Electrodes typically do not provide stimulation near the cochlear apex where low frequencies are normally represented.

- **Advanced Bionics HiFocus 1J**
  - Median Insertion: 391°
  - Frequencies represented: ~695 Hz +

- **Cochlear Contour Advance**
  - Median Insertion: 375°
  - Frequencies represented: ~740 Hz +

(Angles from Landsberger et al., 2015, Frequency estimates from Stakhovskaya et al, 2007)
Apical stimulation may...

- Provide better temporal coding
  - Middlebrooks and Snyder (2010), Stahl et al. (2016)
- Reduce Frequency Mismatch with Spiral Ganglion
  - Landsberger et al. (2015), Vermeire et al. (2015)
- Improve sound quality
  - Landsberger et al. 2016, Roy et al. (2016)
- Improve outcomes
  - Buchman et al. (2014), Buchner et al. (2017)

But...

- Apical regions might only be reached by peripheral processes that might be missing in CI users
- Places of stimulation are less discriminable past ~1.5 turns
- Spread of excitation may be greater at the apex
  - Kalkman et al. (2014)
More research on apical stimulation is needed.

But to study this region, we need to be able to stimulate in the apex.

How can we stimulate the apex?
Method 1: Longer Electrode Arrays

Longer electrode arrays are inserted more deeply.

**MED-EL 31mm electrodes**
Median Insertion: ~650°
 Frequencies represented: ~161 Hz +

**Pros:**
- Straightforward
- Most direct way of providing stimulation
- Easy to model / understand where each apical contact is located.

**Cons:**
- Requires lateral wall arrays
- Increasing length potentially yields:
  - More frequent incomplete insertions
  - Greater insertion force and more damage
- Does not stimulate beyond ~650°
Method 2: “Phantom” Stimulation

“Current shaping” can push current more apical than the most apical contact on an array

Pros:
- Requires no additional surgery or surgical risk
- Can be used to extend range of currently implanted patients
- Effectively makes an electrode array function like a longer electrode array

Cons:
- Additional depth is relatively small
  - Between 0.5 and 2 extra mm (e.g. Saoji and Litvak, 2010; Saoji et al., 2013)
- Additional depth is highly variable and somewhat difficult to estimate.
Method 3: Place an electrode at the Helicotrema

Neurelec / Oticon Medical: Digisonic SP
Cochlear: N24 and newer
MED-EL: Combi 40, 40+, Pulsar

Many implants have an available electrode!
Possible Stimulation Modes:

- Apex to case ground (monopolar stimulation in apex)
- Apex to electrode array (wide bipolar stimulation)
- Electrode array to case (monopolar stimulation)
Possible Stimulation Modes:

- Apex to case ground (monopolar stimulation in apex)
- Apex to electrode array (wide bipolar stimulation)
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Possible Stimulation Modes:

- Apex to case ground (monopolar stimulation in apex)
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Possible Stimulation Modes:

Apex to case ground (monopolar stimulation in apex)

Apex to electrode array (wide bipolar stimulation)

Electrode array to case (monopolar stimulation)
Is this effective?

- Two cadaver half-heads
- Implanted with CI24RE Contour Advance (Advance off Stylet technique)
- Ball electrode placed:
  1. Under skin (normal position)
  2. Various locations outside/near apex
  3. Apex opened and ball electrode inserted
  4. Ball removed, superglue sealed apical cochleostomy
- At each location, Electrode Voltage Tomography (EVT; Vanpoucke et al., 2004) was measured

**Hypothesis:**
Apical cochleostomy with a single electrode placed at helicotrema alters current paths to increase apicalward flow.
Electrode Voltage Tomography

- Measures impedance across all pairs of electrodes

Using a model from Vanpouke et al. (2004) we can estimate:
  - The resistance for current leaving the cochlea from each contact ($r_{Trans}$)
  - The proportion of current leaving the cochlea from each contact ($i_{Trans} \%$)
Electrode Voltage Tomography

Before
(Ball: Standard Location)

During
(Ball: Inside Apex)

After
(Ball: Standard Location)

Electrode (1=basal end, 22=apical end)
Pros and Cons of an Helicotrema electrode

Pros:
• Does not require a longer electrode
  – Limits damage from additional forces from long electrode
  – Reduces probability of incomplete insertion
• Provides deepest stimulation
• Allows peri-modular electrodes

Cons:
• Requires apical cochleostomy
• Number of additional effective sites of stimulation remains unknown
Next step… Try it in patients.

- We are will soon implant a few patients placing the ball electrode near the helicotrema
- Both clinical outcome and psychophysical data will be collected
- If successful
  - Patients will benefit from the addition of more apical stimulation
- If not successful,
  - The apical electrode will not be used in the map
  - All clinical stimulation will be monopolar using the case ground, effectively replicating the standard clinical configuration
Thank You!

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