Clinical Tips for Matching Real-Ear Prescriptive Targets

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Discussion topics

• Who’s performing probe-microphone measures routinely and why?

• Back to the basics of probe-microphone measures

• Clinical tips when conducting probe-microphone measures
  - Probe tube insertion depth and its affect on measures – REIG
  - Openness of fitting
  - Speechmapping
  - Insertion gain calculations
  - RESR/MPO: broadband vs. multi-channel
  - Verification of special features
  - AutoFit
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How many of us are routinely conducting probe-microphone measures?

Mueller & Picou, 2010
How often are we routinely conducting probe-microphone measures?

The majority of respondents (52%) used verification no more than Sometimes.
How often are we routinely conducting probe-microphone measures on the day of the fitting?

Figure 2. Percent of respondents who routinely use probe-microphone measures on the day of the fitting. The “Have Equipment” data include only respondents who own or have access to probe-mic equipment.

Nearly half are not using the equipment.
And the survey said…….

Data collected for AudiologyNOW, our online survey:

- 228 respondents
- 42% are routinely conducting probe-microphone measures
To verify or not verify that is the question...

Why are only 1/3 of HCPs routinely running probe-microphone measures?

- Uncertain correlation with hearing aid satisfaction
- Complexity of modern hearing instruments
- Fitting software
- Poor training programs
- Cost of equipment
- Audiologist’s dedication
Why perform probe-microphone measures?

Probe-microphone real-ear measures represent a valid, repeatable and reliable method of assessing the real ear performance of hearing instruments*

Bottom line: We need to objectively measure SPL at the TM for various input levels

*Hawkins & Mueller, 1986
Based on data taken from Sergei Kochkin and his colleagues:

- Hearing aid satisfaction is related to the testing conducted at the time of fitting
- More testing leads to more satisfaction
- Probe-microphone measures are one of the tests that affect these results
The effect of the overall protocol (# of tests administered) on patient satisfaction:

From Kochkin et al, 2010
Additional reasons to consider probe-microphone measures

- Best Practice Guidelines which are stated by the American Academy of Audiology state:

  “Prescribed gain (output) from a validated prescriptive method should be verified using a probe-microphone approach that is referenced to ear canal SPL.”

- Code of Ethics from the American Academy of Audiology state:

  “Members shall maintain high standards of professional competence in rendering services...” and “Members shall provide only services and products that are in the best interest of those served.”
Additional reasons to consider probe-microphone measures

- Nearly all hearing aid fitting software provides graphics showing simulated gain and output for different inputs, in some cases a comparison is made of prescriptive fitting targets.

- Manufacturer’s graphics are useful for making hearing aid adjustments.

- These graphics are not a substitute for probe-microphone verification.

- Very risky to assume, even in the most basic signal processing, that what is displayed on the screen is similar to what is presented in the ear canal.
Firstfit algorithms across four manufacturers

Hearing aids programmed to default fitting; loss was normal in lows to 60 dB loss in highs.
Measured S-RESR output across five manufactures

25-30 dB difference in high Frequency maximum output

Gently sloping moderate hearing loss

Seewald et al., 2008
Some recent findings regarding “software fittings”

• Used software of four different manufactures

• Selected “NAL-NL1” in the fitting software

• Fit the hearing aids to 42 ears

• Conducted REIG testing to determine if hearing aid met target

• Conducted tweaking if it did not match target

• Used lax +/- 10 dB window of acceptance

(Aazh and Moore, 2007)
Pre- and post-fitting results

(Aazh and Moore, 2007)
So what?

- Probe-microphone measures should be an essential component of fitting hearing instruments, yet only 1/3 of HCPs are routinely performing them.

- Consumer reports concluded in July 2009 that 2/3 of all hearing aid fittings are done incorrectly, and that probe-microphone testing is a “must have” procedure for every consumer purchasing hearing aids.

- Catherine Palmer, PhD., suggested that the failure to use probe-microphone measures in the fitting of hearing aids is unethical.
Back to the basics of probe-mic measures
I’m confused...

Actually...

Maybe I’m not...

I think...

OK, just tell me the real meaning of all those letters – **REOG, REUG!!!**
Probe-microphone definitions from ANSI standards

Let’s define some basic terms and their purpose:

- **REUR** (Real Ear Unaided Response)
- **REUG** (Real Ear Unaided Gain)
- **REOR** (Real Ear Occluded Response)
- **REOG** (Real Ear Occluded Gain)
- **REAR** (Real Ear Aided Response)
- **REAG** (Real Ear Aided Gain)
- **REIG** (Real Ear Insertion Gain)
Probe-microphone definitions (cont.)

- **REUR** (Real Ear Unaided Response)
  - Response of the open ear shown in SPL as a function across frequencies relative to a sound source
  - **Translation:** an individual’s ear resonance when it’s open (in SPL)

- **REUG** (Real Ear Unaided Gain)
  - Accounts for the gain in the unaided ear canal provided by the pinna and ear canal
  - REUR (unaided response) - input = REUG
  - **Translation:** same as REUR but subtracting out the sound source input

- **REOG** (Real Ear Occluded Gain)
  - Accounts for the gain across frequencies measured in the ear canal with the hearing aid in place and turned OFF
  - REOR - input = REOG
  - **Translation:** the effect the hearing aid has on the ear’s natural resonance

Pumford & Sinclair, 2001
Probe-microphone definitions (cont.)

- **REAR** (Real Ear Aided Response)
  - Accounts for the frequency response of a hearing aid that is turned on, measured in the ear canal, for a particular input signal
    - **Translation:** the real-ear SPL measured with the hearing aid in place and the hearing aid turned on

- **REIG** (Real Ear Insertion Gain)
  - Accounts for the amount of gain provided by the hearing instrument alone calculated by subtracting the REUG from the REAG across frequencies or by subtracting the REUR from the REAR across frequencies.
    - **Translation:** used to determine whether a particular hearing instrument setting has achieved a particular insertion gain prescriptive target

- **What about REIR?**

Pumford & Sinclair, 2001
Probe-microphone definitions

- What is the difference between terms that end in “R” vs. “G”? (e.g. REUR vs. REUG)
  
  - “R” - refers to response as an absolute measure of output in SPL. There is no consideration given to the input level used to generate the response.
  
  - “G” - refers to gain and is a difference measure. Input level used to generate the response has been subtracted from the absolute output level across frequencies.

Table 1. Example of relationship between 'G' (Gain) and 'R' (Response).

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>250</th>
<th>500</th>
<th>750</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
</tr>
</thead>
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<td>REUR</td>
<td>51</td>
<td>53</td>
<td>53</td>
<td>57</td>
<td>58</td>
<td>60</td>
<td>68</td>
<td>64</td>
<td>58</td>
</tr>
<tr>
<td>REUG - Input</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
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<tr>
<td>REUG</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>18</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

Pumford & Sinclair, 2001
So what?

- Confusion can arise when discussing probe-microphone terminology and procedures if terminology is inconsistent.

- Clearly defining the requisite terminology will give us common ground to begin today’s discussion.

- One of the most common mistakes when discussing clinical results of testing is mixing up the terms “R_ _ R” & “R_ _ G”.
REAR vs. REAG

Insertion gain

Mar 26, 2009 7:12pm

REAR

REAG
Today’s target patient and measured UCLs
Clinical tips

• Probe-tube insertion depth and its affect on measures
  • Openness of fitting
  • Speechmapping
  • Insertion gain calculations
  • R E S R / M P O: broadband vs. multi-channel
  • Verification of special features
  • AutoFit
Probe-microphone depths (REIG)
So what?

- It is necessary to place the probe tube sufficiently past the tip of the hearing aid, earmold or tip/dome to sufficiently measure the high frequency effects of amplification
  - Ideally probe tip should be within 5 mm of TM & 3-4 mm past tip of mold
  - General rule: should be 25-30 mm from intertragal notch
  - General rule of index knuckle is approx 25 mm

- Placement that is too deep (a.k.a. “bump & no pull”) can be painful & counterproductive for the patient
Clinical tips

• Probe-tube insertion depth and its affect on measures
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• Insertion gain calculations
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• AutoFit
Let’s define “open”
Is this “open”?
Is this “open”?
Is this “open”?
Is this “open”?
What does “open” fitting mean?

**Definition:**
An open fit is one where physical insertion of the hearing instrument/plumbing minimally impacts the ear’s natural resonance so that the R EOG (real-ear occluded gain) is similar to the R E U G (real ear unaided gain)

In other words, when the hearing instrument is in the ear & turned off, the natural resonance of the ear remains intact or very similar.
What does a true “open” fitting look like?

- The fit is considered “open” if insertion of hearing instrument/plumbing minimally impacts the ear’s natural resonance.

- The fit is considered “closed” if insertion of the hearing instrument/plumbing impacts the ear’s natural resonance (i.e. REOR is significantly different from REUR).
REOR vs. Occlusion effect

• So that’s the REOR – what about the dreaded occlusion effect?
Occlusion effect

- The open ear canal not only allows sound to travel from outside the ear canal to the TM, it also allows sound to travel outward (e.g. speech)

- When the ear canal is blocked speech resonates and builds up in the nasopharyngeal cavity at levels as high as 130 dB SPL

- This “blockage” of sound is both a perceptual & physical phenomenon which can be measured via probe-microphone in the ear canal
Occlusion effect measured

Subject 2

- Probe microphone: 77.0 dB
- Reference microphone: 80.5 dB
- Occlusion: -3.5 dB
Occlusion effect measured

Subject 5

Occlusion

Mar 26, 2009 12:19am

Max TM SPL  135

Stimulus Filter
Off  C Weighted

Start test

Probe microphone  89.0 dB

Reference microphone  79.0 dB

Occlusion  10.0 dB
Occlusion effect measured

Subject 3

Occlusion

Mar 26, 2009 1:29pm

Stimulus
Filter
Start test

Probe microphone
Reference microphone

Occlusion

Max TM SPL

135

Left

102.0 dB

81.5 dB

20.5 dB
Measured occlusion - final product
So what?

- Because open canal fittings have gained such wide acceptance, the term “open” is widely used and in some cases – incorrectly

- Because of their prevalence, it is important from a clinical perspective when discussing “open fittings” that we all have a clear understanding of the term & use it consistently

- E.g. A small BTE with a slim tube & closed dome/tip/earmold may be very cosmetically appealing & appear “open”, but if the REUR is significantly altered, it is technically not an open canal fitting
Questions?
Clinical tips

- Probe-tube insertion depth and its affect on measures
- Openness of fitting
- **Speechmapping**
- Insertion gain calculations
- RESR/MPO: broadband vs. multi-channel
- Verification of special features
- AutoFit
Using the SPLogram for Speechmapping

Speechmap/NAL-NL1

Hearing thresholds

UCLs

Speechmap targets

Speechmap

THRESHOLD OF NORMAL HEARING
Speechmapping for soft speech inputs

- Patient’s main issue is hearing soft speech
- Good counseling tool
- Visual representation of how far unaided speech is from target
Speechmapping for soft speech inputs

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Speechmapping for soft speech inputs

- Patient’s main issue is hearing soft speech
- Good counseling tool
- Visual representation of how far unaided speech is from target
Speechmap first fit

Remember Aazh & Moore?
Pre- and post-fitting results

(Aazh and Moore, 2007)
Will we be able to match target for this patient?

- More on that later...
So what?

• It is important to understand the clinical application of Speechmapping

• Remember to follow the manufacturer’s guidelines when using probe-microphone equipment to verify target matching (e.g. do not use live speech when using the Audioscan Verifit, but rather the carrot passage)
  – In most cases the displayed targets for a given manufacturer’s fitting software are for a specific input signal

• Live speech can be used for counseling as well as a “promotional tool”, but should **NOT** be used for verification in most protocols
Clinical tips

- Probe-tube insertion depth and its affect on measures
- Openness of fitting
- Speechmapping
- **Insertion gain calculations**
- RESR/MPO: broadband vs. multi-channel
- Verification of special features
- AutoFit
Speechmapping vs. REIG

NAL-NL1 First Fit

Max TM SPL 135

Insertion gain

Max TM SPL 135
NAL first fit target match

What would you do if this was your patient?

First fit for average input
First fit for soft input
First fit for soft input
Soft input target match

Soft input target match (50 dB)
First fit for loud input
Loud input target match
65 dB target match - post soft/loud match

Average input target match (65dB)
Loud input target match

Loud input target match (80 dB)
Loud input target match

Loud input target match (80 dB)
65 dB target match - post soft/loud match

Average input target match (65dB)
Target match for soft, average & loud
Target match for soft, average & loud

Insertion gain

Max TM SPL 135

Target match for soft, average & loud inputs
Target match for soft, average & loud inputs
Target match for soft, average & loud inputs
Target match for soft, average & loud inputs
Target match for soft, average & loud
Target match: insertion gain vs. Speechmap

Target match for soft, average & loud inputs

Target match for soft, average & loud inputs
NAL target match: start to finish

**Initial Speechmap results prior to tweaking response**

**Speechmap target match for soft, average & loud inputs**
So what?

- A bad match to target is a bad match to target regardless of the measurement condition.

- Conversely a good match to target is a good match to target regardless of the measurement condition.

- In addition to being a quantifiable method of verifying the fitting, Speechmapping can also serve as a valuable counseling tool.
Clinical tips

• Probe-tube insertion depth and its affect on measures
• Openness of fitting
• Speechmapping
• Insertion gain calculations
• RESR/MPO: broadband vs. multi-channel
• Verification of special features
• AutoFit
Single channel MPO initial fit

Speechmap/NAL-NL1

UCLs

Single channel AGC-O
Single channel MPO adjusted

Single channel AGC-O
Multi-channel MPO adjusted

**Speechmap/NAL-NL1**

Max TM SPL 135

Multi-channel AGC-O

Feb 18, 2010 6:45pm

Right
So what?

- Single-channel AGC-O will activate whenever the kneepoint is reached at any frequency: The result is an unnecessary limiting of the output for all other frequencies.

- Multi-channel AGC-O will allow loudness to grow at adjoining frequencies even after the kneepoint has been reached at one specific frequency region.

- The result is increased headroom and better utilization of the residual dynamic range. This would seem to be especially important for infants and children with narrow dynamic ranges where audibility is critical.
Clinical tips

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• Speechmapping
• Insertion gain calculations
• RESR/MPO – broadband vs. multi-channel
• Verification of special features
• AutoFit
Verification of special features

- Digital noise reduction (DNR)
- Front-to-back directionality
- Live vs. recorded Speechmapping
DNR effects

Input signal: Pink noise

[Image of a graph showing the effect of DNR on the input signal]
Front-to-back directional ratio

Speechmap/NAL-NL1

Max TM SPL 135

0 degree azimuth

180 degree azimuth

Feb 18, 2010 6:18pm

Right
Equalized directional microphone vs. omni
Live vs. recorded speech inputs

- Live speech S1
- Live speech S2
- Recorded speech
So what?

- Stimulus type will have an impact on the DNR
  - Temporally modulated signals are best to “trick” the DNR
  - Steady-state noise signals are more appropriate for DNR evaluation

- When matching a specific prescriptive fitting algorithm, follow the probe-microphone manufacturer’s recommended protocol

- When using Speechmapping remember live voice is acceptable for counseling & demonstration of aided vs. unaided audibility, but generally not acceptable for matching a prescriptive formula
Clinical tips

• Probe-tube insertion depth and its affect on measures
• Openness of fitting
• Speechmapping
• Insertion gain calculations
• RESR/MPO – broadband vs. multi-channel
• Verification of special features
• AutoFit
AutoFit feature

- Some manufacturers are developing software that allows for automatic adjustment of the electroacoustical parameters on the hearing aids to match a prescriptive fitting target.

- This symbiotic relationship between systems allows the audiologist to quickly & effectively match a prescriptive fitting algorithm.

- The end result is a more time-efficient means of clinically matching targets.
REAG

50 dB Target
65 dB Target
80 dB Target

REUG
Summary

- Probe-mic measures are essential for all hearing aid fittings
- Know/understand your system & follow the recommended protocol
- Validated prescriptive targets as well as specific input/output levels can and should be evaluated as part of the verification process
- Adaptive algorithms such as directional microphones and noise reduction algorithms can and should also be evaluated
- Having an appreciation of the various fitting nuances will:
  - Make you a more effective clinician
  - Result in a higher standard of clinical care
  - Increase patient satisfaction
References


Questions?

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