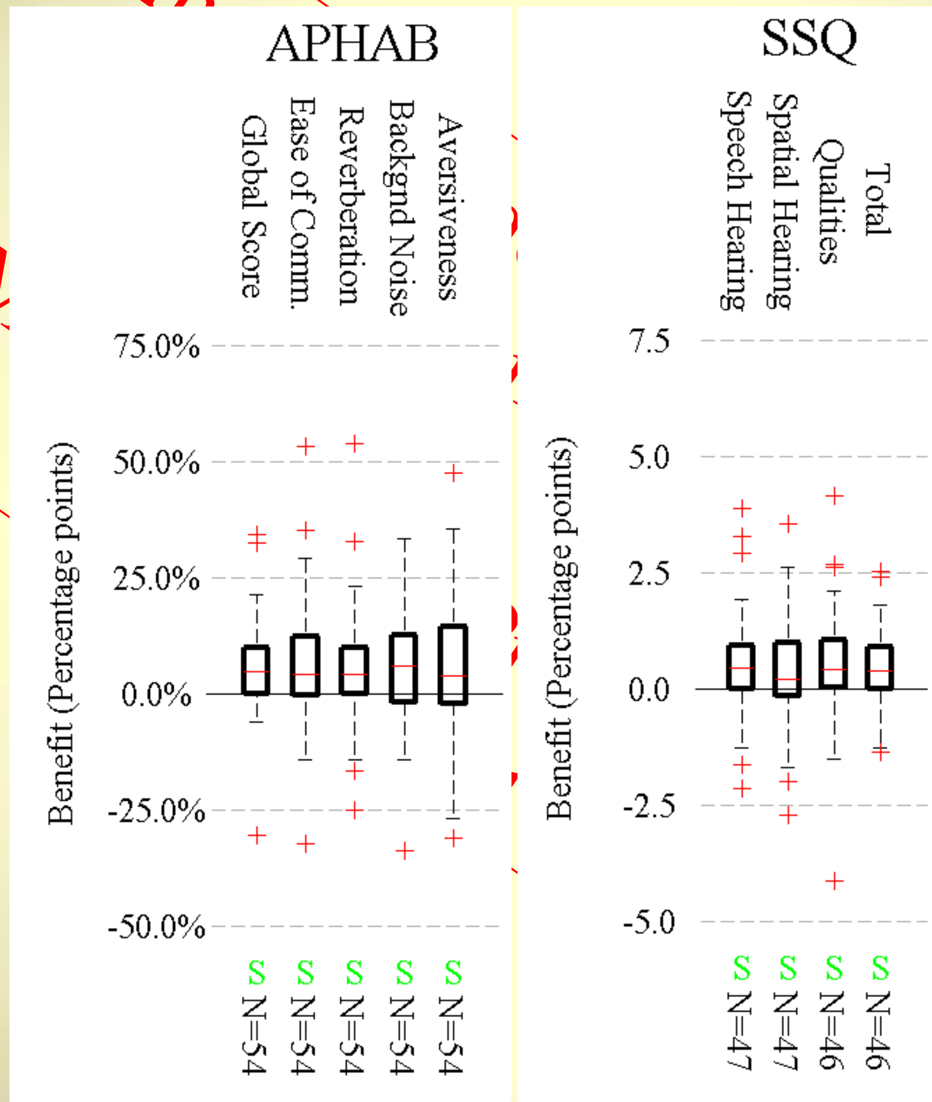
HYPOTHESES

- 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


Control Ear
Adjusted Ear
Bilateral
CNC Words
CNC Phonemes
AzBio quiet
AzBio 10 dB
AzBio 5 dB
SMD 0.5 c/o
SMD 1.0 c/o
BKB-SIN
Benefit (Percentage points)
75.0%
50.0%
25.0%
0.0%
-25.0%
-50.0%
17.6dB
11.8dB
5.9dB
0.0dB
-5.9dB
-11.8dB
Benefit (dB)
NS NS NS NS NS NS NS NS
N=23 N=23 N=23 N=13 N=9 N=22 N=22 N=23
S S S S S S S S
N=64 N=64 N=64 N=40 N=23 N=54 N=54 N=64
S NS S S S S
N=43 N=43 N=43 N=35 N=25 N=42

RESULTS


APHAB
Aversiveness
Backgnd Noise
Reverberation
Ease of Comm.
Global Score
Benefit (Percentage points)
75.0%
50.0%
25.0%
0.0%
-25.0%
-50.0%
S N=54
S N=54
S N=54
S N=54
S N=54
SSQ
Total
Qualities
Spatial Hearing
Speech Hearing
Benefit (Percentage points)
7.5
5.0
2.5
0.0
-2.5
-5.0
S N=47
S N=47
S N=46
S N=46

ACUTE COMMENTS

- 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.

CHRONIC COMMENTS

- 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

NIH NIDCD
R21 DC012620 & R01 DC009404