Single Sided Deafness

Outline
- Define Single Sided Deafness (SSD)
  - Deficits
- Define SSD Diagnostics
  - Measure hearing sensitivity
  - Measure communication deficit
  - Measure patient reaction to deficit
- Define SSD Devices
  - Requirements
  - Compare devices
- Define SSD Device Performance

Single Sided Deafness

• Definition
  - Normal hearing in one ear (no hearing aid)
  - Deaf in contralateral ear (unusable hearing)
  - Acquired (not congenital)
  - Suffer from loss of spatial hearing
• Incidence
  - 200 new cases/million
  - 60,000 new cases/year in USA
  - Variety of etiologies

Single Sided Deafness

• Spatial Hearing
  - Sense of omnidirectional hearing
  - Identify sources of sounds
  - Locate direction of sound source
  - Discriminate speech in noisy environments
  - Interpret acoustic environment accurately
  - No difficulty in particular environments (Car, eg)
Single Sided Deafness

- One ear sound cues (Pinna shape)
  - Distinguish sounds from front or behind
  - Locate sound source (vertical plane)
  - Identify sound source using spectral content
- Two ear sound cues (Head size)
  - Locate sound source (horizontal plane)
  - Time differences (low frequencies)
  - Level differences (higher frequencies)

SSD & Head Shadow

SSD Device
- Picks up Speech Without Noise
- Transfers to Normal Ear

SSD & Speech

- Speech recognition in noise increases with additional high-frequency speech signals
  - Horwitz, Ahlstrom and Dubno, JLSHR, 2008
- Natural speech contains information >6 kHz
  - Moore et al., Ear and Hearing, 2008
- Speech energy between 8 and 16 kHz is essential for accurate speech localization
  - Best, Carlile, Jin and Schalk, JASA, 2005

Summary of SSD

- Loss of Spatial Hearing
  - Loss of omnidirectional hearing
  - Reduction in hearing on deaf side
  - Reduction in sound localization ability
  - Importance of high frequencies
- Loss of Speech Understanding
  - Speech on deaf side
  - Speech in noise
  - Importance of high frequencies
- Significant Handicap
Summary of SSD

- Acquired SSD is Significant Handicap
- Intervention—Restore Binaural Hearing
  - Provide frequencies up to 16 kHz
  - Cochlear implant
  - Regeneration
- Intervention—Improve Monaural Hearing
  - Restore sense of omnidirectional hearing
  - Provide a device (Many options)
  - Provide frequencies up to 16 kHz

SSD Diagnostics

- Medical
  - Asymmetrical hearing
  - Fluctuating hearing
  - Complete all medical intervention
- Audiological
  - Audiogram
  - Definition of SSD
  - Questionnaires (Hearing Handicap)
  - Counseling (Device demonstration)

SSD Diagnostics

- Pure Tone Average
  - 500 Hz
  - 1000 Hz
  - 2000 Hz
  - 3000 Hz
- 3000 Hz Missing
  - Interpolate
  - 2000 Hz/4000 Hz

Hearing Measurement

- Air Conduction
  - Electrodynamic
  - Sennheiser HDA200
- Bone Conduction
  - Electrodynamic
  - Radioear B-71

From Gurgel, Jackler, Dobie, & Popelka, OHNS, 2012
Hearing Measurement

- Bone Conduction Technology

- Electrodynamic
  - Low f: Yes
  - High f: No

- Piezoelectric
  - Yes

- Magnetostrictive
  - Yes

Experimental Transducer

<table>
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<tr>
<th>B-71</th>
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<tr>
<td>Location</td>
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<td>Force</td>
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<td>Surface</td>
<td>Flat</td>
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Summary of SSD Diagnostics

- Medical Evaluation
  - Diagnosis
  - Completion of all medical intervention

- Audiological Evaluation
  - Air and bone conduction thresholds
  - Consider Right/Left asymmetry (Zapala, 2013)
  - Consider fluctuating hearing
  - Consider frequencies up to 16 kHz

- Measure Handicap
  - Consider SSD measures during intervention

Existing SSD Devices

- Locate Microphone on Deaf Side
  - Many different locations
  - Microphone location can affect performance

- Transfer Signal to Normal Side
  - By air conduction (CROS)
  - By bone conduction (May different methods)

- Prosthetic vs Hearing Aid
  - Insurance considerations
Existing SSD Devices

- **Gain**
  - Fitting to a normal cochlea (Linear gain)
  - Real ear gain with loudness balancing
  - Real ear gain set to 0 dB for frequencies >750 Hz
  - Aided thresholds in normal range (<25 dB HL)

- **Output**
  - No limiting (Fitting to a normal cochlea)
  - Limiting useful to prevent distortion

- **Features**
  - Directional microphones

Air Conduction CROS

- **Behind-The-Ear (BTE) Open Fit**

Original wireless patent, 1964

Bone Conduction Canal

- **Advantages**
  - No surgery
  - Adequate microphone placement

- **Disadvantages**
  - Limited effectiveness
  - Limited frequency bandwidth
  - Uncomfortable

Bone Conduction Band

- **Advantages**
  - No surgery
  - Immediate

- **Disadvantages**
  - Limited effectiveness
  - Limited patient acceptance
  - Suboptimal microphone placement
  - Limited frequency bandwidth
Bone Conduction BAHA

• Behind-The-Ear (BTE) Module (Microphone)
• Transducer (Currently all electrodynamic)
• Surgically Implanted Component
  – Osseointegrated post (Percutaneous direct)
  – Flat plate (Subcutaneous with skin)
  – Transducer (Subcutaneous direct)
• Considerations
  – Percutaneous vs subcutaneous
  – Soft tissue in vibratory pathway
  – Amount of bone removed (Affects microphone)

Bone Conduction BAHA

• Percutaneous Osseointegrated Post

• Subcutaneous Plate (Soft tissue in pathway)

• Subcutaneous Transducer

Bone Conduction BAHA

• Advantages
  – Very effective
  – Comfortable

• Disadvantages
  – Requires surgery (Plus complications)
  – Limited patient acceptance
  – Suboptimal microphone placement
  – Limited frequency bandwidth

Bone Conduction Dental

• Advantages
  – No surgery
  – Optimal microphone
  – Very effective
  – Removable

• Disadvantages
  – Requires healthy molars
  – Comfort preference differences
  – Requires dentist
  – Insurance coverage variable (in process)
Bone Conduction Overview

Surgically Implanted

Soft tissue may or may not be in pathway

Non-Surgical Dental

No soft tissue in pathway

Electrodynamic
Low Frequency

Surgical Percutaneous

Baha, Ponto

Bone Conduction Overview

Connection

• SSD Cases
  – All devices functionally identical
  – All devices FDA Cleared (Acquired, Congenital)

• Permanent Conductive Hearing Loss
  – Inoperable cases, chronic otitis media
  – All devices FDA cleared

• Mixed Hearing Loss
  – Depends on bone conduction sensitivity only
  – Not all devices FDA cleared

Transducer

• Electrical
  – Floating Mass

• Micophone Location

• Behind Pinna

• Within Pinna

Current Device Overview

Removable Dental

Baha, Ponto

Alpha 1, 2

Bonebridge

SoundBite

Electrodynamic
Low Frequency

Electrodynamic
High Frequency

Floating Mass
Low Frequency

Piezoelectric
High Frequency

Surgical Subcutaneous

Surgical Subcutaneous

Surgical Subcutaneous

Baha, Ponto
### Current Device Overview

<table>
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<th>Process</th>
<th>Surgically Implanted</th>
<th>Non-Surgical Dental</th>
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<td><strong>Medical Process</strong></td>
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<td>- Diagnosis of Condition</td>
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<td>- Surgery</td>
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<td>- Diagnosis of oral health</td>
<td>X</td>
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<tr>
<td>- Dental impression</td>
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<tr>
<td><strong>Audiological Process</strong></td>
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<td>- Discussion of options</td>
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<td>- Processor programming</td>
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### Current Device Performance

- **Safety**
  - Adverse events
- **Efficacy**
  - Aided thresholds (Very difficult to measure)
  - Sound localization (Not expected, still monaural)
  - Speech understanding in noise (HINT, QuickSin)
- **Benefit**
  - Standardized questionnaire (APHAB, SADL, SSQ)
  - Custom questionnaire (Individualized for SSD)
  - Utilization (Do patients utilize the device)

### Previous CROS Devices

- **Bishop et al.** *Laryngoscope, 2010*
  - Universal rejection by SSD patients
  - Remaining hearing ear blocked
  - Large physical size (comfort, cosmetics)
  - Direct wire connection (cosmetics)
  - Wireless connection
    - Increased battery usage
    - Poor sound quality (electrical interference, inconsistent)
  - 42.5% Use >4 hours per day
  - 32.5% Use <4 hours per day
  - 25.0% Use Occasionally

- **Linnebjerg & Wetke** *Hearing, Balance, Commicn, 2013*
  - Effectiveness equal to or better than old BiCROS
  - Benefit equal to or better than old BiCROS
  - No information on acceptance
**BAHA Devices**

- **Safety**
  - Many adverse events

- **Efficacy**
  - Aided thresholds (Difficult to measure)
  - Sound localization (Not expected, still monaural)
  - Speech understanding in noise (Improved)

- **Benefit**
  - APHAB (Improved)
  - Questionnaires (Improved)
  - Utilization (Patients utilize the device regularly)

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**SoundBite Safety**

- **Safety**
  - No medical adverse events
  - No dental adverse events
  - No audiological adverse events

- **Peer-Reviewed Publications**
  - Lab study  N=  4  1 site  2010
  - 1 Month Trial  N=28  2 sites  2011
  - 6 Month Trial  N=22  2 sites  2011
  - 6 Month Trial  N=34  7 sites  2013
  - 12 Month Trial  N=87  14 sites  Prep

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**SoundBite Efficacy**

- **Aided Thresholds**
  - In normal range for single sided deafness
  - No changes over 6 months

- **Peer-Reviewed Publications**
  - 6 Month Trial  N=22  2 sites  2011
  - 1 Month Trial  N=  9  1 site  2013
  - 6 Month Trial  N=34  7 sites  2013

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**SoundBite Efficacy**

- **Speech Perception in Noise**
  - Improved HINT scores
  - Improved QuickSIN scores

- **Peer-Reviewed Publications**
  - 1 Month Trial  N=28  2 sites  2011
  - 1 Month Trial  N=  9  2 sites  2013
SoundBite Benefit

- Benefit
  - Improved Abbreviated Profile Hearing Aid Benefit
  - High patient satisfaction scores
  - High wearing time (average >8 hrs/day)
- Peer-Reviewed Publications
  - 1 Month Trial  N=28  2 sites  2011
  - 6 Month Trial  N=22  2 sites  2011
  - 1 Month Trial  N=9  1 site  2013
  - 6 Month Trial  N=34  7 sites  2013
  - 12 Month Trial  N=87  14 sites  Prep

SoundBite Questionnaire

- Benefit
  N=34  6 mos

From Gurgel & Shelton, Laryngoscope, 2013

SoundBite Questionnaire

- Benefit
  N=34  6 mos

From Gurgel & Shelton, Laryngoscope, 2013

SoundBite Summary

- Safety
  - No reportable adverse events
- Efficacy
  - Aided thresholds in normal range for SSD
  - Substantial improvement in hearing in noise
  - Substantial improvement in APHAB benefit scores
- Patient Reported Benefit
  - High percentage report improvement
  - High percentage report satisfaction
  - High percentage report likelihood to recommend
  - Results remained over 12 month period
BAHA vs Dental

- Measure Spatial Hearing Ability
  - Pinna effects
  - Sound localization ability

BAHA vs Dental

- Subjects (N=9)
  - Unilateral profound sensorineural hearing loss
  - Prospective, randomized, crossover 30 day trial
- Devices
  - Existing implanted device (Baha, Ponto)
  - New dental device (SoundBite)
- Measures
  - Frequency specific sound field aided thresholds
  - Spatial hearing tasks
  - Speech perception in noise
  - Device benefit

From Moore & Popelka, IJA, 2013

BAHA vs Dental

- Sound Field Thresholds
  - 1000 Hz to 6000 Hz
- Spatial Hearing
  - Localization
  - Front vs back
- Speech in Noise
<table>
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<td>#8</td>
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</table>

From Moore & Popelka, IJA, 2013

BAHA vs Dental

- Signal
  - Better ear muffled
  - 0 degree azimuth
  - FM
- Devices
  - Linear
  - Use gain
- Results
  - Reflect hearing ear
  - Reliable
  - Dental device 10 dB better

From Moore & Popelka, IJA, 2013
• Localization
  – Unaided poor
  – Devices improve

• Front/Back
  – Unaided poor
  – Devices improve

• No Differences
  – Between devices
  – Over time

From Moore & Popelka, IJA, 2013

• Unaided
  – Poor

• Improved
  – #1, #2, #3

• Not Improved
  – #4, #5, #6
  – #7, #8

• Devices
  – No differences

From Moore & Popelka, IJA, 2013

• Dental Device
  – Significant Benefit
  – Greatest for BN

• Implanted Devices
  – No benefit
  – Not typical result

From Moore & Popelka, IJA, 2013

• Sound Field Thresholds
  – Reflect sensitivity of better ear
  – Better for dental device (~10 dB)

• Spatial Hearing
  – Localization slightly better than no device
  – Front/Back detection slightly better than no device
  – No difference between devices or over time

• Speech in Noise
  – Improved when speech on poorer side, noise other

• Benefit
  – Dental device provides substantial benefit

From Moore & Popelka, IJA, 2013
Presentation Summary

• Single Sided Deafness
  – Acquired SSD is a significant handicap
• SSD Diagnostics
  – Consider permanency, asymmetry
  – Consider high frequency hearing sensitivity
• SSD Devices
  – Consider all device configurations
• SSD Device Performance
  – Consider device physical differences
  – Consider device high frequency differences